THE MACHINE GUN

VOLUME IV, PARTS X AND XI

UNITED STATES NAVY

BUREAU OF ORDNANCE

THE MACHINE GUN

VOLUME IV

PARTS X AND XI

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Design Analysis of Automatic Firing Mechanisms and Related Components

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VOLUME IV, PARTS X AND XI

Prepared for the Bureau of Ordnance
Department of the Navy

1955

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. — Price $6.50 (Buckram)

PREFACE

Held to the strictest interpretation of the definition [1] and to the means by which the function is accomplished, there is only one primary force that actuates any automatic weapon: namely, the energy generated by the explosion of the powder charge contained in the chamber of the barrel. There have been, to date, only two known means that can be derived from this source of power that have resulted in successful operation: (1) the rearward thrust of the recoiling mass; and (2) pressure generated in the bore by the expanding gas of the progressive burning charge. The former is known as recoil actuation, while the latter is labeled gas operation. All known means used in making an automatic weapon complete a full cycle fall into this broad classification, whether the mechanics employed be reciprocating or rotary.

The recoil-operated type of weapon can be further broken down into two distinct classifications: short and long recoil. Gas operation, however, seems to have no limit in its application. For instance, the residual pressure remaining in the bore a few milliseconds after the projectile has cleared has been, for lack of a better term, called blowback, while in reality it is but another form of gas operation.

However, the most common method of employing the energy created by the gas of the exploding propellant is to tap the barrel and let the expanding gas be brought to bear on an actuating device such as a piston, lever, etc. The system is universally referred to as "gas operation", erroneously implying that this is the only way gas pressure is utilized as a source of power.

If one were satisfied only with generalities, it would be quite in order to state that there are only five known practical applications for accomplishing sustained fire as outlined in the definition of an automatic gun: (1) short recoil; (2) long recoil; (3) gas pressure in the bore bled off externally through an orifice (gas operation); (4) residual pressure remaining in the bore a few milliseconds after the projectile has cleared (blowback); and (5) blast energy generated by the expanding gases after being released from the confines of the barrel at the muzzle end (muzzle blast actuation).[2] These are considered the basic principles and from these simple variants of power, more than 3,000 patents have been issued since 16 June 1884 on operational features of machine guns.

So thoroughly have the gun designers of the past covered the subject that since World War I the individual was indeed skilled in his profession if he could even make an improvement on a feature that had already been in existence a long time, much less originate something that could rise to the dignity where it could truthfully be called an invention.

There is a tendency to use general terms too loosely in describing certain types of actions. For instance, the word "blowback" is invariably employed when describing any weapon that uses this form of actuation either wholly or in part. This unusual power supply has been exploited to such a degree that it takes at least four distinctly different classifications to cover the application of this method of utilizing residual pressure for completing a cycle of operation: (1) pure blowback (Bergmann); (2) retarded blowback (Schwarzlose); (3) delayed blowback (Scotti); and (4) advanced primer ignition (Becker). Each system is strictly adaptable to certain types of actions and is utterly impractical other than for a specific purpose. For example, the caliber .22 Colt Woodsman pistol uses *pure blowback* and is a well-balanced, highly efficient hand arm, and for this type of weapon such a method practically defies improvement. However, if this system were applied to a conventional 20 mm cannon, the bolt alone would need to weigh in the neighborhood of 380 pounds, with an approximate rate of fire of 200 rounds a minute, both of which would be totally unacceptable. If *advanced primer ignition* were used, the weight of the 20 mm weapon could be held to 90 pounds and

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[1] AUTOMATIC MACHINE GUN—A weapon capable of sustained fire with its operating energy being derived wholly from the force generated by the explosion of the propellant charge.

[2] Although relatively unimportant, two other systems should be mentioned to complete the picture. "Blowforward" is a method in which the barrel is held to the rear by heavy spring pressure against a solid non-recoiling breech that supports the cartridge, gas pressure driving the projectile forward through the bore to move the barrel off the empty cartridge case. "The Gast system" is a double-barrel arrangement whereby the firing of one barrel furnishes the power to load, lock, and feed the other barrel, with unlocking being tied in with the first part of recoil movement.

the rate of fire would be about 600 rounds a minute, while if *delayed blowback* were employed, the over-all weight of the gun would be slightly more (about 100 pounds), but the weight of the bolt or recoiling parts could be held to a bare minimum (6 pounds), and the rate of fire could be brought up to as much as 1,000 rounds a minute. On the other hand, the maximum elasticity of the conventional type cartridge case, coupled with the inevitable high chamber pressures of today, makes the timing factor too critical to permit any consideration of *retarded blowback* in the design of a large caliber automatic weapon. Such comparisons are limitless when based on the fundamental principles governing the design of automatic weapons.

It is the purpose of Volume IV of "The Machine Gun" to analyze these principles in such a way that the designer has before him at all times the minimum and maximum potentialities of any system of his choosing. Each and every one has its strong and weak points. No two are alike, but all have one thing in common. For every obvious virtue there is a hidden feature that is extremely critical and the designer who meets with any degree of success will still have to depend not so much on some clever way to utilize an unlimited power source but on his thorough knowledge of all systems so that he can work his way out of traps of his own creation.

The conventional 20 mm cartridge has been used arbitrarily in both the text and illustrations of this work as it represents the first step above rifle caliber and the starting bore diameter in automatic cannon design. It seems to be the most acceptable reference point for the designer regardless of the eventual caliber of his product. Likewise, emphasis has been placed on the airborne automatic weapon because its use under widely varied conditions requires a mechanism that must approach the ultimate of perfection. Having mastered its difficulties, the designer should find most of his other problems have been made relatively easy.

Part X of "The Machine Gun" provides detailed engineering and mathematical analyses of the basic sources of energy that set automatic weapons into activity. This information is the result of observations and practical experience accumulated over the years and translated by the mathematician into a theoretical yardstick for practical design. In Part XI the illustrator replaces the writer. In the chapters of this portion of the book, outstanding design features such as feed mechanisms, locking systems, revolver actions, accelerators, sears, extractors, ejectors, and other components are depicted for the guidance and stimulation of the designer. The sources for the drawings range from early patents and prototypes of actual weapons to theoretical designs of the future. These sources are intentionally omitted from the pages where the drawings are reproduced so that they may be considered on their merits without any conscious or unconscious influence by the fame or obscurity of the originators. Appendix A provides identification of these sources

Additional appendices contain an annotated bibliography listing source materials on machine guns and other automatic arms by topic and a similar subject listing of important patents of the 19th and 20th centuries, each with an abstract of its most outstanding features.

If this work can help in any small way to revive in this country the almost forgotten art of automatic weapon design, a field so thoroughly dominated by Americans in the past, the effort and toil that have been spent in preparing the book will have been well repaid.

ACKNOWLEDGMENTS

With each volume of this series the debt owed to the many persons and institutions that have contributed to the project grows in size. The following persons are listed in at least partial gratitude for their help and encouragement:

Rear Adm. F. S. Withington, Chief of Bureau of Ordnance; Rear Adm. M. F. Schoeffel, former Chief of Bureau of Ordnance; Rear Adm. P. D. Stroop, Deputy Chief of Bureau of Ordnance.

Capt. E. B. Hooper, USN, Asst. Chief of Bureau for Research and Division Director; Capt. B. C. Lovett, USN, Asst. Division Director; Capt. E. E. Christensen, USN, Asst. Director Aviation Ordnance; Comdr. H. H. Klare, Jr., USN, Lt. Comdr. N. F. Campbell, USN, Lt. W. J. Kwitkoski, USN, N. V. Toussaint, DM2, USN, and Miss Dorothy White, Aviation Ordnance Branch, Bureau of Ordnance.

Messrs. Val A. Browning, M. Bigelow Browning, Matt S. Browning, Marriner A. Browning, and John Val Browning, of the Browning Arms Company.

Capt. H. Hull, USN, Comdr. E. L. Dashiell, Jr., USN, Comdr. F. H. Price, USN, Mr. L. L. Henry, Mr. R. M. Decatur, Mr. Matthew Gradijan, Mr. F. W. Holtzberger, Mr. E. L. MacKenzie, Mr. R. J. Martin, Mr. J. F. X. Mayhew, CWO R. S. Harris, USN, and CWO P. L. Chisolm, USN, Naval Gun Factory.

Capt. E. S. Keats, Capt. S. B. Strong, Capt. R. N. Sharp, Capt. J. M. Elliott, Capt. T. H. Ahroon, Capt. J. E. Clark, Capt. W. R. Smith, III, Capt. Richard Matter, Capt. F. B. Miller, Comdr. J. J. Hinman, III, Comdr. W. R. Staggs, Comdr. D. W. Snively, Comdr. Paul Pugh, Comdr. Marvin Franger, Aviation Ordnance Chief J. W. Cospers, U. S. Navy.

Col. R. D. Salmon, Col. L. S. Moore, Col. C. T. Mattison, Col. R. E. Galer, Col. K. D. Kerby, Col. R. H. Richard, Lt. Col. W. E. Clasen, Lt. Col. F. E. Hollar, Lt. Col. Gay Thrash, Lt. Col. L. O. Williams, Lt. Col. E. W. Kelley, Lt. Col. H. Ross Jordan, Maj. Donald Fenton, Maj. J. L. Herndon, Maj. E. Anderson, Maj. Charles Guy, Capt. G. C. Daskalakis, Capt. J. H. Lawson, Capt. H. Leroy, Lt. P. L. Lockaby, Lt. John Elliott, CWO John Scarborough, CWO F. C. Petet, M. Sgt. B. C. Woods, M. Sgt. P. L. Balarezo, M. Sgt. J. J. Lang, M. Sgt. Morris Waldorf, M. Sgt. R. O. Bennett, M. Sgt. Burl Hayes, M. Sgt. Robert Alsop, M. Sgt. Ben Madden, M. Sgt. T. E. Gitz, M. Sgt. Robert Parks, M. Sgt. C. B. Robinson, M. Sgt. T. A. Ward, Jr., T. Sgt. H. E. Johnson, and St. Sgt. George Nelson, Jr., U. S. Marine Corps.

Capt. T. K. Wright, USN, Comdr. L. W. Van Antwerp, USN, Mr. N. D. Marden, Mr. Thomas Crutcher, Mr. Louis Ehrman, Mr. William Jewby, Mr. Philip Grier, Mr. William Blaine, Mr. Augustus Grueter, and Mrs. Rachel Hall, Naval Aviation Ordnance Test Station, Chincoteague, Va.

Mr. H. P. White and Mr. B. D. Munhall, H. P. White and Co.; Mr. Herman P. Dean, Standard Publishing Co.; Mr. Leo X. Abernethy, Bureau of Aeronautics, U. S. Navy Dept.; Mr. John H. Moore, Eastern Glas Laminates, Inc.; Col. George W. Hicks, Pittsburgh Post-Gazette; Mr. J. J. King, author and international big game hunter; Col. Melvin M. Johnson, Jr.; Mrs. Ruth H. Stoeger; Col. Leo A. Codd and Mr. R. E. Lewis, American Ordnance Asso.; Dr. S. G. Green; Mr. H. Peterson, National Park Service; Lt. Col. E. Naramore; Maj. Gabriel D. Moncada; Maj. Alonso Aguirre Ramos; Sr. Domingo G. Cañez; and the late Col. Calvin H. Goddard, USA.

Comdr. L. R. Beiser, USN, and Miss M. Quinn, Security Branch; Mr. G. D. O'Brien and Mr. J. T. Schrott, Patent Branch; Mr. C. H. Grover, Mrs. M. A. Pflaging, Mr. P. P. Shepley, Mr. C. W. Pierrot, and Rev. E. B. Cunningham, Publications Branch; Miss Lillian Martin and Mrs. Margaret Miller, Office Services Branch; Mrs. C. S. Touhey, Material Division, Bureau of Ordnance; Mr. M. S. Solomon and Mr. R. E. Landon, Government Printing Office.

Dr. Remington Kellogg, Director, U. S. National Museum; Mr. P. R. Garber, Director, U. S. National Air Museum; Mr. M. L. Peterson, Curator, Military History; Mr. C. L. Goins, Jr., Museum Curator; and Mr. J. R. Sirlouis, Asst. Museum Curator, Smithsonian Institution.

Col. J. J. Driscoll and Col. F. S. Allen, Jr., U. S. Air Force.

The Hotchkiss Memorial Library, Lakeville, Conn.; Olin Mathieson Chemical Corp.

Deep appreciation is expressed to Maj. Gen. J. S. Hatcher, USA Retired, Col. E. H. Harrison, USA Retired, Mr. W. J. Howe, Mr. W. D. Waite, Mr. J. A. Harper, and the staff of the National Rifle Association, who upon many occasions acted in the capacity of an advisory board and willingly gave needed assistance drawn from their long and colorful careers spent in the art of weapon development.

The untiring personal interest, guidance, and professional advice of Mr. Henry Marschalk, Head, Publications Branch, Bureau of Ordnance, is largely responsible for whatever measure of success the four volumes of "The Machine Gun" have achieved.

Special thanks are extended to Col. G. B. Jarrett and the staff of the Library and Museum Branch, Aberdeen Proving Ground, for their splendid cooperation, especially in loaning representative weapons for illustration.

For their excellent cooperation and service thanks are extended to the staffs of many libraries, museums, and other activities which were consulted. These institutions include the Library of Congress (where particular gratitude must be extended to Col. Willard Webb, Chief, Stack and Reader's Division), the National Archives, Main Navy Library, Bureau of Ordnance Technical Library, Bureau of Aeronautics Library, Ordnance Technical Museum, and the Pan American Union Library.

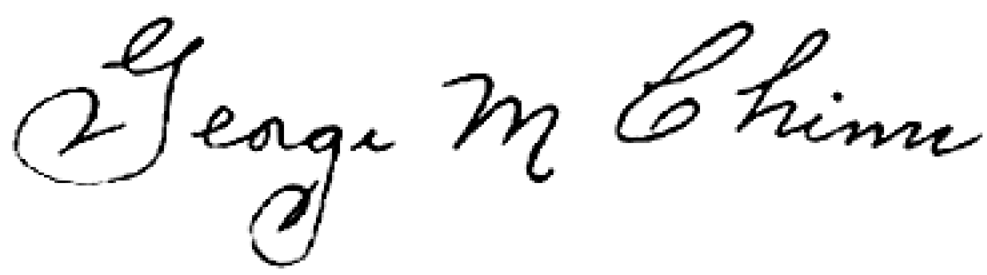
Finally, recognition is gratefully given for the contributions of the four associates who aided in preparing and assembling this work for publication:

Having no precedent as a guide, Mr. James Fleming has performed an outstanding task in setting down the mathematical and engineering analysis of the basic systems of automatic fire. Pioneering in one of the most debatable fields of ordnance, he carried out this analysis from the practical, as well as the theoretical, side of ordnance, making use of field reports, research studies, personal observations, and actual physical participation in firing tests any time the apparent solution to the problem contained an element of doubt.

Mr. Edward Hoffschmidt, internationally known for his drawings and articles on firearms, has demonstrated great originality and resourcefulness in preparing the illustrations for this work. Despite their great volume, he has carried the same high quality and attention to detail into each picture. His unusual skill in bringing out features of automatic mechanisms of varying calibers and projecting them in a standardized form demonstrates his thorough knowledge of weapon design.

One cannot overestimate the importance of the part played by Master Sergeant George McGarry, USMC, in the completion of this publication. Sergeant McGarry's task in disassembling practically every known automatic firing mechanism and studying it in order to highlight its outstanding features was performed in a skillful manner that reflects the quality of his extensive background in automatic weapons.

The text has been edited by Mr. Franklin W. Clark, who displayed not only professional competence in the technical details of organizing a complex manuscript into readable form, but a unique ability in coordinating controversial subject matter varying from the elementary to the technical in a manner that minimizes the inevitable questions that arise.



Lieutenant Colonel, USMCR.

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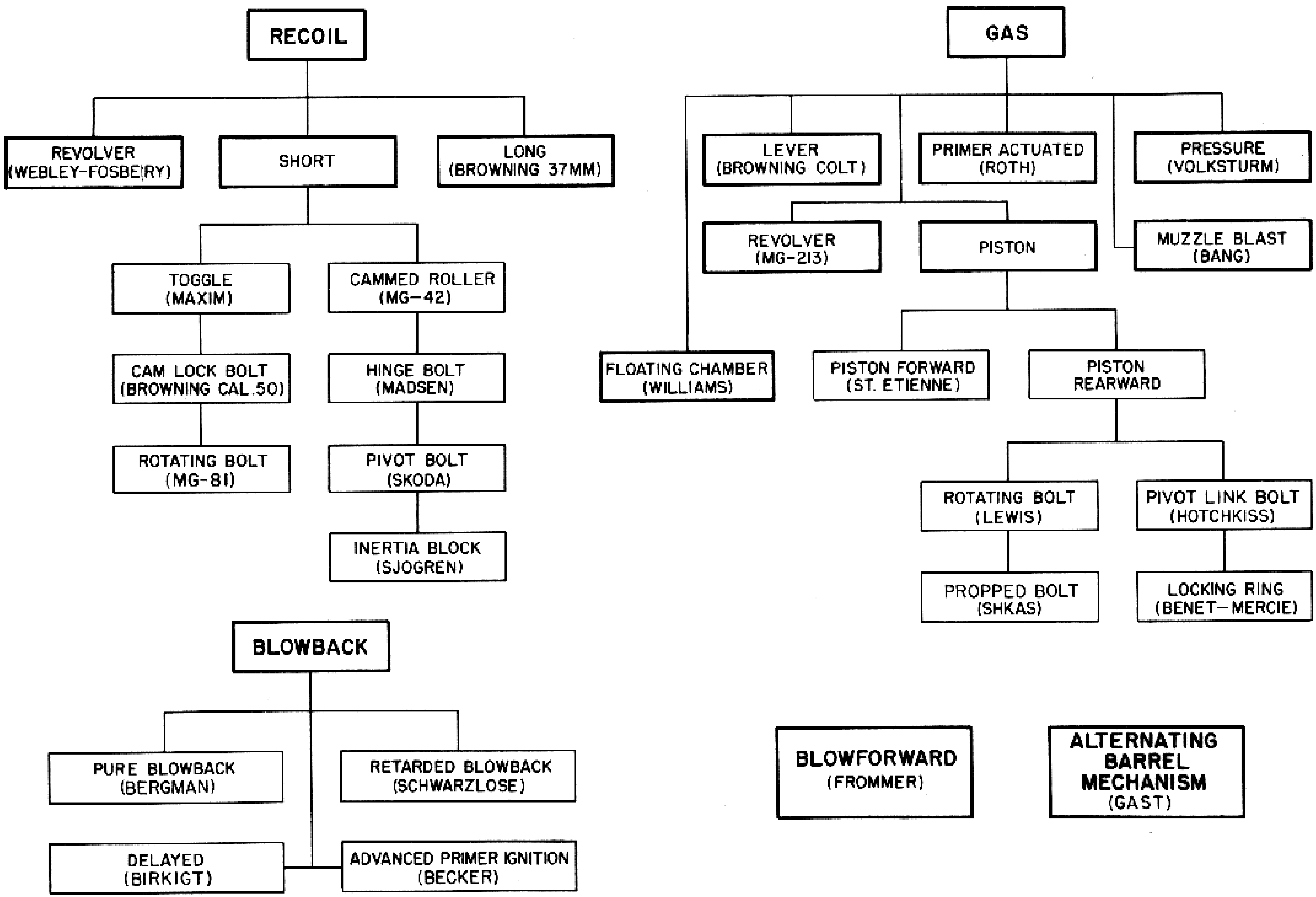

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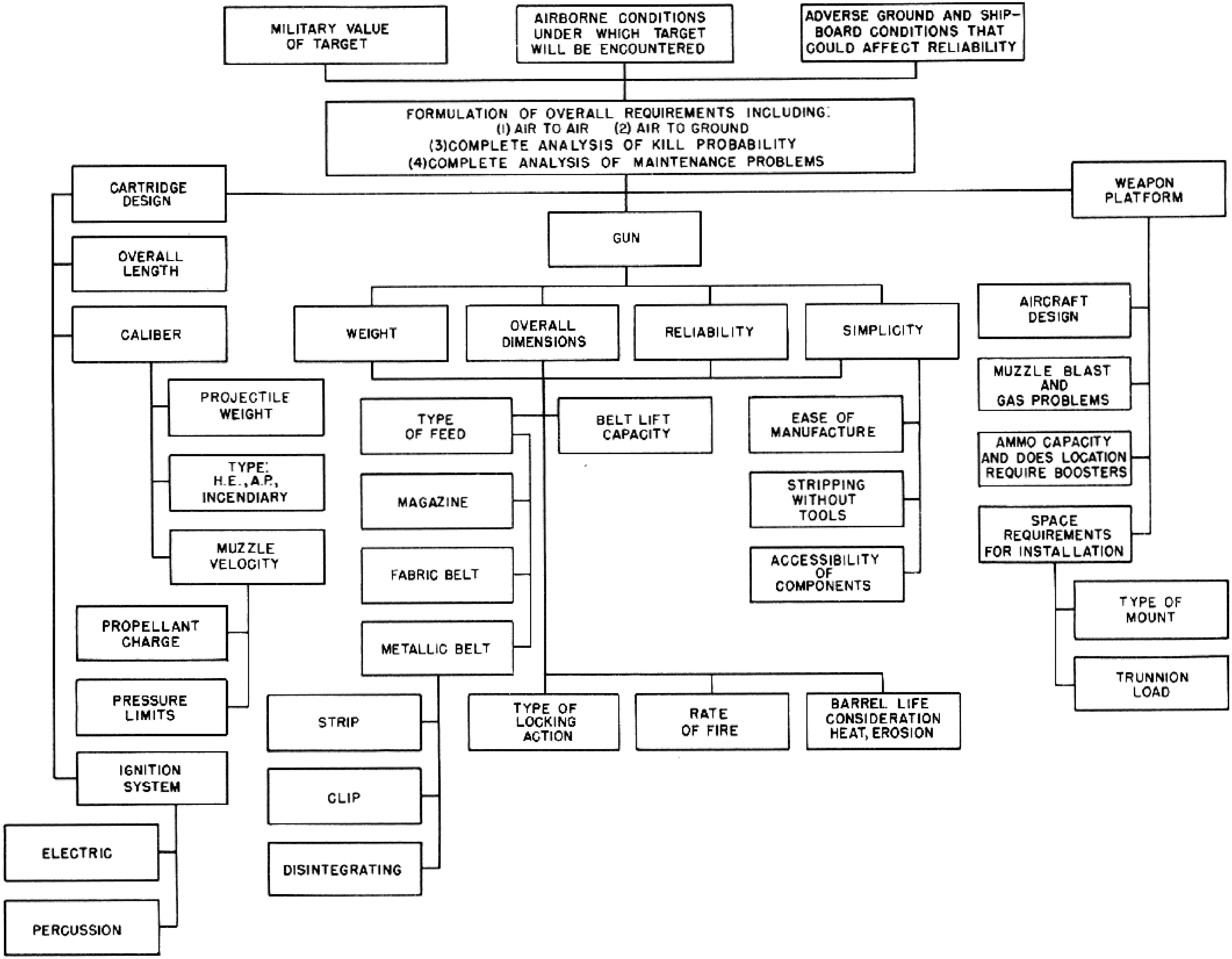

PART X

ANALYSIS OF SYSTEMS

Chapter 1

BLOWBACK

BLOWBACK OPERATION

In the design of any gun, great care must be exercised to be sure that the cartridge case is adequately supported to withstand the tremendous rearward thrust exerted by the powder gases. In many guns, this is accomplished by providing locking devices of great strength and positive action which hold the bolt rigidly closed until the pressure of the powder gases has dropped to zero or at least has decreased to an operating limit at which the breech may be opened safely. However, absolutely rigid support is not mandatory and some movement of the bolt and cartridge case is permissible, providing that the movement is controlled in accordance with definite principles. This controlled movement can then be utilized as a source of energy for automatic operation of the gun mechanism.

The system of operation in which the power required for operating the gun mechanism is derived from the motion of the cartridge case as the case is thrust to the rear by the pressure of the powder gases is called for lack of a better name the "blowback" system. In some guns (which invariably must employ low-powered ammunition) all of the energy used for performing the entire cycle of operation is derived from plain blowback; in other guns, the energy derived from blowback may perform only certain functions in the cycle or may merely supplement the operational energy derived from another system of automatic operation.

In the larger sense, blowback might well be considered to be a special form of gas operation. This is reasonable because the cartridge case may be conceived of as a sort of piston driven by the powder gases.

Actually, blowback involves so many special problems that it is best considered to be in a class by itself. The question of whether or not it should be included within the more general classes of gas operation or recoil operation is purely academic. The important point is that it partakes of some of the properties of both classes and, depending on the particular problem at hand, may be considered to be in either one.

The distinguishing characteristic of a blowback weapon is that the cartridge case must move under the direct action of the powder gas pressure. Thus, any gun in which the bolt is permitted to move while there is pressure in the chamber will be subject to some blowback action. The extent to which blowback is utilized depends on the manner in which the bolt movement is controlled and on what proportion of the operating energy is derived from other systems of operation. The major problem encountered in blowback operation is the problem of controlling the bolt movement so that the motion of the cartridge case is kept to a bare minimum (based on the ultimate strength of the case) during the action of the tremendous gas pressures existing until the projectile leaves the muzzle of the gun. This is necessary in order to maintain effective sealing and also because excessive motion under peak pressures can result in separation or rupture of the cartridge case.

Behavior of the Cartridge Case

The most important single factor to be considered in analyzing blowback operation is the behavior of the cartridge case as it is affected by the pressure of the powder gases. Since this primary factor is so critical and controls all of the basic design features which distinguish blowback operated guns, it will be described fully in the following paragraphs before any further discussion of the details of blowback systems. (Most of the numerical values mentioned in this description apply to a 20-mm gun and typical 20-mm ammunition. This caliber has been selected for purposes of illustration because it is representative of high-powered heavy machine guns.)

When a gun is fired, the explosion of the propellant charge results in the generation of exceedingly high pressures which vary with extreme rapidity. (See fig. 1–1.) Although the curves for

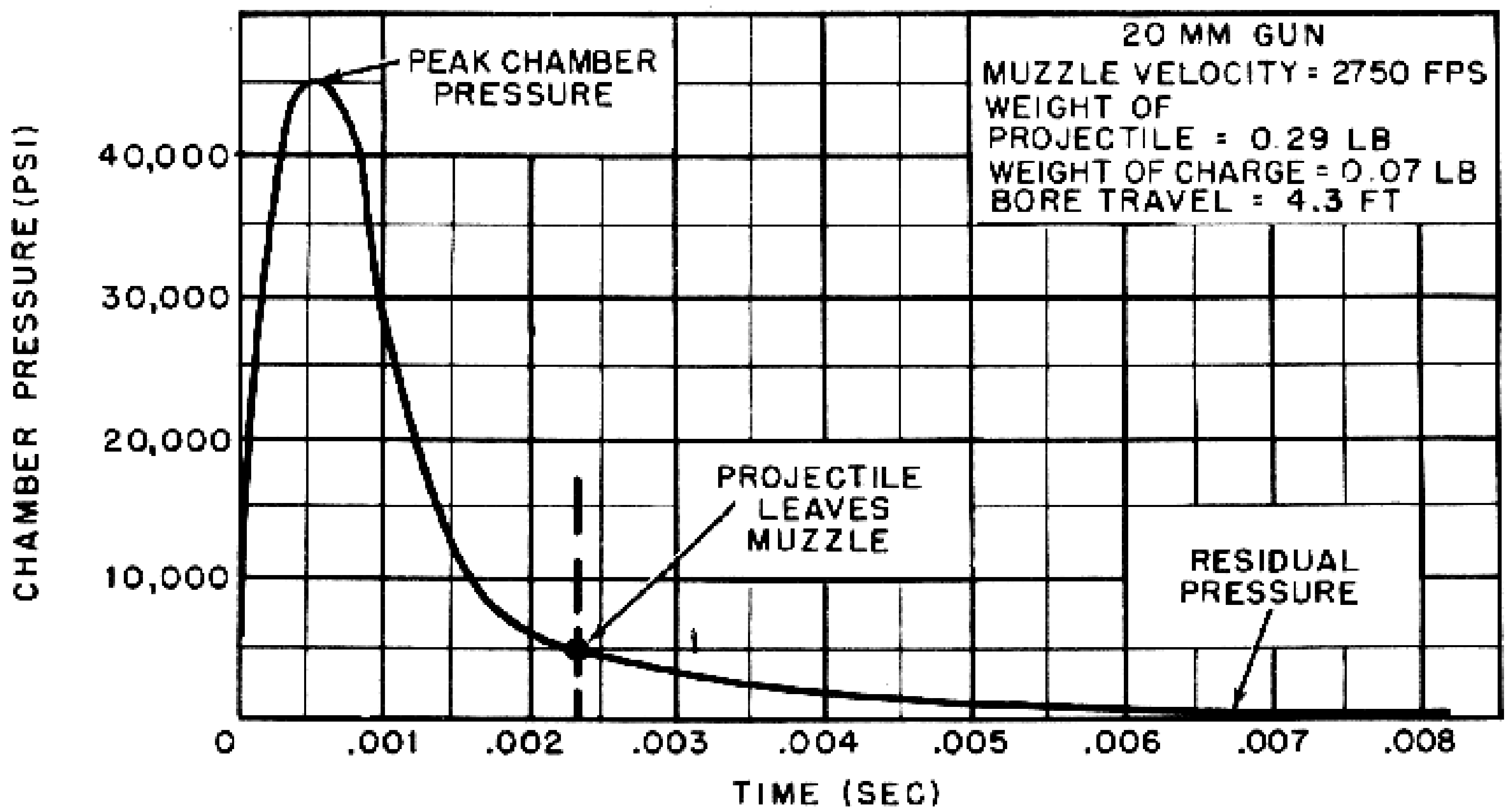

Figure 1–1. Variation of Chamber Pressure With Time.

varying types of 20-mm ammunition, when used in different types of guns, are not all exactly the same, the values shown by the curve in the figure are more or less typical of modern ammunition of this caliber. As shown in fig. 1–1, the gas pressure builds up to a peak of 45,000 psi within 0.0005 second after ignition of the primer, then (for the particular barrel length cited in fig. 1–1) decreases until it is 5000 psi when the projectile leaves the muzzle at 0.0023 second, and finally falls off quickly to zero as the gases leave the muzzle. The pressure which exists during the small fraction of a second after the projectile leaves the muzzle is called the "residual" pressure. This pressure may be considered to decrease exponentially with time and to be practically zero within 0.008 or 0.009 second after ignition of the primer.

The gas pressure acts uniformly in all directions against the inside of the cartridge case as shown in fig. 1–2. The radial components of the pressure act on the walls of the case to expand the case against the walls of the chamber, thus creating a seal which prevents the escape of the powder gases to the rear. (It should be realized that the radial forces acting on the case walls are of tremendous magnitude. In fact, the walls of the case are crushed so tightly against the chamber walls and the temperature in the chamber is so high that there is almost a tendency for the case to be spot-welded to the chamber.)

The net sum of the axial pressure components acting against the cartridge case creates a force which tends to drive the case to the rear against the resistance offered by the bolt. When the case

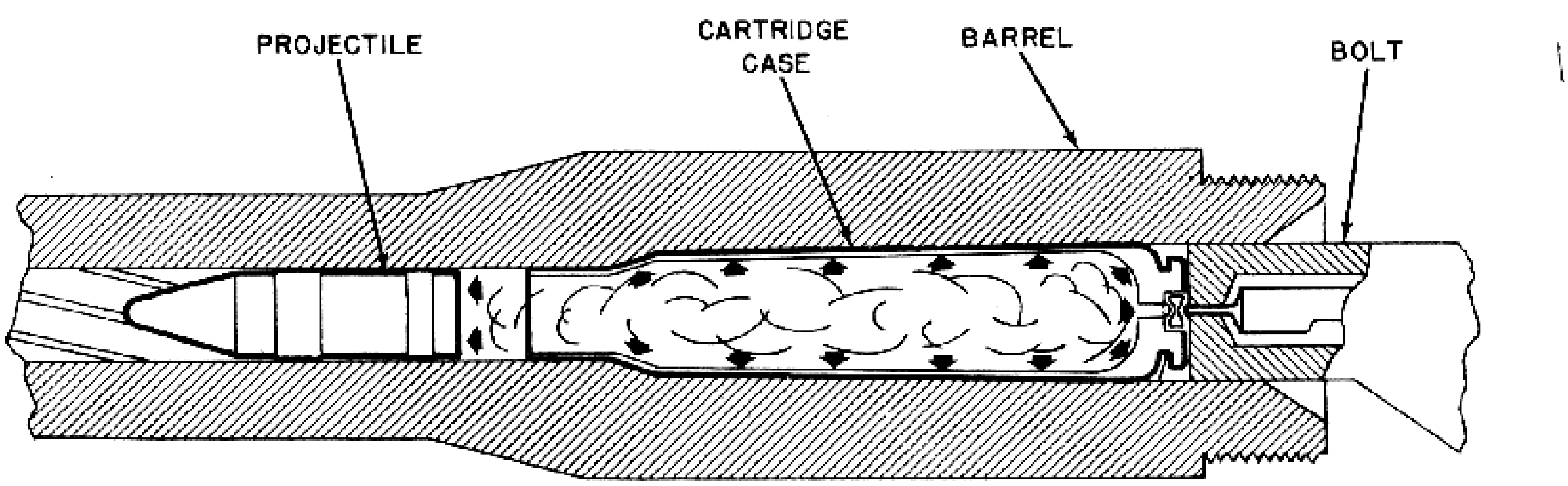

Figure 1–2. Pressure in Chamber.

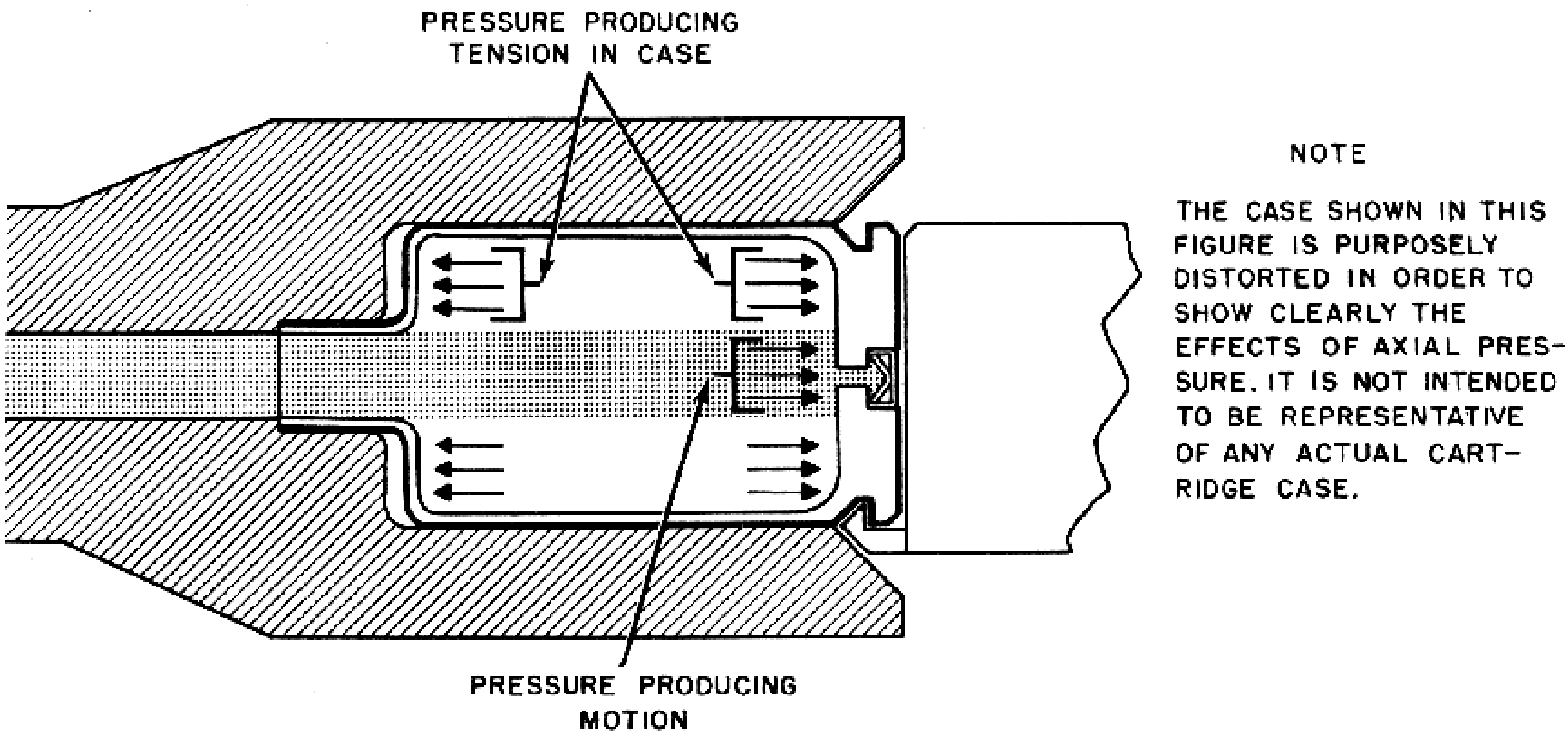

Figure 1–3. Effects of Axial Pressure.

is free to slide in the chamber, this net force is equal to the chamber pressure multiplied by the total cross-section area of the mouth of the case (not the projected area of the inside of the base). (See fig. 1–3.) If the projected area of the base of the cartridge case is greater than the area of the mouth, the force on the base is of course greater than the net force. However, the difference between the forces is cancelled by the axial component on the tapered or necked portion of the case. (This component is directed forward.) Note that if the entire case were free to move, the difference between the net force and the force on the base would cause a tension in the walls of the case.

If the bolt were rigidly locked and held firmly against the base of the cartridge case (that is, if there were zero excess head space), the gas pressure would merely compress the material of the cartridge case against the chamber walls and bolt face. However, with blowback operation, the case and the bolt must be free to move at some predetermined time during the action of the gas pressure so that the required energy can be transmitted to the bolt. For purposes of examining the effects of this movement, it will be assumed that the bolt is not locked at any time and that it resists movement only by its inertia. (As will be pointed out later, these conditions do not apply for all blowback weapons.) The movement of the cartridge case can be considered to occur in the following three phases:

PHASE 1. The pressures which exist during the first 0.0001 second of the propellant explosion are relatively low but are sufficient to expand the thin brass near the mouth of the cartridge case against the chamber wall, thus forming the seal which prevents the powder gas from escaping to the rear. Since the radial pressure is not extremely high during this phase, the friction between the cartridge case and the chamber is not excessive. Therefore, the axial component of the pressure causes the entire case to stretch or slide back slightly in the chamber so that it first takes up any excess head space which may exist and then starts to impart motion to the bolt. Because of the high inertia created by the mass of the bolt, the velocity of this motion is relatively low.

NOTE: If the excess head space is very large, it may not be taken up entirely before the chamber pressure builds up to a high value. In this event, the conditions described in Phase 2 are applicable.

PHASE 2. The second phase of the cartridge case movement occurs during the period of extremely high pressure on either side of the peak shown in fig. 1 1. The behavior of the cartridge case during this phase depends entirely upon whether or not the case is suitably lubricated.

If the cartridge case is entirely unlubricated or is insufficiently lubricated, it is expanded heavily against the chamber walls, producing a high-pressure metal-to-metal contact which results in a very high friction between the case and the chamber. Because of the friction between the walls of the case and the chamber, the pressure acting against the base of the case will result in a tensile stress in the walls of the case. In fact, the forward portion of the case may be gripped so tightly during the period of high chamber pressure that the frictional resistance exceeds the tensile yield strength of the case walls. In this event, the forward portion of the case sticks to the chamber wall but the rear portion continues to move, causing the case to stretch plastically. If the bolt does not provide sufficient resistance to prevent the stretching of the case from exceeding the allowable elongation of the case material (about 0.015 inch), the case will separate.

At this point, special mention should be made of what effect excessive head space would have if an attempt were made to use unlubricated ammunition. As pointed out in Phase 1, the motion of the case may not take up all the head space before the chamber pressure builds up to a value high enough to cause the forward portion of the cartridge case to stick. Assuming that some excess head space still remains, the base of the case will be unsupported and the high pressure will cause the case to be stretched. If the excess head space is so large that it is not all taken up before the stretch exceeds the allowable elongation of the case material, separation will occur.

NOTE: It should be realized that the forces produced by the peak chamber pressures are vastly in excess of the strength of the thin brass of the cartridge case. With forces of this magnitude, the case stretches quite easily. This may be illustrated as follows: With the forward portion of the case stuck, the force tending to stretch the case is equal to the pressure multiplied by the area of the inside of the base. Since the maximum chamber pressure for a 20-mm cartridge is 45,000 psi and the inside base area is approximately 0.5 square inch, the stretching force is in the neighborhood of 22,000 pounds. The area of metal in tension for the case wall may be approximately 0.1 square inch and the ultimate strength of the half-hard brass of which the case is made is about 50,000 psi. Therefore, the maximum resistance which the case can offer to stretching and separation is only approximately 5000 pounds. It easily can be seen that this resistance is practically negligible when compared to the stretching force of 22,000 pounds. In fact, forces sufficient to produce separation can occur whenever the chamber pressure is over 10,000 psi, and as shown in fig. 1–1, such pressures exist for almost the entire time the projectile is still in the bore. (Note that the force expended in overcoming friction or in stretching the case reduces the force applied to the bolt. If this effect is excessive, the gun may fail to continue firing because the energy transmitted to the bolt is insufficient to operate the gun mechanisms).

The preceding description applies to the condition in which the case is either entirely unlubricated or insufficiently lubricated. If a fairly thick film of a suitable lubricant is applied between the cartridge case and the chamber wall, an entirely different condition results. It should not be thought that the purpose of the lubricant is merely to make the cartridge case "slippery". Its true purpose is to form a continuous film which remains between the case and the chamber wall and effectively "insulates" their surfaces from metal-to-metal contact, even under extremely high chamber pressures. Since there is no metal-to-metal contact to cause seizing and sticking, the case slides freely in the chamber and the only resistance to its movement (except for the resistance offered by the bolt) is the force required to produce shear in the lubricant film.

According to established laws regarding friction, the frictional resistance for well-lubricated, smooth metallic surfaces is relatively very low and is practically independent of the pressure between the surfaces. The major considerations are the area of the lubricant film in shear, the viscosity of the lubricant, and the speed of the relative movement between the surfaces. Thus, a well-lubricated cartridge case will move almost as freely under high chamber pressure as under low pressure and therefore proper lubrication should completely eliminate seizing of the cartridge case, which is the basic cause of case separation.

Although proper lubrication will eliminate seizing of the cartridge case, other difficulties can occur if the case is permitted to move too far while the chamber pressure is extremely high. Excessive movement will result in a condition where the rear portion of the case is out of chamber and will therefore receive no radial support from the chamber walls. The high internal pressure may then cause the case to swell at the base portion or even to rupture. Furthermore, if in the chamber, the seal between the case and chamber may be broken thus permitting the escape of hot powder gases at the breech. (In most rapid-firing blowback guns some escape of gases at the breech is inevitable, but if this effect is excessive it can cause damage to the breech mechanism or may even be dangerous for operating personnel.)

It is of interest to note a special difficulty which can occur with ammunition having a cartridge case of large diameter when compared to the projectile diameter (bottle-necked or strongly tapered case). With this type of case, the internal pressure tends to produce high tensile stresses in the case walls. (See fig. 1–3.) If the case is bottle-necked, the rearward movement of the case creates a space between the shoulder of the case and the chamber. Since this leaves the forward portion of the case unsupported, the internal pressure tends to deform the case by pushing the shoulder forward to fill the space created by the movement. If the case is of the tapered type, the rearward movement tends to create a gap between the wall of the case and the chamber. Since this leaves the wall of the case unsupported, the internal pressure expands the case to close the gap.

Under either of the conditions described above, the deformation of the case can be of considerable magnitude if the movement of the bolt is excessive and it is quite possible that the deformation will exceed the allowable limit of the brass. This may cause the case to tear or rupture in such a way as to cause a separation or to cause difficulties in extraction or ejection. For this reason, plain cylindrical cases or cases with only a slight taper are to be preferred for use in blowback guns.

PHASE 3. The final phase of the cartridge case movement starts when the chamber pressure has decreased to a level which permits the case to contract, thus reducing the friction to a negligible value. After this point, the remaining pressure continues to drive the case to the rear but the forces on the case are low enough so that there is no danger of the case failing by separation or rupture. This phase ends as the gas pressure approaches zero (0.008 or 0.009 second after ignition of the primer). Although at this point the driving force is reduced to zero, the case and bolt continue to move of their own momentum with sufficient kinetic energy to complete the extraction and ejection of the case and to operate the gun mechanisms for the remainder of the automatic cycle.

Conclusions

All of the points discussed in the preceding description of the behavior of the cartridge case in a blowback gun may be summarized in one very important principle which controls all of the characteristics and fundamental design requirements for this type of weapon. This principle may be stated simply as follows:

THE PRIMARY DIFFICULTIES IN BLOWBACK OPERATION ARE THE DIRECT RESULT OF EXCESSIVE CARTRIDGE CASE MOVEMENT DURING THE PERIOD OF EXTREMELY HIGH CHAMBER PRESSURE AND THESE DIFFICULTIES ARE AGGRAVATED BY INADEQUATE CASE LUBRICATION.

In the design of blowback guns, each factor mentioned in this statement must be considered carefully in order to avoid operational difficulties. This analysis leads to the following general conclusions.

CHAMBER PRESSURE. All of the difficulties that arise are the direct result of extremely high chamber pressure. Therefore, it follows that if the chamber pressure could be kept low, these difficulties would disappear immediately. Unfortunately, high chamber pressures are essential in high-powered heavy machine guns (which are the main concern of this publication) and accordingly, the use of low chamber pressure cannot be considered as a solution to the design problem. (The relative ease with which the blowback principle can be applied to low-powered small-caliber ammunition is amply demonstrated by the large number of self-loading pistols, sub-machine guns, and light machine guns that have used this principle successfully.)

CASE MOVEMENT. The major problem confronting the designer of a high-powered blowback gun is how to limit the movement of the cartridge case during the action of the extremely high pressures resulting from the explosion of the propellant charge. This problem and the design difficulties related to it are the direct result of a number of conflicting requirements.

Since, in blowback weapons, the source of the power for operating the mechanism is derived from the thrust applied to the cartridge case by the powder gases, it is essential for the cartridge case to move while the gas pressure is acting. However, it is this very motion under pressure which causes separations and other damage to the cartridge case. When steps are taken to reduce these difficulties by limiting the movement of the cartridge case, care must be exercised to insure that sufficient energy will be available to operate the gun effectively at the desired rate of fire. Furthermore, if adequate lubrication of the cartridge case is provided so that a fairly high bolt velocity can be tolerated during the period of high chamber pressure, it may be found that the resulting rapid extraction of the case will cause rupture of the case or cause the breech seal to be broken too soon.

The foregoing considerations and other points which will be discussed later cause the design of a blowback gun to be a problem in balancing various critical factors, one against the other, in order to obtain the required performance characteristics. There are many possible solutions to this design problem and the particular solution employed is what determines the basic features of the gun. A detailed explanation of how these solutions are applied in practice is given later under the heading "Blowback Systems".

LUBRICATION. The importance of providing suitable lubrication for high-powered ammunition used in blowback guns cannot be emphasized too strongly. Experience has shown that without proper lubrication, difficulties such as case separation, chamber seizure, loss of bolt recoil energy and poor extraction seem to make it impossible to attain high performance in a blowback gun. In fact, so essential is lubrication to this type of weapon that the term "oil-omatic" has been suggested as being more suitable than "automatic" for use in referring to blowback machine guns.

It is very important to realize that under practical operating conditions, factors may be encountered which make it very difficult to maintain suitable lubrication for ammunition. For example, guns and ammunition used in arctic operations or carried by aircraft flying at very high altitudes can be subjected to extremely low temperatures that can cause ordinary lubricants to fail completely. It also should be remembered that greasy substances applied to the ammunition or chamber wall easily pick up sand or other contamination that can cause the lubricant film to be broken and cause the cartridge case to seize in the chamber. This problem is particularly serious for any gun which is to be used in the field. All things considered, one of the first things that the designer of a blowback gun must do is find an ammunition lubricant which is suitable both for its intended purpose and for the operating conditions to which the gun will be subjected. If such a lubricant can not be found, it is safe to say that blowback operation will not be practical and should be abandoned in favor of some other system of operation in which cartridge case lubrication is not of such critical importance.

Although the term "lubricant" usually brings to mind an oil or grease, there are many other substances which can qualify (at least from the theoretical point of view) as ammunition lubricants. This is so because the only really important requirements for an ammunition lubricant are that it must form a continuous insulating film and that the force required to produce shear in the film must be smaller than the force required to produce separation of the cartridge case. It can be seen readily that in order to satisfy these requirements, a substance need not have any of the unctuous or "slippery" character usually associated with lubricants used for minimizing friction.

The fact that it is relatively easy to think of almost any number of substances which could satisfy the theoretical requirements might lead one to believe that it would be a small problem to find an ammunition lubricant suitable for any and all conditions. The sad truth of the matter is that such a substance has been sought eagerly but unsuccessfully ever since 1898. In this quest of over half a century, designers, inventors, research groups, and just plain practical men have suggested an amazing number of materials which seemed to have possibilities. The list includes waxes, graphite mixtures, a variety of liquids, and solid coatings, all of which are so numerous that recording them here would take too much space. However, controlled tests and the hard lessons of practical experience have eliminated them all.

Other more radical attempts to avoid case seizure through the use of such devices as chromed, fluted, or stepped chambers have met with a similar lack of success. These suggested materials and remedies have failed because they all amounted to stepping out of one difficulty into another. For example, one coating which seemed otherwise satisfactory was scraped off the ammunition by the feeder in the form of small shavings that soon gummed up the breech mechanism. Other substances produced excessive fouling in the chamber, and so on.

The result of all this experimentation is that today, as in 1898, heavy-bodied oil and grease, with all their attendant difficulties, are still the only substances which have been used to lubricate ammunition with any reasonable degree of success. Either of them will produce a good film which will provide the required insulating effect and under many conditions of operation the difficulties encountered in their use are not too serious.

It should be remarked here that light oil, such as sewing machine oil, is not a satisfactory lubricant for ammunition. It may be argued that even light oil can form a film and is just as incompressible as heavier oil or grease and therefore should serve as well to provide the required insulation. However, practical experience has shown that the use of light oil is not effective in preventing case separations. Apparently, the difficulty with light oil is that a sufficiently thick film can not be maintained. As shown in fig. 1–4A, the light oil will form a film which covers the entire cartridge case, but there are bound to be small irregularities in the cartridge case wall. When the case is expanded in the chamber by the pressure of the powder gases, as shown in fig. 1–4B, the light oil will be caused to flow off the high spots into the low spaces and since the film is so thin, there will not be sufficient oil to over-fill these spaces. Therefore, all the oil will be forced off the high spots, thus permitting metal-to-metal contact to occur at these spots. On the other hand, a sufficiently thick film of a heavier bodied lubricant can be maintained so that even though there is some flow into the low spaces, there is still enough lubricant to cover the high spots (figs. 1–4C and 1–4D).

There is another advantage to the use of heavier bodied lubricants. In any gun, the exploding powder gases produce a flame which escapes around the cartridge case during the extremely brief instant required to expand the neck of the case against the

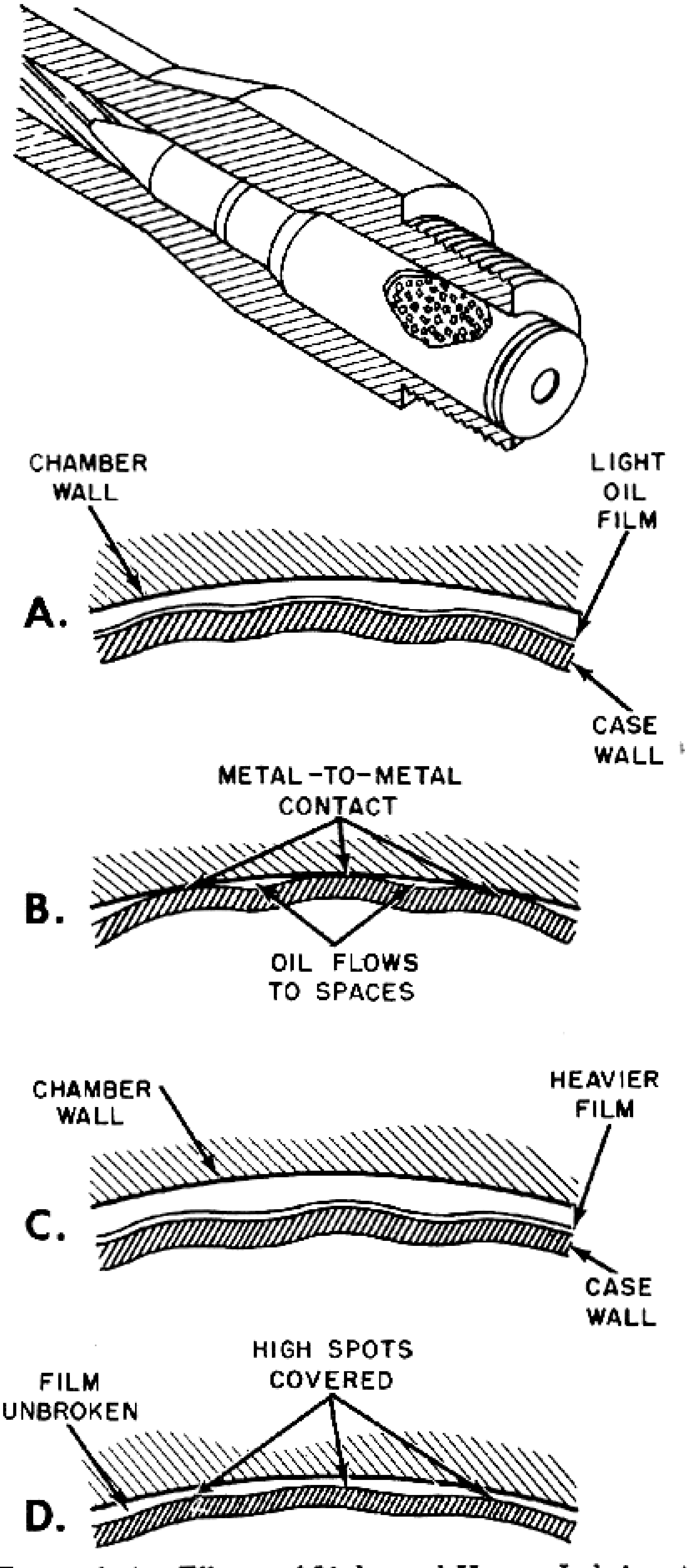

Figure 1–4. Effects of Light and Heavy Lubricant Films.

chamber. (This effect is especially noticeable when the rotating band of the projectile is larger in diameter than the neck of the case. With this condition, the case neck must be expanded considerably before the seal is made with the result that the escaping flame will be longer in duration.) The escaping flame tends to burn off or dry up the lubricant applied to the case. Light oil is particularly subject to this burning or drying action. The thicker films formed by heavier oils or grease seem not only to stand up better but also to provide a seal which helps to limit the escape of the flame.

THE CARTRIDGE CASE MUST BE THOROUGHLY LUBRICATED FOR THE ANALYSIS GIVEN IN THE PRECEDING PARAGRAPHS TO APPLY. WHEN A THICK FILM OF OIL EXISTS AROUND THE NECK OF THE CARTRIDGE, THE GAS PRESSURE IS NOT SEALED OFF FROM THE OUTSIDE OF THE CASE BUT IS TRANSMITTED HYDRAULICALLY BY THE OIL FILM. THIS CONDITION MAKES THE ENTIRE CARTRIDGE CASE ACT AS A HYDRAULIC PISTON AND PRODUCES A REARWARD FORCE EQUAL TO THE BREECH PRESSURE TIMES THE CROSS-SECTION AREA OF THE CHAMBER AT ITS LARGEST DIAMETER. THEREFORE, WITH THE USE OF A HEAVY-BODIED LUBRICANT, THE INITIAL FORCE DRIVING A NECKED CARTRIDGE CASE TO THE REAR IS CONSIDERABLY GREATER THAN IT WOULD BE FOR AN UNLUBRICATED CASE, MAKING ADEQUATE LUBRICATION ABSOLUTELY NECESSARY IN ORDER TO OBTAIN CONSTANT PERFORMANCE. THIS IS ONE OF THE REASONS THAT THE PRESENCE OF OIL ON THE AMMUNITION IS VITAL FOR WEAPONS EMPLOYING ANY FORM OF BLOWBACK.

CARTRIDGE CASE. In many instances when a gun is designed, the designer is required to use a particular type of available ammunition or at best he finds it possible to choose one of several available types. It rarely happens that a new type of ammunition can be developed to suit the special requirements of a new gun design. In other words, the characteristics of the ammunition are usually not under the control of the gun designer and he has to do the best he can with what ammunition is available to him.

Although the gun designer usually has little or no control of the ammunition he must use, there may be occasions when he can exercise some choice in selecting some of its characteristics. For blowback weapons, there are definite advantages to be gained from selecting ammunition with certain desirable cartridge case characteristics. These characteristics may be outlined as follows:

1. The case should be made as strong as possible in order to minimize the possibility of separations or other damage. One way to accomplish this is to provide a relatively great thickness of metal at the points where the case is likely to fail. Another method is to use a strong material in fabricating the case. To illustrate this point, the half-hard brass from which cases are usually made may have an ultimate strength in tension of approximately 50,000 psi while other materials, depending on the type used, may have an ultimate strength two or three times greater than this value.
2. Other factors influence the choice of the case material. The material should be highly elastic so that it can be expanded considerably by the chamber pressure without undergoing plastic deformation. If the material has this property, the case will more readily shrink back to its original dimensions when the chamber pressure drops to a low value, thus facilitating extraction. In addition, the material should have a large allowable elongation for suddenly applied loads so that the case can be stretched considerably without separating.
3. In order to minimize deformation of the cartridge case, the case should be nearly cylindrical with only a slight taper and little if any bottle neck. The reasons why taper and bottle neck should be avoided have been explained previously under PHASE 2 of the behavior of the cartridge case.
4. The finish and dimensions of the case should be such as to minimize frictional resistance to the movement of the case. The case should be smooth and free of scratches or other irregularities which would tend to impair the efficiency of the lubricant by causing discontinuities in the lubricant film. Also, the case should be as small as possible in order to keep the area of the case walls to a minimum. Then for any given chamber pressure, the friction forces on the case will be minimized.

Evaluation of the preceding characteristics will reveal that the attainment of one desirable characteristic may make it difficult or impossible to attain one or more of the others. Furthermore, it may happen that the attempt to obtain qualities which make the cartridge more suitable for use in a blowback weapon may introduce other problems such as poor ballistic performance or difficulties in manufacture. Nevertheless, all of these characteristics should be considered carefully in the selection of an existing cartridge for use in a blowback weapon or in setting up the requirements for a new cartridge. Close attention paid to the problem of obtaining the most suitable cartridge case may spell the difference between success and failure for a new gun design.

BLOWBACK SYSTEMS

Blowback is defined as a system of operation in which energy used for providing power for the gun mechanism is obtained from motion of the cartridge case as the case is pushed rearward out of the chamber by the pressure created by the explosion of the powder charge. This thrust on the cartridge case is a direct result of the total reaction to the forward thrust applied in moving the projectile and the expansion of the powder gases.

In some guns, all of the energy required for the performance of the automatic cycle is obtained through blowback action while in others only a portion of the required energy is obtained through blowback, the remainder being derived from some other system of operation. In any event, the blowback effect is present, at least to some extent, whenever the bolt of a gun is not locked while there is powder gas pressure in the chamber.

When blowback action occurs, the energy derived from the pressure of the powder gases appears in the form of kinetic energy transferred to the bolt mechanism, or in other words appears in the form of a velocity imparted to the bolt mass. The basic problem involved in blowback operation is in controlling this velocity so that the gun will operate as desired. There are many methods by which the control of the rearward motion of the bolt may be accomplished in guns employing blowback and these various methods are referred to as blowback "systems".

In the following pages the various systems used for controlling the bolt velocity are described and analyzed by considering the sequence of events during the automatic operating cycle. This analysis is concerned only with the functioning of the mechanisms and with the general factors affecting design.

PLAIN BLOWBACK SYSTEM

The problems encountered in controlling the bolt velocity in a blowback gun can be appreciated best by analyzing the so-called "plain blowback system". In this system, blowback provides all of the operating energy and the motion of the cartridge case is limited only by the inertia of the bolt.

NOTE: As will be explained, the plain blowback system is not suitable for application in a high-powered heavy machine gun. It is treated here because it serves to illustrate many of the basic principles involved in other more successful variations of blowback.

Although the actual form of the mechanism for a particular gun of this type may differ considerably from that shown in fig. 1–5, the mechanism shown in the figure is representative of the type from the standpoint of function. The mechanism consists essentially of the bolt (which backs up the cartridge case and is free to slide in the breech casing) and the driving spring (which absorbs the kinetic energy

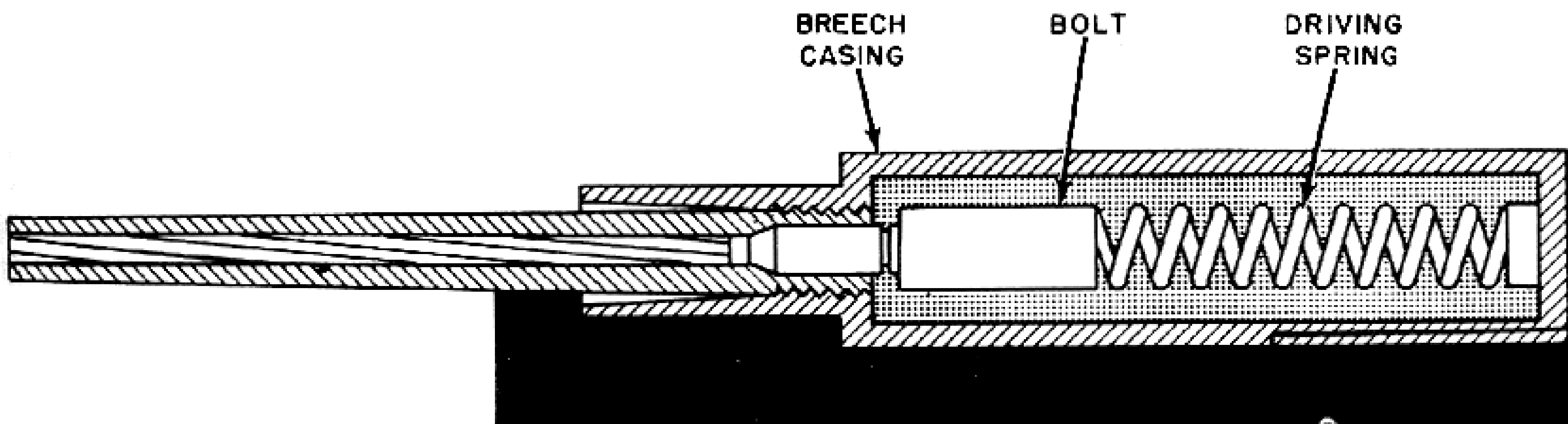

Figure 1–5. Simplified Schematic of Blowback Mechanism.

of the bolt when the bolt is blown back and then drives the bolt back to the firing position).

Cycle of Operation

The automatic cycles of operation for guns employing simple blowback are all more or less the same and occur as follows:

The cycle starts when the bolt is driven against the base of the cartridge in the chamber, firing the round. When the cartridge is fired, the pressure of the powder gases drives the projectile through the barrel of the gun and at the same time immediately drives the cartridge case to the rear against the resistance offered by the bolt. At this point, the only significant resistance to the acceleration of the bolt is due to the inertia of the bolt mass.

The force exerted by the powder gases exists for a relatively very short time. In a typical 20-mm gun with a total barrel length of slightly over five feet, the projectile leaves the muzzle after approximately 0.0023 second and the residual gas pressure continues to act for another 0.008 or 0.009 second. Thus the bolt is subjected to accelerating forces only during the first 0.008 or 0.009 second after ignition of the primer. After this point, the powder gas pressure is zero and the force driving the bolt back is also zero but the case and bolt continue to move of their own momentum. As the bolt moves back, the case is extracted from the chamber and ejected. The bolt slows down as its motion compresses the driving spring until the resistance of the spring combined with the action of the buffer has decreased the bolt velocity to zero. At this point, all of the kinetic energy originally imparted to the bolt (except for losses resulting from extraction, ejection, and friction) is stored in the spring as potential energy.

The driving spring then pushes the bolt forward. As the bolt moves forward, it cocks the firing mechanism, picks up a fresh cartridge from the feed mechanism, and carries this cartridge into the chamber. Just before the bolt reaches its fully forward position, the potential energy stored in the driving spring has been transformed back into kinetic energy of the bolt and cartridge (except for losses occasioned in feeding the cartridge, in cocking the firing mechanism, and in overcoming friction). Therefore the bolt is moving with considerable velocity and the kinetic energy resulting from this velocity is absorbed by impact at the end of the forward travel. As the bolt comes to rest, ignition occurs and a new cycle begins.

Analysis of Plain Blowback

In the preceding description of blowback operation, it was pointed out that the most critical factor affecting the design of a gun employing this system is the movement of the cartridge case during the action of the powder gas pressure. There are two considerations relating to this movement which impose definite limitations in the design.

1. If no lubrication is provided, the high pressures generated in the early part of the explosion will cause the cartridge case to seize in the chamber. Therefore, separation of the case will result unless the movement of the bolt is limited so that the allowable elongation of the case material is not exceeded while the case is stuck. Although the precise elongation limit for a specific cartridge case can be determined only by careful experimentation, a good rule for the brass cases of 20-mm rounds is that the bolt movement should not exceed 0.015 inch during the first 0.0015 second of the propellant explosion. In other words, the average velocity of the bolt during this time should not exceed 10 inches per second or at the most one foot per second.
2. Even if chamber seizure can be avoided by means of adequate lubrication, the cartridge case can not be permitted to move out of the chamber so far that its thin walls do not receive any radial support while the residual pressure is still fairly high. If this were permitted to happen, it could easily result in swelling or bursting of the case near the base. Here again, the exact limit for a particular cartridge case can only be determined experimentally, but a good rule to follow for brass 20-mm cases is that the movement should not exceed 0.250 inch during the first 0.010 second of the propellant explosion. By this time, the residual pressure will be zero or at least so low that further movement of the case can occur without any danger. This means that during this time the average velocity of the bolt should not exceed 25 inches per second or approximately two feet per second.

This limit is based on the use of an ordinary cartridge case which enters the chamber only to the

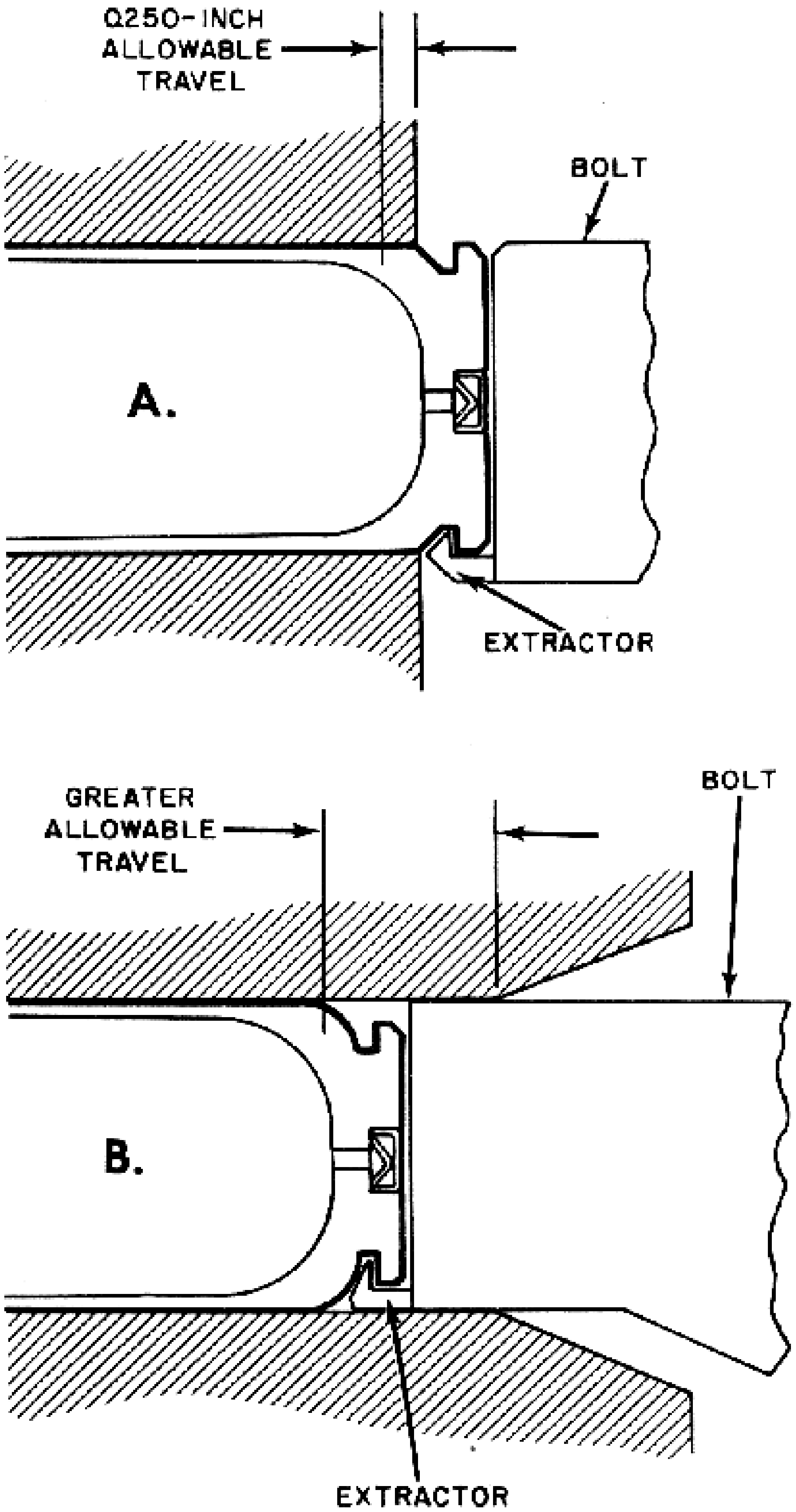

Figure 1–6. Advantage of Using Special Cartridge Base Form for Blowback.

point shown in fig. 1–6A (as is necessary to allow for the presence of the extractor in the extractor groove). If a cartridge case with the special base form shown in fig. 1–6B is used, the cartridge may be pushed further into the chamber and when it is blown back it may therefore travel a greater distance before the walls near the base become unsupported. By this means, the allowable bolt velocity during the first 0.01 second may be increased somewhat but it should be realized that even with this provision, the velocity will still be limited to a relatively low value.

IMPORTANT NOTE: There are two extremely significant points which may be arrived at from further consideration of the foregoing rules:

Fig. 1–7 shows graphically the manner in which the bolt velocity varies in a plain blowback gun during the first 0.010 second of the cycle of operation. The shape of the curve shows that the velocity increases rapidly for the first one or two thousandths of a second and then, as the powder gas pressure falls, it increases much more gradually. (The *shape* of the curve will be the same for any plain blowback gun. Only the vertical *scale* will vary, depending on the particular gun design.) If the gun is designed to permit an average bolt velocity of one foot per second during the first 0.0015 second in order to comply with the first rule, the scale of the graph is then determined so that the average velocity over 0.010 second will be approximately two feet per second, which is the limit required in accordance with the second rule.

In other words, if lubrication is employed to prevent case separation in an attempt thus to escape the limitation of the first rule, the bolt velocity still can not be increased because this will result in exceeding the limitation imposed by the second rule. This means that to gain any significant benefit from lubrication in a plain blowback gun, special steps must be taken to permit a greater average bolt velocity than two feet per second during the first 0.010 second. (As pointed out previously, some moderate improvement in this direction can be achieved by the use of the special type of cartridge case shown in fig. 1–6B.)

The important point involved in these considerations is that, without lubrication, the results of using both of the given rules are so similar that either rule may control the design of the gun. If lubrication is used, the second rule will control, and the average bolt velocity allowable in the first 0.010 second will still be two feet per second unless some special means are employed to increase this limit. In any case, the average bolt velocity must be limited to a very small value, somewhere in the order of

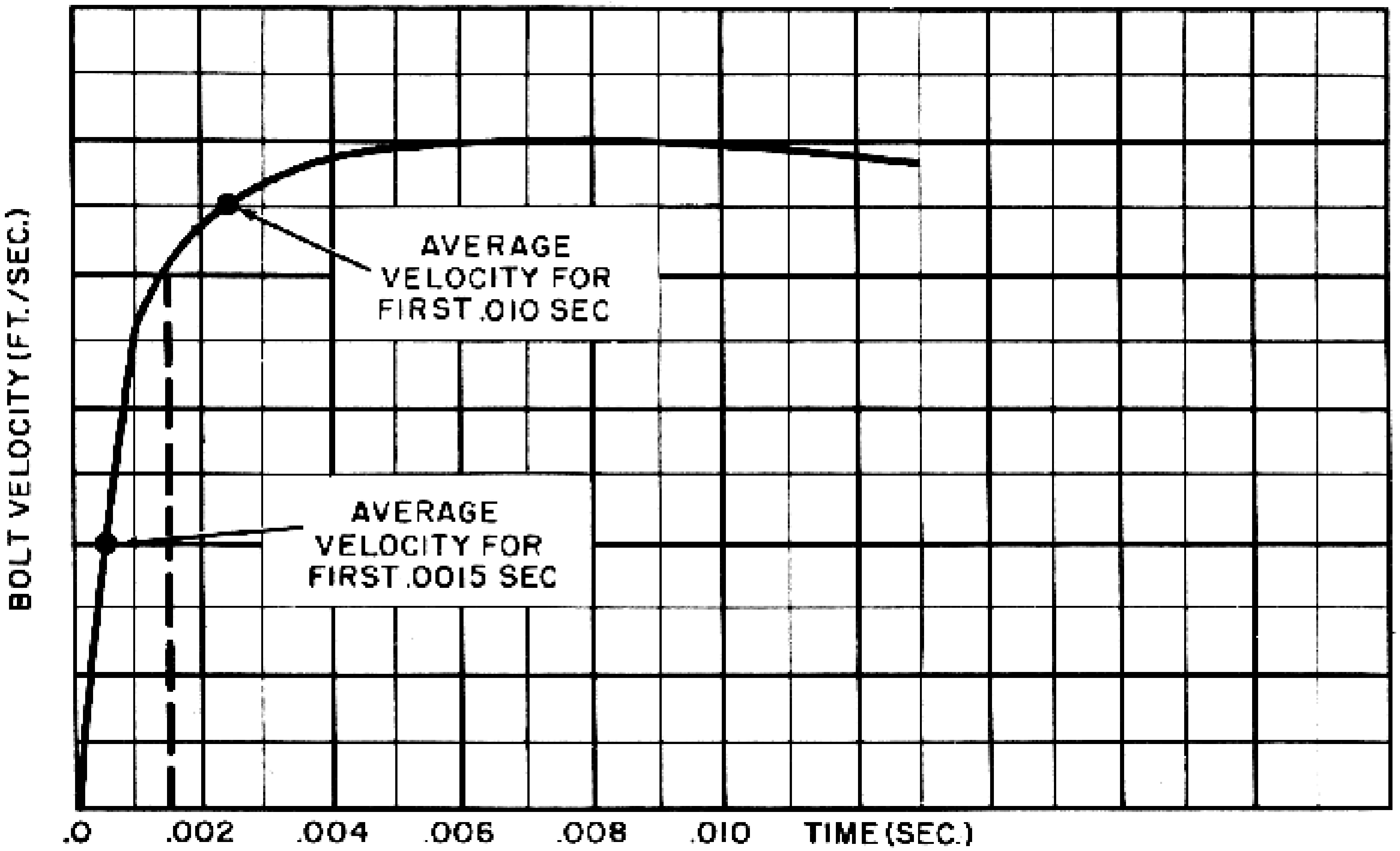

Figure 1–7. Bolt Velocity Versus Time in a Plain Blowback Gun.

a few feet per second. Furthermore, from the shape of the curve in fig. 1–7, it can be seen that even the maximum bolt velocity attained will not be much greater than this value.

The second important point is that with such a low bolt velocity allowable, a high-powered plain blowback machine gun could never attain a reasonable rate of fire. To illustrate this point, the bolt of a 20-mm gun must open about 10 inches in order to permit feeding. Thus, in opening and closing, it must travel a total distance of nearly two feet per cycle, and if it does this at an average velocity of about two feet per second, the firing rate will be the ridiculously low figure of approximately 50 or 60 rounds per minute.

There are other difficulties encountered with a high-powered plain blowback gun and, in fact, these difficulties are so serious that it is difficult to make such a gun function as an automatic weapon. These difficulties are examined further in the following paragraphs. It might seem that such an analysis would amount to an unnecessary preoccupation with an impractical system. However, although this analysis deals with exaggerated conditions, it is made intentionally to disclose and highlight the fundamental concepts involved in the blowback principle and to provide a basis for understanding the other forms of blowback.

Fig. 1–8 shows the condition existing in a blowback gun a few ten-thousandths of a second or so after the ignition of the propellant charge. The pressure of the powder gases is driving the projectile forward and at the same time is driving the cartridge case and bolt to the rear. At this time, the chamber pressure is approximately 45,000 pounds per square inch and the force driving the projectile and cartridge case will be in the neighborhood of 22,000 pounds (for a typical 20-mm round). Of course, some of the driving force is expended in overcoming the friction resisting the motion of the projectile and an additional portion of the driving force is used in imparting rotation to the projectile as it is spun in the barrel by the rifling. At the breech end, similar losses occur in overcoming the frictional resistance to the motion of the cartridge case and bolt and in compressing the driving spring. However, these losses, at the very most, can amount to only two or three thousand pounds. This means that the remaining force of nearly 20,000 pounds is applied entirely in producing the forward acceleration of the projectile mass and the rearward acceleration of the bolt mass. In other words, the only significant factor affecting the motion of these masses is the inertia of the projectile and of the bolt. Therefore, for purposes of simplified analysis, the frictional losses, the losses to projectile rotation, and the resist-

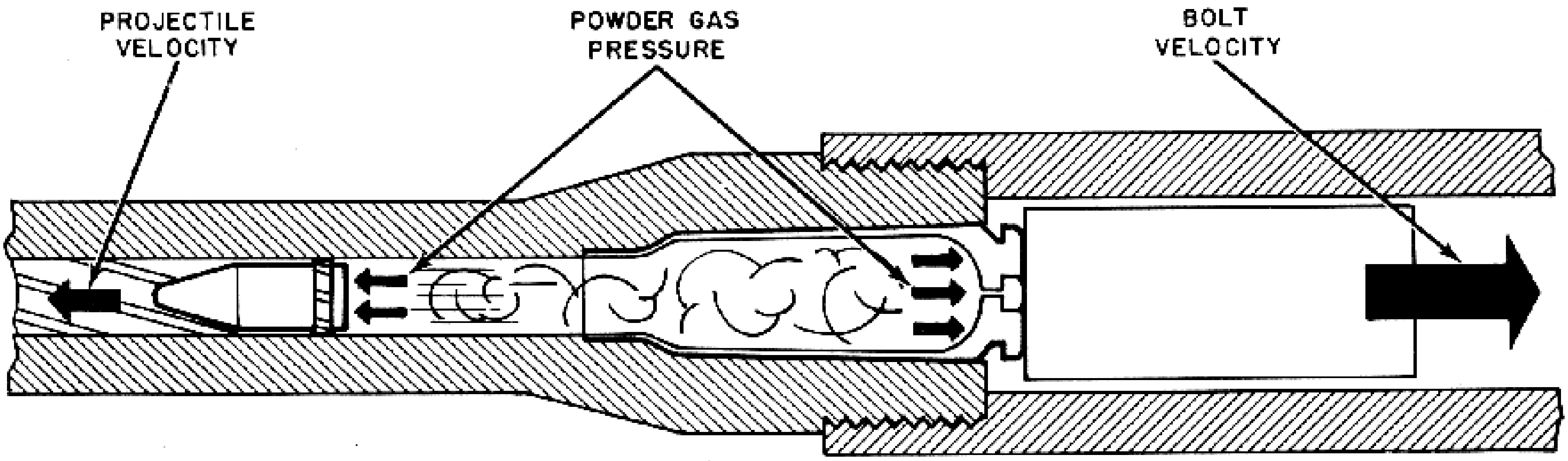

Figure 1–8. Velocities in a Blowback Gun.

ance of the driving spring can be ignored completely.

NOTE: There is one point which requires special clarification at this time. In many descriptions of blowback actions, it is strongly implied that the driving spring contributes a substantial portion of the resistance which limits the acceleration imparted to the bolt by the powder gases. Actually, this is not so. Although it is true that the driving spring absorbs the kinetic energy of the recoiling bolt and thus limits the total distance it moves, the resistance of the spring does not have any real effect in the early phase of the cycle of operation. The bolt acceleration occurs mainly while the powder gas pressures are high and are exerting a force of many thousands of pounds on the bolt. The driving spring, in order to permit the bolt to open enough to allow feeding, must offer a relatively low resistance. Although this resistance is sufficient to absorb the bolt energy over the comparatively great distance through which the bolt moves in recoil, it is not great enough to offer significant opposition to the powder gas pressure until the chamber pressure has dropped to a relatively low level well after the projectile has left the muzzle.

Now consider for a moment what would happen if the bolt had the same weight as the projectile (0.29 pound). If we admit the far-fetched assumption that the cartridge case will remain in one piece, the bolt will be blown back with nearly the same speed as the projectile is driven forward. The four-inch long cartridge case will be blown entirely out of the chamber when the projectile is only four inches down the bore and the hot powder gases, at a pressure of about 45,000 pounds per square inch, will blast out of the breech. Whatever portion of the breech mechanism is not ruined by the blast effect of the explosion will be smashed by the bolt as it flies back at such a high velocity. Even though the bolt has been subjected to only part of the total explosive force, it will have an energy nearly as great as the muzzle energy of a high-powered rifle bullet.)

By increasing the weight of the bolt, we can reduce the velocity at which it recoils and thus eliminate the dangerous condition described in the preceding paragraph. However, as previously explained, the velocity must be limited to a very low value in order to avoid case separation or rupture of the case at its base, and consequently the maximum rate of fire attainable will be somewhere around 60 rounds per minute. It is not necessary at this point to describe the methods used for computing the bolt weight necessary to accomplish this condition, so suffice it to say that it will be about 500 pounds. It is apparent that this weight is much too great to consider in any practical 20-mm gun design.

It has often been remarked that a plain blowback machine gun could be built to fire high-powered 20-mm ammunition providing that there was no objection to the excessive weight necessary in the bolt or to the inherent low rate of fire. The fact of the matter is that such a gun would be entirely impractical for other more cogent reasons. For example, if it is assumed that the initial velocity of the 500-pound bolt mass is about 2.50 feet per second, the energy imparted to the bolt will be only about 50 foot-pounds. Since this energy is supplied to the gun mechanism only 50 times per minute, or at the rate of 2500 foot-pounds per minute, only 8/100 horsepower will be available for doing the work necessary for feeding, firing, ejecting, overcoming friction, and for performing the other functions required of the gun mechanisms. This seems hardly sufficient power to operate a machine in the class of the breech mechanism of a conventional 20-mm gun. In other words, the heavier the bolt, the less energy it will absorb from the propellant explosion and if the bolt is too heavy, the gun may fail to function automatically because insufficient power will be available to operate the mechanism.

Another reason why the gun will fail to operate is because the driving spring would of necessity be a pitifully weak affair. Since the spring must absorb only 50 foot-pounds of energy and must do this over a movement of at least 10 inches in order to permit feeding a 20-mm round, the average force exerted by the spring can be no more than 60 pounds (60 pounds $\times$ 0.833 feet $=$ 50 foot-pounds). It is hardly necessary to point out that a spring as light as this will not work very successfully as the driver for a 500-pound bolt and it is also doubtful whether it could exert enough direct force to operate the feed mechanism or to perform other tasks requiring a fairly powerful thrust. Another serious shortcoming of such a spring would become obvious by the embarrassing way in which the bolt would slide open whenever the gun is elevated a little above the horizontal.

The principal points disclosed in the preceding analysis of a high-powered plain blowback gun may be summarized as follows:

1. To prevent case separation or rupture of the case near its base, the bolt velocity must be limited to an extremely low value.
2. For this system, lubrication of the ammunition does not permit a significantly higher bolt velocity.
3. In order to limit the bolt velocity as required, the weight of the bolt must be excessively great.
4. Because of the necessity for low bolt velocity, the rate of fire is too low for any practical purpose.
5. The driving spring is not a significant factor in limiting bolt velocity.
6. The bolt of a blowback gun is the means whereby energy for operating the mechanism is obtained from the propellant explosion. Because of the excessive bolt mass required in a plain blowback gun, and the low rate of fire, insufficient power is obtained for maintaining automatic operation.
7. The driving spring is of necessity very weak and can not exert sufficient direct force to perform its function satisfactorily.

All of these points demonstrate amply why no successful plain blowback machine gun has ever been developed to fire high-powered ammunition.

Mathematical Analysis of Plain Blowback

The following paragraphs describe a systematic procedure for performing the computations necessary in a basic analysis of a plain blowback gun. For the most part, the methods described are conventional and follow the lines of analysis which have been used for some time in general engineering studies of guns, particularly artillery weapons. The main endeavor in this present analysis was to reorganize the existing methods and to modify and supplement them as necessary to adapt them for convenient application to the specific problems encountered in the design of blowback machine guns.

It must be emphasized at the outset that the principal concern of this analysis is to establish a method which may be used to determine the bolt mass required to limit the bolt recoil velocity to a safe value and, on the basis of this mass, to make preliminary calculations for determining the driving spring design data, rate of fire, bolt motion characteristics, and other useful information.

In this analysis, no attempt will be made to discuss the straightforward machine design methods by which the results are applied in arriving at the particular physical form of a breech mechanism. Also, no detailed computations are made to cover the effects of such factors as friction or the incidental forces imposed on the breech mechanism by the auxiliary mechanism such as the feeder, firing device, or ejector. These effects are entirely negligible in determining the bolt mass, but they will have some influence on the overall bolt motion and rate of fire. In any case, they can be properly taken into account only in the more or less advanced stages of a design when the form of the gun mechanism becomes fairly well established. At this point, the preliminary values determined can easily be modified as required.

The analysis which follows is based on the assumption that a particular cartridge with known characteristics is to be used and that the desired muzzle

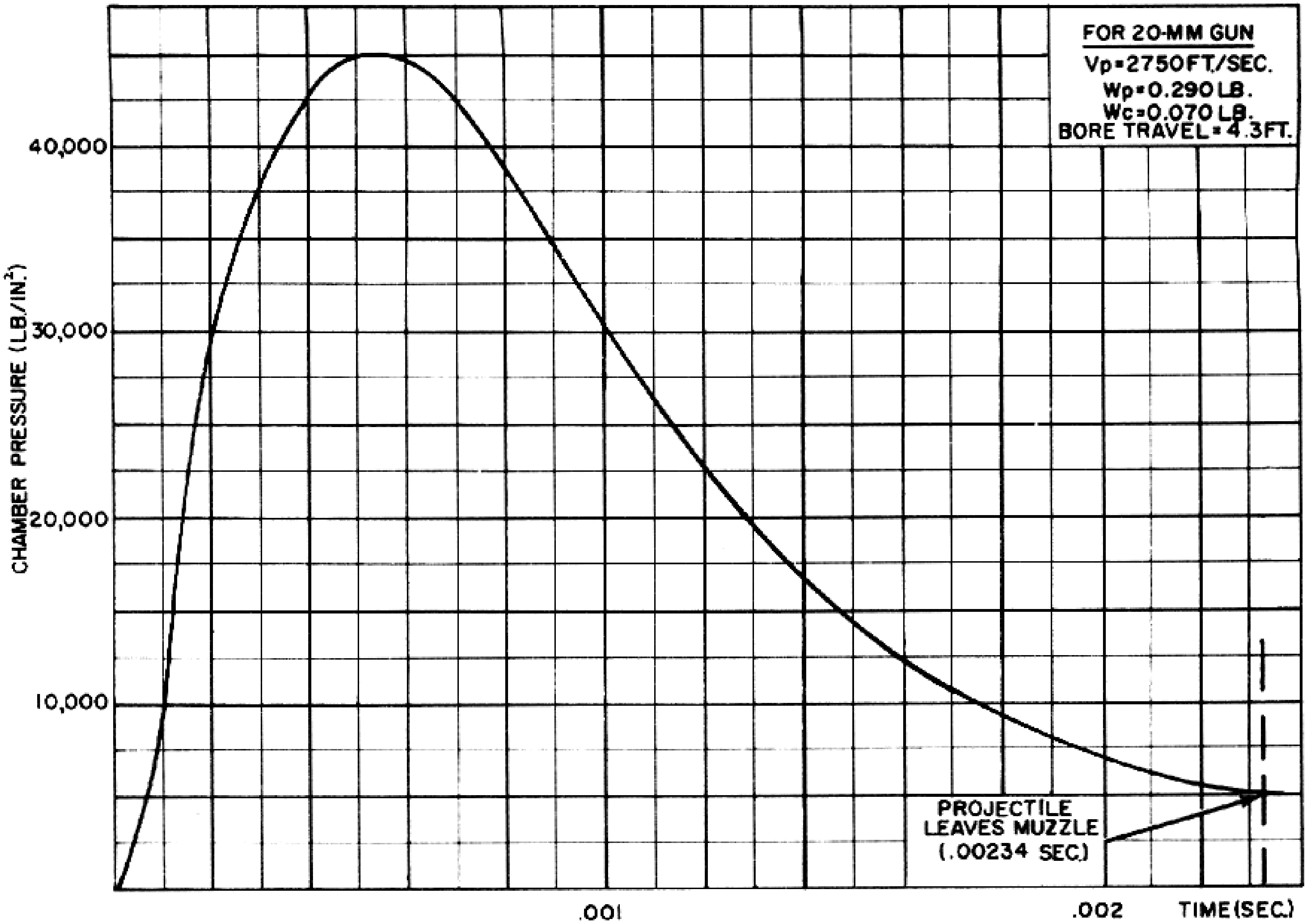

Figure 1-9. Graph of Chamber Pressure Versus Time (20 mm Gun).

velocity and barrel length have been predetermined. It is also assumed that all necessary interior ballistics data are known and that graphs showing the time variation of projectile velocity and chamber pressure are available (figs 1-9, 1-10, and 1-11).

NOTE: For some design problems, all or part of this information may not be available. Analytical methods by which the required data and graphs can be approximated for use in preliminary studies may be determined by conventional interior ballistics computations.

As the analysis progresses, its application will be illustrated by means of sample calculations. Although these calculations and related graphs are for a specific 20-mm cartridge and barrel, the methods are applicable to a gun of any caliber. The calculations cover the following important points:

1. Determination of the bolt weight required to limit the recoil velocity to a safe value.
2. Determination of the data necessary for designing a driving spring which will permit the bolt to open the required distance for feeding.
3. Computation of the rate of fire.
4. Development of graphs showing how bolt velocity and bolt travel vary with time.
5. Computation of power absorbed by the bolt.

In the course of describing these computations, the following fundamental formulas will be developed and explained:

a. Momentum relation for time projectile is in bore.
b. Formula for determining momentum and velocity of free recoil.
c. Expression for duration of residual pressure.
d. Formula for determining initial bolt energy.
e. Formulas for determining spring retardation.

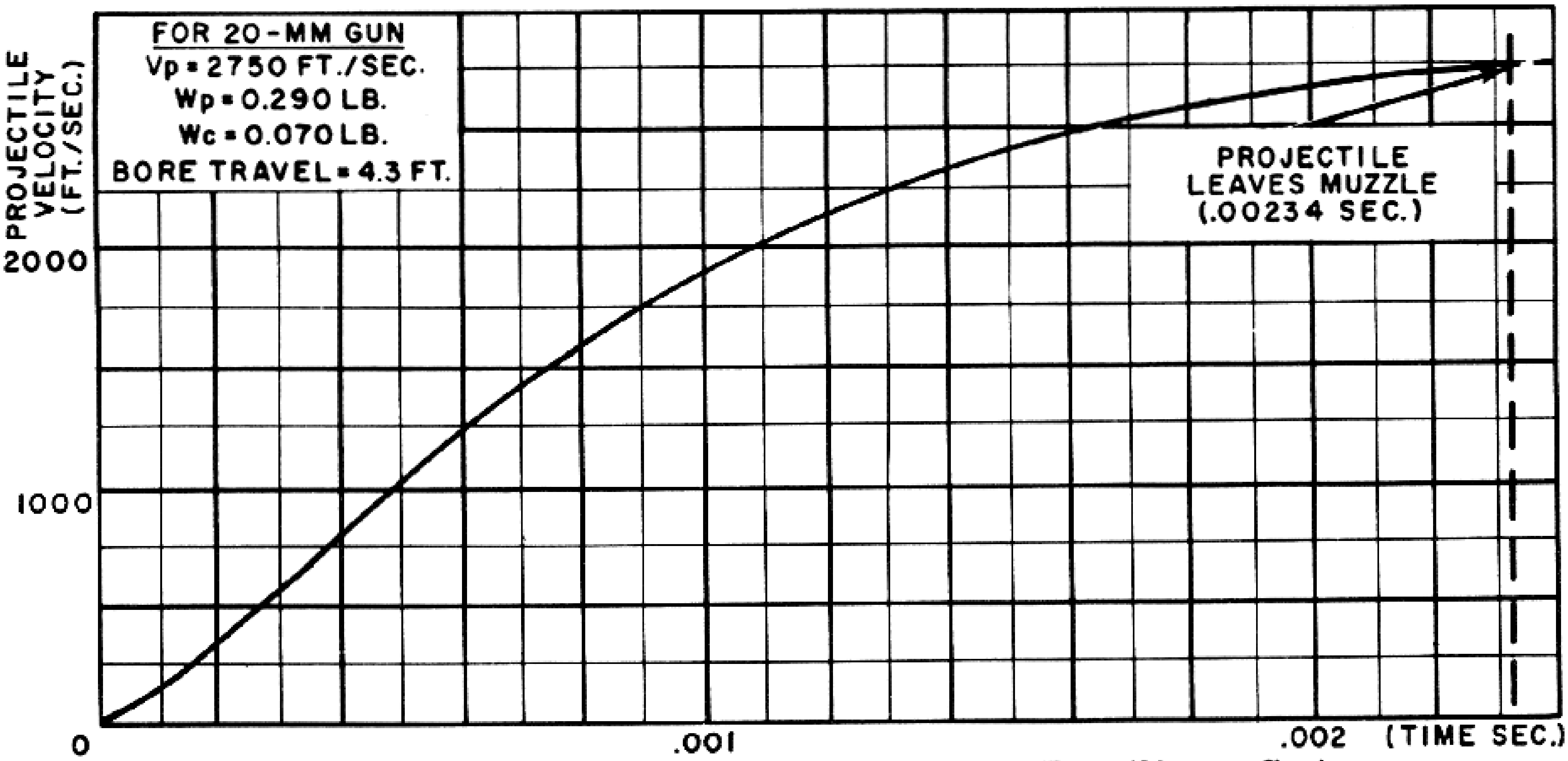

Figure 1–10. Graph of Projectile Bore Travel Versus Time (20 mm. Gun).

f. Energy equation for bolt and driving spring.
g. Formula for determining time to recoil.
h. Expression for computing rate of fire.

1. *Determination of bolt weight*

When the propellant charge is exploded, the projectile and powder gases move forward through the bore while the bolt is driven to the rear. Since the bolt is not connected to the barrel, the forces resisting the motion of the projectile are not equal to the forces resisting the motion of the bolt. However, because such an extremely small percentage of the explosive impulse is required to overcome friction and account for other losses, it may be assumed with very little error that the momentum of the bolt at any time is equal to the combined momentum of the projectile and powder gases. Assuming that the center of mass of the powder gases moves through the bore at one-half the velocity of the projectile, the momentum equality may be expressed as follows:

$$(1-1) \quad M_r v_{r_f} = M_p v_p + M_c \frac{v_p}{2} = \left(M_p + \frac{M_c}{2}\right) v_p$$

The subscript, f, in the symbol for the bolt velocity indicates that this is the *free* or unretarded bolt velocity. In other words, it is assumed for the present that the bolt motion is not subjected to the retarding effects of the driving spring or friction. This assumption will not introduce any significant inaccuracy for the time during which the powder

Symbols Used in Analysis

A	Area of bore cross-section—in.^{2}
C	Arbitrary constant of integration
D	Total recoil travel of bolt—ft.
d	Recoil travel of bolt for time t—ft.
E_r	Initial bolt energy—ft. lb.
F_{av}	Average spring force over distance D—lb.
F_o	Initial compression of spring—lb.
g	Acceleration of gravity—32.2 ft./sec.^{2}
K	Spring rate—lb./ft.
M_c	Mass of powder charge—lb.sec.^{2}/ft.
M_p	Mass of projectile—lb.sec.^{2}/ft.
M_r	Mass of bolt (recoiling parts)—lb.sec.^{2}/ft.
P	Muzzle pressure—lb./in.^{2}
T	Time to recoil—sec.
t	Time—sec.
T_{res}	Time of duration of residual pressure—sec.
V_p	Muzzle velocity of projectile—ft./sec.
v_p	Velocity of projectile in bore at time t—ft./sec.
v_r	Velocity of retarded recoil at time t—ft./sec.
V_{r_f}	Maximum velocity of free recoil—ft./sec.
v_{r_f}	Velocity of free recoil at time t—ft./sec.
$v_{r_f(all)}$	Allowable average recoil velocity—ft./sec.
W_c	Weight of powder charge—lb.
W_p	Weight of projectile—lb.
W_r	Weight of bolt (recoiling parts)—lb.

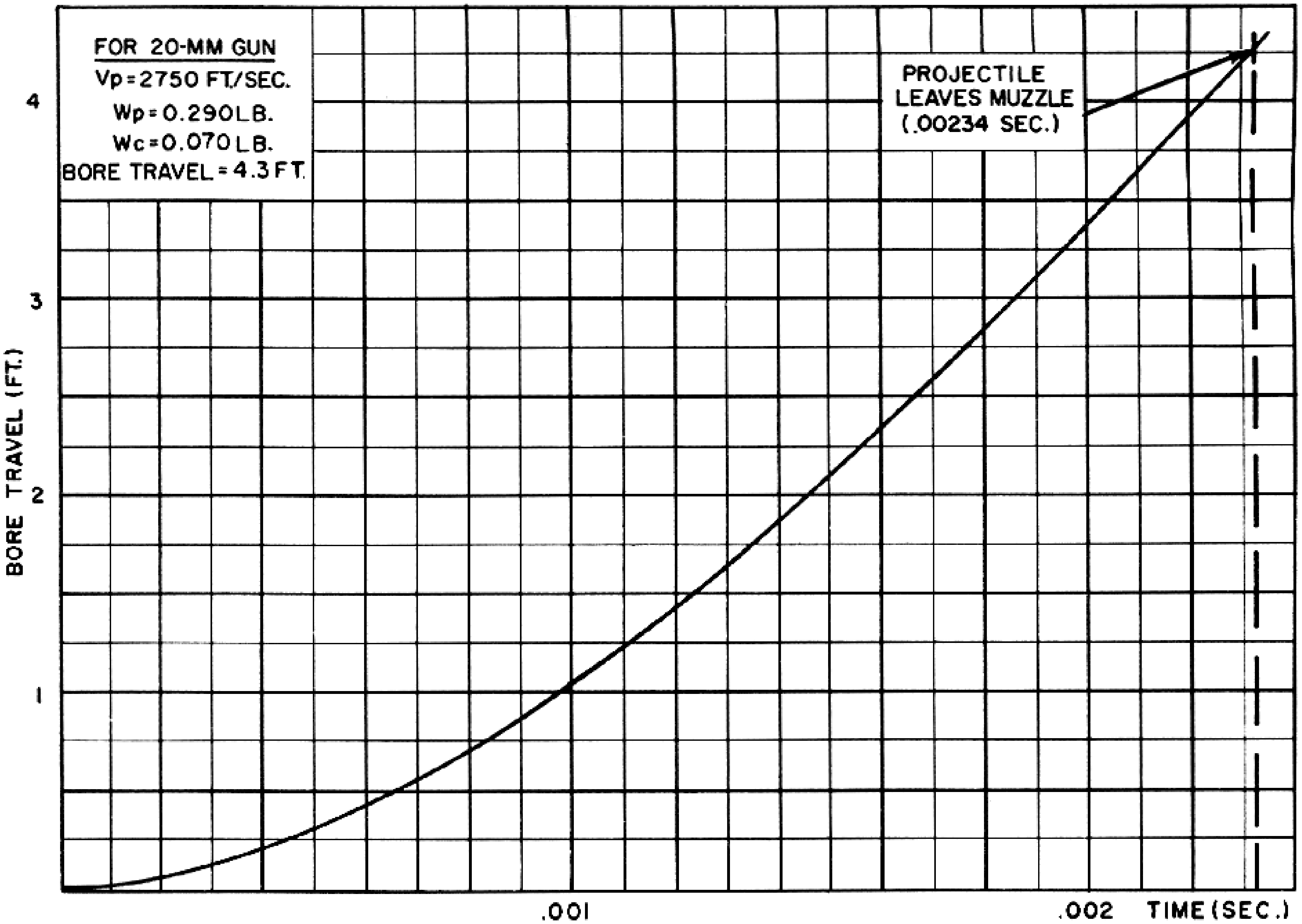

Figure 1-11. Graph of Projectile Bore Travel Versus Time (20 mm Gun).

gas pressures act because the retarding forces are negligible when compared to the forces exerted by the powder gases.

Equation 1-1 can be used to plot a graph of bolt momentum versus time for the period before the projectile leaves the muzzle. The weights of the projectile and powder charge are both known and fig. 1-10 gives the projectile velocity at any time. Therefore, the ordinate of the bolt momentum curve at any time, t, can be determined by multiplying the corresponding ordinate of the projectile velocity curve by the factor

$$\left(M_p+\frac{M_c}{2}\right)$$

For the 20-mm cartridge upon which fig. 1-10 is based:

$$M_p+\frac{M_c}{2}=\frac{1}{g}\left(W_p+\frac{W_c}{2}\right)=\frac{1}{32.2}\left(.29+\frac{.070}{2}\right)=.00101$$

Therefore, before the projectile leaves the muzzle, the bolt momentum is:

$$M_r v_{r_t}=.00101\ v_p\ \text{(lb. sec.)}$$

The curve obtained by using this relation is shown in fig. 1-12. The same curve is also shown in fig. 1-13 as the portion between t=0 and t=.00234 sec. (In this figure, the time axis is compressed in order to permit consideration of what happens after the projectile leaves the muzzle.)

The momentum relations which exist after the projectile leaves the muzzle cannot be formulated simply, but a special method can be employed to extend the curve plotted by using equation 1-1. To draw the remainder of the curve, use is made of the maximum free bolt momentum as determined from the equation:

$$M_r V_{r_f}=M_p V_p+4700\ M_c \qquad (1\text{-}2)$$

This is an empirical relation based on the results of experimental firings of various guns. It amounts to saying that the final momentum imparted to the recoiling parts is equal to the sum of the muzzle

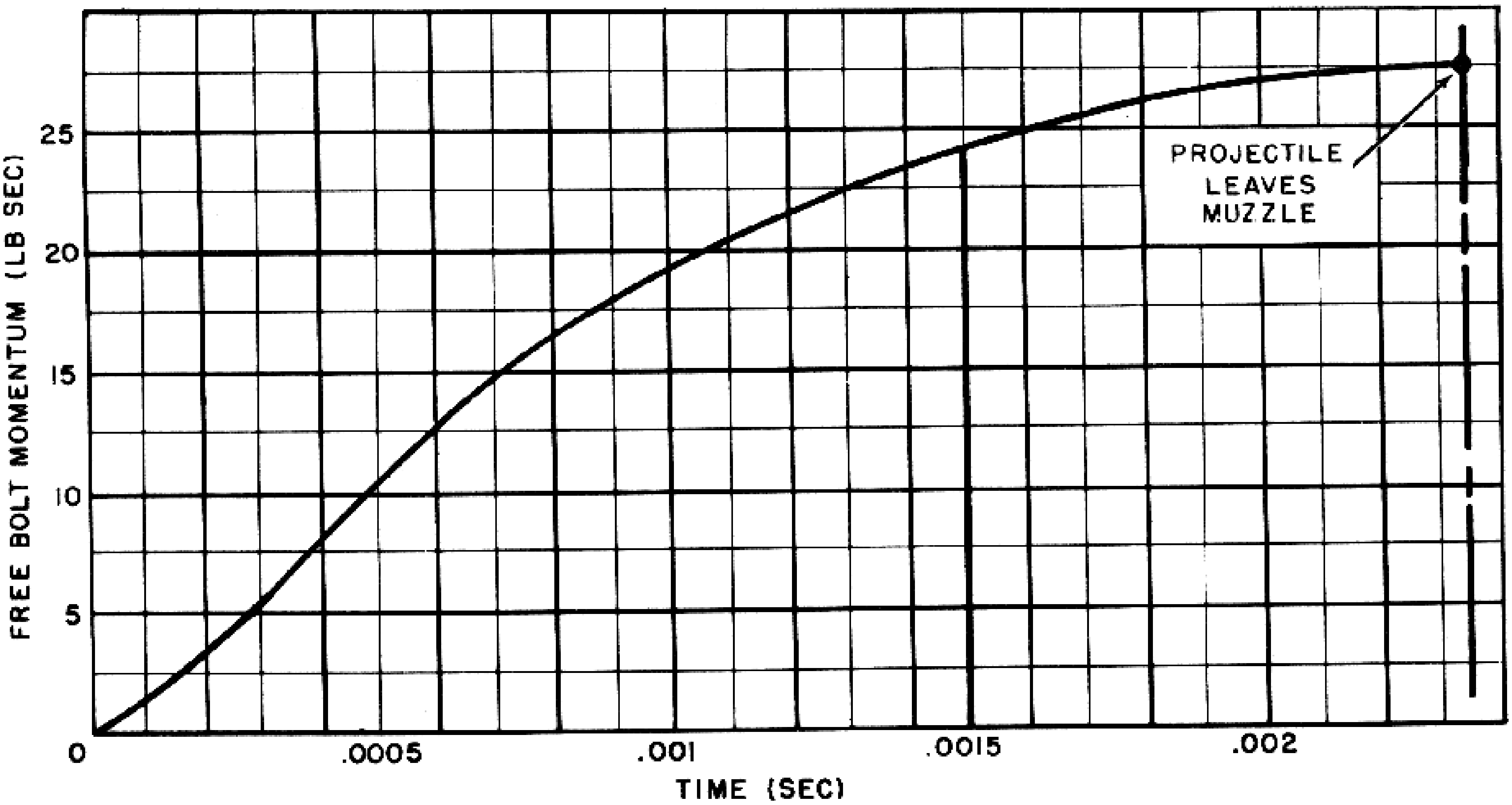

Figure 1–12. Free Bolt Momentum for First 0.0015 Second.

momentum of the projectile and the momentum of the powder gases, assuming that the powder gases leave the gun at an average velocity of 4700 feet per second. For the cartridge and barrel used as an example:

$$M_r V_{r_f} = \frac{.29}{32.2}\,2750 + 4700\,\frac{.070}{32.2} = 35 \text{ (lb. sec.)}$$

A line representing this value of free bolt momentum is drawn on the bolt momentum graph (fig. 1–13) and the curve previously drawn is extrapolated until it becomes tangent to the line. The point at which the curve is tangent represents the time at which the residual pressure becomes zero and therefore imparts no further momentum to the bolt. Although an error in locating the exact point of tangency will not have any serious effect on the accuracy of the results, it may be of some assistance in plotting to determine this point by using Vallier's formula for approximating the duration of the residual pressure:

(1–3) $$T_{res} = \frac{M_c}{AP}\,(9400 - V_p)$$

For the sample cartridge and barrel:

$$T_{res} = \frac{.070}{32.2 \cdot \frac{\pi}{4}(.790)^2 \cdot 5000}\,(9400\text{–}2750) = .00592 \text{ (sec.)}$$

To obtain the total time of action of the powder gases, this value is added to the time at which the projectile leaves the muzzle:

$$T_{res} = .00234 + .00592 = .00826 \text{ (sec.)}$$

Extending the original curve until it is tangent at this point gives the complete free bolt momentum curve shown in fig. 1–13.

This curve can be used directly to determine the bolt weight necessary to limit the bolt velocity to a safe value over a given interval of time. By integrating under the curve for the desired time interval and then dividing the result by the time interval, the average bolt momentum for the interval can be found. Dividing this average momentum by the allowable average velocity for the interval will give the required bolt mass. That is to say:

(1–4) $$M_r = \frac{\int_{t_1}^{t_2} (M_r v_{r_f})\, dt}{(t_2 - t_1)\, v_{r_{f(all)}}}$$

A simple and sufficiently accurate method of evaluating the integral in equation 1–4 is to measure the area under the curve by use of the so-called trapezoidal rule or some other method of approximate integration such as Simpson's rule.

Now assume that the cartridge case is not lubricated. As previously explained, this condition re-

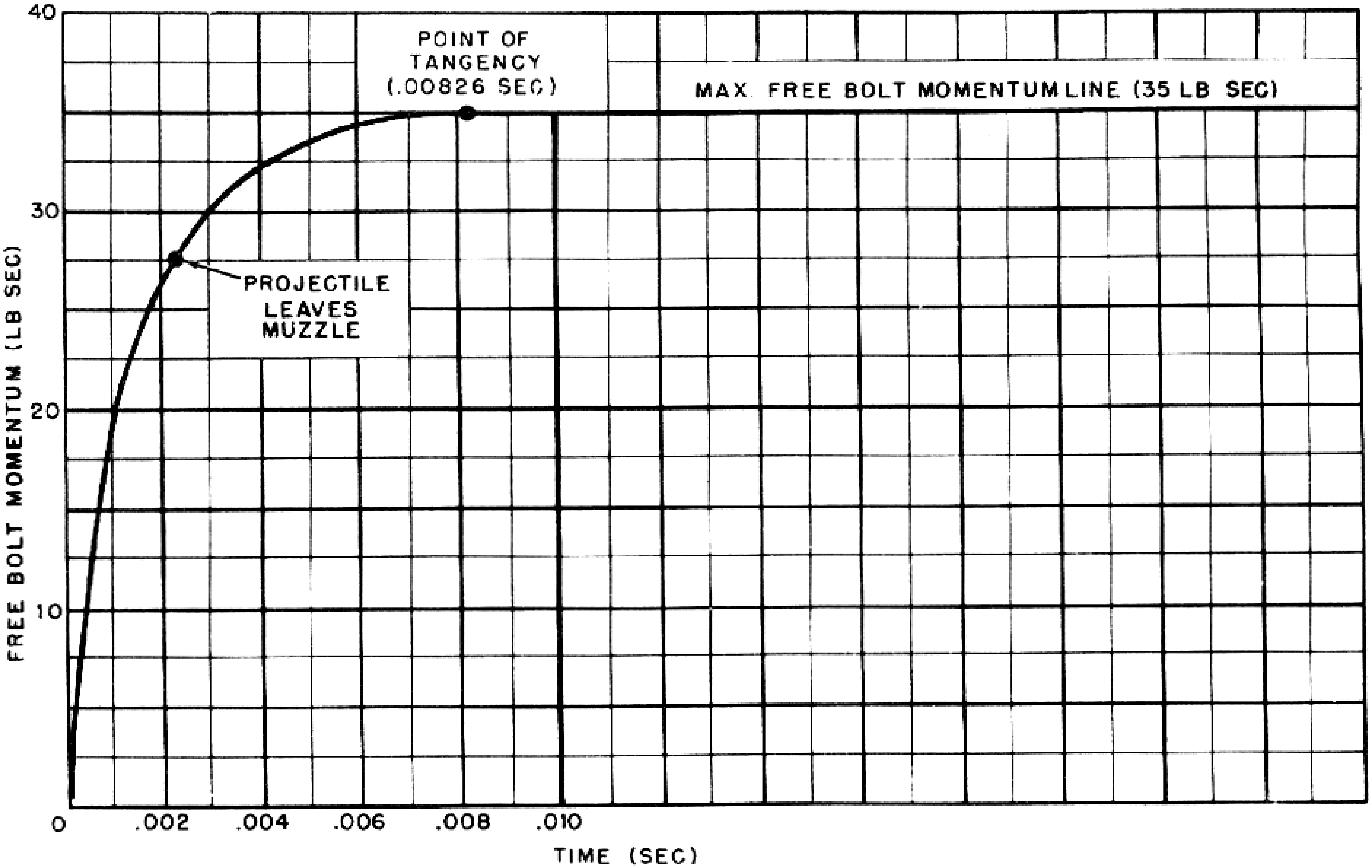

Figure 1–13. Free Bolt Momentum for First 0.010 Second.

quires that the average bolt velocity be limited to one foot per second for the first 0.0015 second in order to prevent case separation. Integrating under the curve shown in fig. 1–12 from t=0 to t=.0015 gives a total area of 0.02298 (lb. sec.^{2}). Using equation 1–4 to evaluate M_r gives:

$$M_r = \frac{.02298}{.0015 \cdot 1} = 15.32 \left(\frac{\text{lb. sec.}^2}{\text{ft.}}\right)$$

Therefore, the required weight is:

$$W_r = gM_r = 32.2 \cdot 15.32 = 493 \text{ (lb.)}$$

It was also pointed out previously that if the cartridge case is of the form shown in fig. 1–6A, the average bolt velocity (even with lubrication) must be limited to two feet per second for the first 0.010 second in order to prevent rupture near the base of the case. Assuming this limitation, integrating under the curve shown in fig. 1–13 from t=0 to t=.010 gives a total area of 0.305 (lb. sec.^{2}). Using equation 1–4 to evaluate M_r gives:

$$M_r = \frac{.305}{.010 \cdot 2} = 15.25 \left(\frac{\text{lb. sec.}^2}{\text{ft.}}\right)$$

Therefore, the required weight is:

$$W_r = gM_r = 32.2 \cdot 15.25 = 492 \text{ (lb.)}$$

Note that this weight is almost exactly the same as obtained by assuming the first limitation. As previously explained, the necessary bolt weight can be decreased somewhat if lubrication is used and some special method can be found by which the allowable average velocity over the first 0.010 second can be increased to more than two feet per second. However, for purposes of continuing the analysis, these special methods will be ignored and the bolt weight will be taken as 500 pounds.

2. *Determination of driving spring design data*

Equation 1–2 gives the maximum free recoil momentum as:

$$M_r V_{r_f} = M_p V_p + 4700\ M_c$$

Solving this equation for V_{r_f} gives the maximum free recoil velocity as:

$$(1\text{–}5) \quad V_{r_f} = \frac{M_p V_p + 4700\ M_c}{M_r} = \frac{W_p V_p + 4700\ W_c}{W_r}$$

For the 500-pound bolt and the conditions of the example:

$$V_{r_f} = \frac{.29 \cdot 2750 + 4700 \cdot .070}{500} = 2.2 \left(\frac{\text{ft.}}{\text{sec.}} \right)$$

Since the total acceleration of the bolt occurs in less than 0.010 second and since the retardation which can be offered during this interval by the driving spring is very small, it may be assumed, when considering the effect of the driving spring, that the initial velocity of the bolt is equal to the maximum free recoil velocity expressed by equation 1 5.

The initial bolt energy is given by the expression:

$$(1\text{-}6) \qquad E_r = \frac{1}{2} M_r V_{r_f}^2 = \frac{W_r V_{r_f}^2}{2g} \text{ (ft. lb.)}$$

Evaluating this expression for the condition of the example gives the initial bolt energy as:

$$E_r = \frac{500 \cdot 2.25^2}{2 \cdot 32.2} = 39.4 \text{ (ft. lb.)}$$

In other words, the bolt may be considered to start compressing the driving spring with an initial energy of 39.4 foot pounds. The spring must be proportioned so as to absorb this amount of energy over the entire distance through which it is compressed times the average force required to produce this deflection. That is:

$$(1\text{-}7) \qquad E_r = F_{av} D \text{ or } F_{av} = \frac{E_r}{D}$$

If it is assumed that the bolt in the example must open 10 inches (0.833 feet) in order to permit feeding of a 20-mm cartridge, the average force exerted by the spring must be:

$$F_{av} = \frac{39.4}{.833} = 47.2 \text{ (lb.)}$$

It should be noted here that friction between the bolt and its slide will produce an essentially constant retarding force. If it is expected that the force required to overcome the friction will be considerable, this force should be determined and subtracted from the average spring force computed by using equation 1 7. However, for purposes of the present analysis, the friction force will be neglected.

Having the average spring force, the remaining problem is to choose spring characteristics such that this average force will result from compressing the spring through the required recoil distance. The values to be chosen are the initial compression, F_o, and the spring rate, K. For example, if the initial compression is taken as 17.2 pounds, a maximum force of 77.2 pounds will produce the required average force of 47.2 pounds. Since the difference between the maximum force and initial compression is 60 pounds and the recoil distance is 10 inches, the spring rate will be 6 pounds per inch or 72 pounds per foot. Any other combination of F_o and K could be chosen, providing that they produce an average force of 47.2 pounds.

> NOTE: Actually, the design of a driving spring for a practical machine gun is a rather complex problem and can not be disposed of so easily. Spring losses, shock loads, forced vibrations set up along the length of the spring, and other factors can cause serious difficulties in operation and may even result in unpredictable breakage. For this reason, the design of springs to be used in a rapidly oscillating mechanism like a machine gun is a specialized art in the field of machine design. Special techniques of analysis are necessary and often a successful design can be arrived at only through careful experimentation. Also, as will be explained later, the choice of F_o and K can have an effect on the rate of fire attainable.

Although the factors mentioned in the preceding note should receive due consideration in an actual design problem, it will be assumed here that the arbitrarily selected combination of $F_o = 17.2$ pounds and $K = 72$ pounds per foot will result in a satisfactory spring.

The required bolt weight and the characteristics of the driving spring have now been determined and this determination was made in accordance with the stipulated requirements for limiting the bolt motion and for allowing sufficient recoil travel to permit feeding. In other words, the basic design of the gun is now established and the only task remaining is to consider what performance this design will give.

It is obvious that a gun having such a heavy bolt and such a weak driving spring will not be practical. However, the only way to improve the design would be to employ some special method for permitting a higher average bolt velocity. The question of whether or not such a method can be found is not important for the purposes of the present analysis and will therefore be left to the ingenuity of the designer. The main purpose of this analysis is to establish a method of approach to the design of a plain blowback gun and this method can be applied regardless of what particular bolt velocity is allowable.

3. *Derivation of bolt motion equations*

Since the bolt weight and driving spring data have been determined, it is now possible to investigate the performance of the gun. The first step in this investigation will be to derive a number of important equations relating to the motion of the bolt. These derivations will all be based on the fact that, as the bolt moves in recoil, the driving spring absorbs and stores energy. If it is assumed that the losses due to friction and other causes are negligible, the energy remaining in the bolt at any time during recoil is expressed by the equation:

(1–8) $$\frac{M_r v_r^2}{2} = E_r - \int_0^d (F_o + Kd)\,dd$$

$$= E_r - \left(F_o d + \frac{Kd^2}{2}\right)$$

This equation may be used for deriving the equation expressing the relation between time and bolt motion as follows: Solving for v_r gives:

$$v_r = \sqrt{-\frac{K}{M_r}d^2 - \frac{2F_o}{M_r}d + \frac{2E_r}{M_r}} = \frac{dd}{dt}$$

$$dt = \frac{dd}{\sqrt{-\frac{K}{M_r}d^2 - \frac{2F_o}{M_r}d + \frac{2E_r}{M_r}}}$$

From a table of integrals, this expression is of the form:

$$\int \frac{dd}{\sqrt{ad^2 + bd + c}} = \frac{1}{\sqrt{-a}} \sin^{-1} \frac{-2ad - b}{\sqrt{b^2 - 4ac}} + C$$

where: $a = -\frac{K}{M_r}$ $(a < 0)$

$$b = -\frac{2F_o}{M_r}$$

$$c = +\frac{2E_r}{M_r}$$

Therefore:

$$t = \sqrt{\frac{M_r}{K}} \left[\sin^{-1} \frac{\frac{2K}{M_r}d + \frac{2F_o}{M_r}}{\sqrt{\frac{4F_o^2}{M_r^2} + \frac{8KE_r}{M_r^2}}} \right] + C$$

$$= \sqrt{\frac{M_r}{K}} \left[\sin^{-1} \frac{Kd + F_o}{F_o^2 + 2KE_r} \right] + C$$

But at the end of the recoil movement, the energy stored in the driving spring is equal to the initial bolt energy:

$$E_r = F_o D + \frac{KD^2}{2}$$

Therefore:

$$F_o^2 + 2KE_r = F_o^2 + 2K\left(F_o D + \frac{KD^2}{2}\right)$$

$$= F_o^2 + 2KF_o D + K^2D^2$$

$$= (F_o + KD)^2$$

Substituting this value in the equation for t gives:

$$t = \sqrt{\frac{M_r}{K}} \left[\sin^{-1} \frac{Kd + F_o}{KD + F_o} \right] + C$$

to evaluate C: When $t=0$, $d=0$ and therefore

$$C = -\sqrt{\frac{M_r}{K}} \sin^{-1} \frac{F_o}{KD + F_o}$$

Substituting this expression for C gives the equation for the time, t, required to recoil any distance, d.

(1–9) $$t = \sqrt{\frac{M_r}{K}} \left[\sin^{-1} \frac{Kd + F_o}{Kd + F_o} - \sin^{-1} \frac{F_o}{KD + F_o} \right]$$

Solving this equation for d gives the inverse relation expressing the distance recoiled in any time, t.

(1–10)

$$d = \frac{KD + F_o}{K} \sin\left[\sqrt{\frac{K}{M_r}}\, t + \sin^{-1} \frac{F_o}{KD + F_o} \right] - \frac{F_o}{K}$$

Equation 1–9 may also be used to obtain the total time T required for the bolt to move through the entire recoil distance D. Substituting D for d gives:

$$T = \sqrt{\frac{M_r}{K}} \left[\sin^{-1} 1 - \sin^{-1} \frac{F_o}{KD + F_o} \right]$$

(1–11) $$T = \sqrt{\frac{M_r}{K}} \left[\frac{\pi}{2} - \sin^{-1} \frac{F_o}{KD + F_o} \right]$$

$$= \sqrt{\frac{M_r}{K}} \left(\cos^{-1} \frac{F_o}{KD + F_o} \right)$$

If it is assumed that the losses are negligible, although this is impossible, the time for the bolt to return will be equal to the recoil time. That is, the time for a complete cycle of operation will be 2T seconds. On this basis, the rate of fire in rounds per minute will be:

$$N = \frac{60}{2T} = \frac{30}{T}$$

(1–12) $$N = \frac{30\sqrt{\frac{K}{M_r}}}{\cos^{-1} \frac{F_o}{KD + F_o}}$$

Evaluating N for the conditions of the example gives the rate of fire as:

$$N=\frac{30\sqrt{\frac{72\cdot 32.2}{500}}}{\cos^{-1}\frac{17.2}{72\cdot .833+17.2}}=48 \text{ (rounds per minute)}$$

With the rate of fire and bolt energy known, the power absorbed by the bolt can be computed by means of the formula:

$$\text{(1–13)} \qquad HP=\frac{E_r N}{33{,}000}$$

The horsepower absorbed by the bolt in the gun of the example will be:

$$HP=\frac{39.4\cdot 48}{33{,}000}=.0573$$

4. *Development of theoretical time-travel and time-velocity curves*

Curves which show the bolt travel and bolt velocity with respect to time are very useful in determining what performance can be expected of a design and also provide useful data for the design of the feeder, ejector, firing device, and other auxiliary mechanisms. The formulas derived under the preceding heading may be used to obtain such curves and other data of interest. However, it should be realized that all of these equations were derived under the assumption that the initial bolt energy was transferred to the bolt instantaneously and therefore do not take into full consideration the period of time during which the powder gas pressures act. For a gun having a low rate of fire, the events which occur during this period of time are negligible in considering the total bolt travel but when the rate of fire is high, the powder gas pressures exist for a significant portion of the time required for recoil. For this reason, it is usually desirable to take the effects of the powder gases into consideration when developing bolt motion curves.

Since the effects of the powder gases can not be formulated readily, a special method is employed to plot the curves. The method consists essentially of plotting a curve of free bolt velocity and then subtracting from each ordinate of this curve the loss in velocity resulting from the retarding effect of the spring.

The free bolt velocity curve can be derived directly from the free bolt momentum curve previously plotted (figs. 1–12 and 1–13) by dividing each ordinate of the momentum curve by the mass of the bolt. The resulting curves are shown in figs. 1–14 and 1–15.

To determine the retarding effects of the spring, use is made of the law expressed by the equation:

$$\text{(1–14)} \qquad F\,dt=M\,dv$$

This law states that the change in the momentum of a mass is equal to the applied impulse (the product

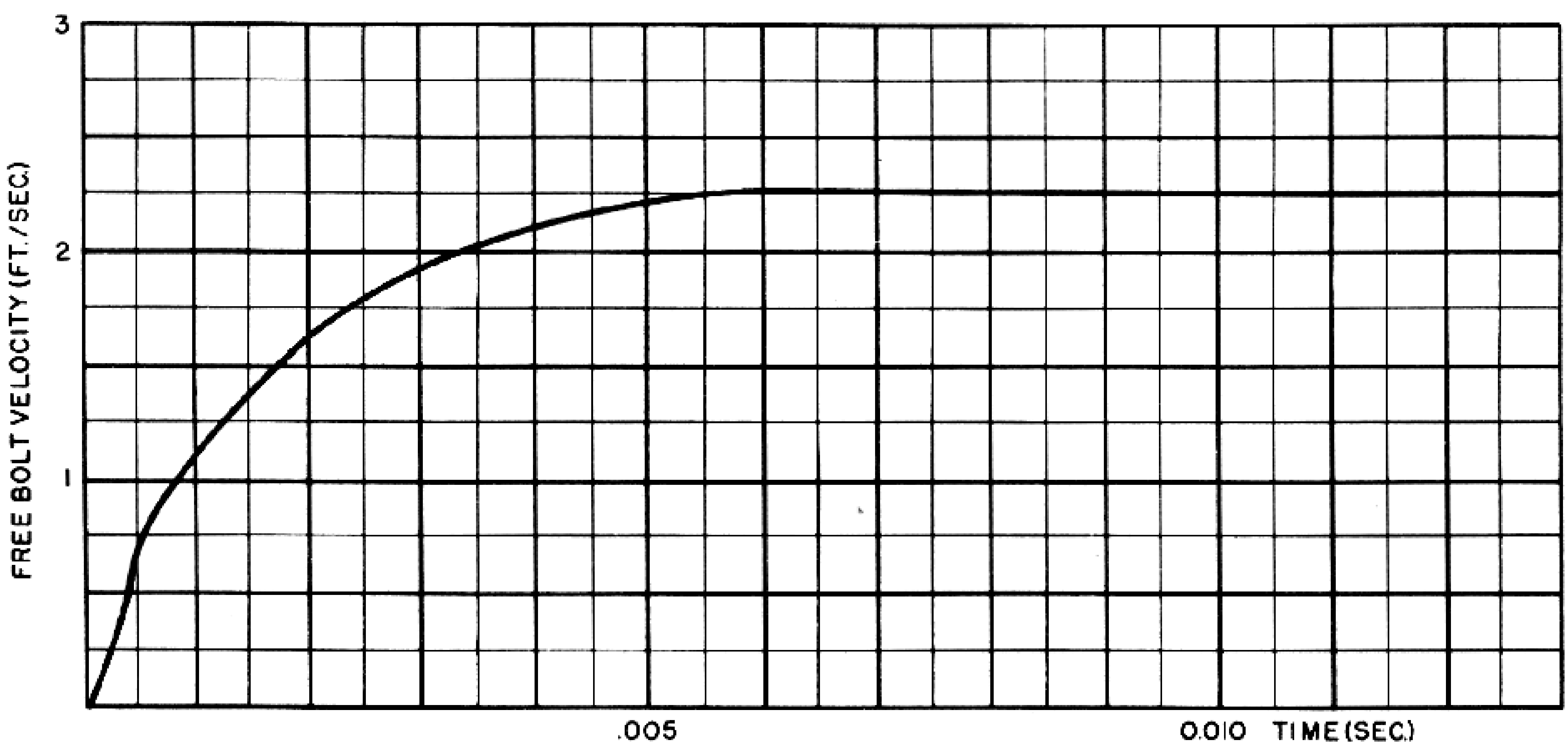

Figure 1–14. Free Recoil Velocity Versus Time (0–0.010 Sec.).

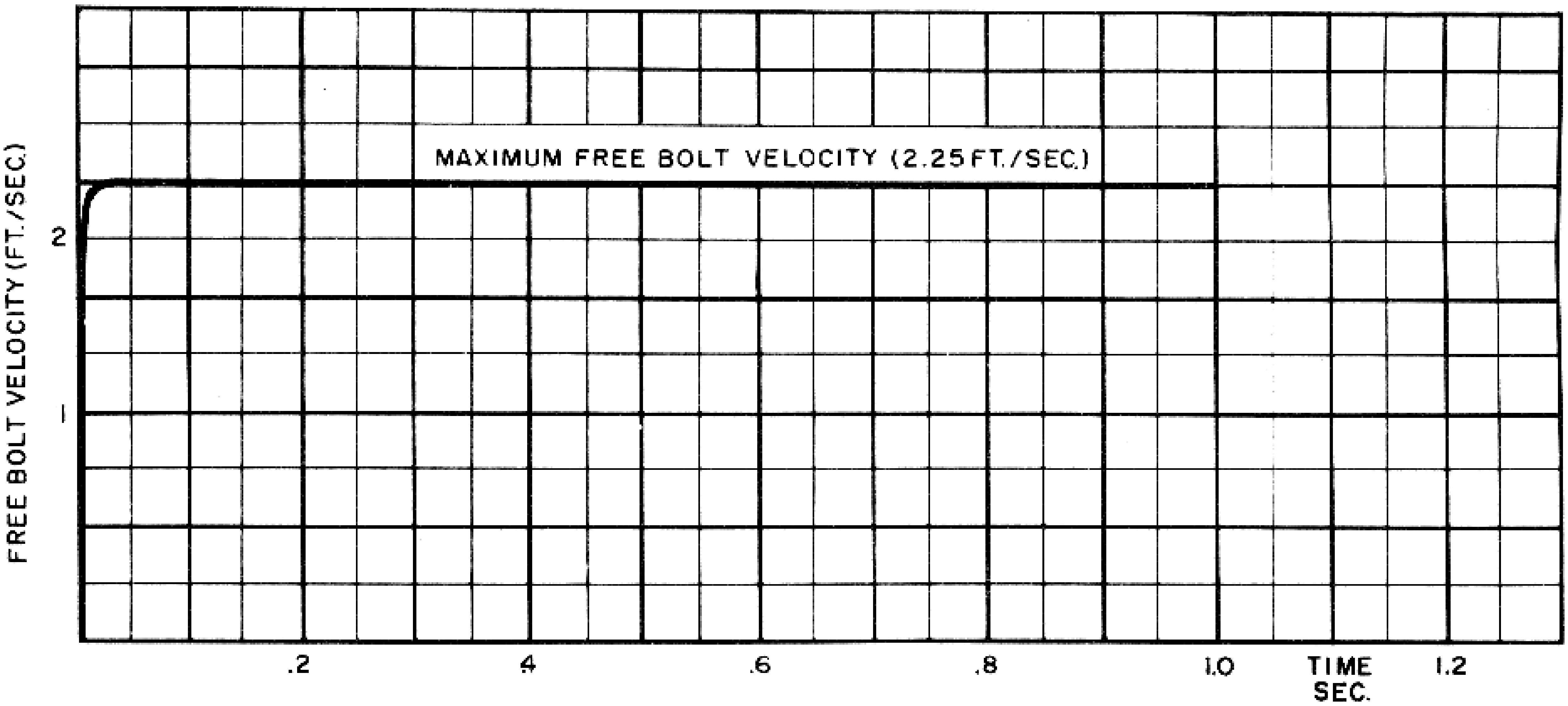

Figure 1–15. Free Recoil Velocity Versus Time (0–1.0 Sec.).

of the force and the time for which it is applied). Solving for dv gives:

$$dv=\frac{Fdt}{M}$$

To obtain the variation of the change in velocity with respect to time, this expression is integrated.

$$(1\text{–}15)\qquad v=\int_0^t \frac{Fdt}{M}=\frac{1}{M}\int_0^t Fdt$$

In accordance with equation 1–15, the retarding effect of a force on a given mass can be determined as follows:

1. Plot a curve showing the variation of the force with respect to time.
2. Measure the area under the curve between $t=0$ and some time t_1.
3. Divide the measured area by the mass. This gives the ordinate of the retardation curve for the time t_1.
4. Repeat 2 and 3 for other values of t and plot the retardation curve.

When this procedure is applied to the driving spring and bolt, the resulting curve shows the loss in bolt velocity resulting from the resistance of the spring. Since the free bolt velocity curve shows the gain in bolt velocity resulting from the thrust of the powder gases, the difference between the curves will be the net bolt velocity, or in other words, the velocity of retarded recoil.

If the retarding force were constant or if its variation with respect to time were known, the application of this method would be very simple. However, when the force varies with bolt displacement as it does in the case of the driving spring, a difficulty is encountered. In order to plot a graph showing the variation of the retarding force with respect to time, it is necessary to have a curve showing the variation of bolt displacement with respect to time and it is this very curve that we are attempting to plot.

This difficulty can be circumvented by considering the problem in two stages. For the first 0.010 second while the powder gas pressures are acting, the retardation offered by the spring will be small and in any case will be almost entirely due to the constant effect of the initial compression. The varying force due to the spring rate during this interval will almost certainly be negligible but, if necessary, it can be approximated very closely. These considerations make it possible to obtain accurate results for the first 0.010 second. For the remainder of the cycle of operation, the powder gas pressures are not acting and the displacement of the bolt can be determined analytically without any trouble.

The procedure for plotting the velocity and displacement curves for the first 0.010 second is as follows:

1. Plot curve of free bolt velocity versus time (fig. 1 14).

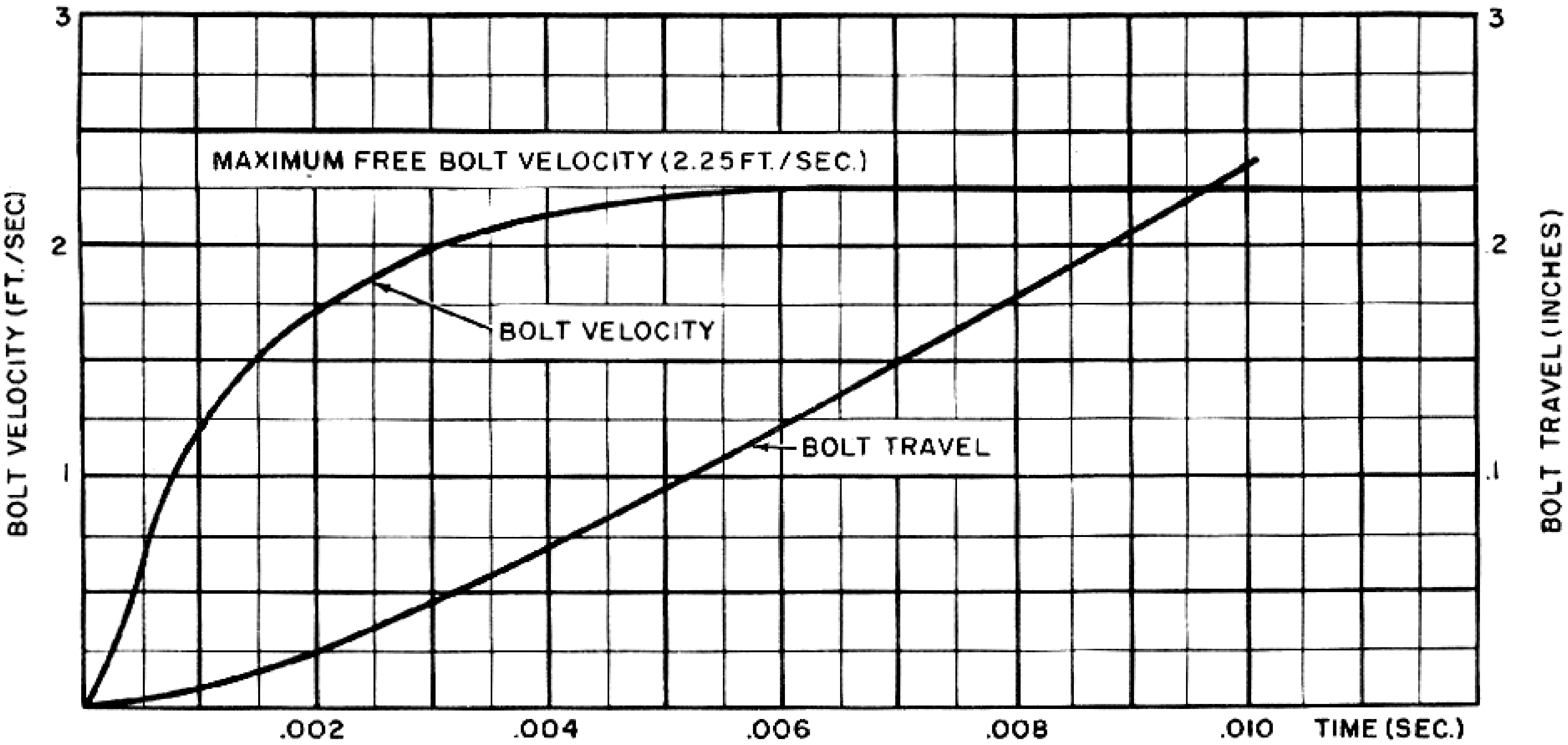

Figure 1–16. Time-Travel and Time-Velocity Curves (0–0.010 Sec.).

2. The loss in velocity due to the initial compression of the driving spring is equal to $F_o t/M_r$. Determine the velocity loss for various values of t, subtract each from the corresponding ordinate of the free bolt velocity curve and draw a curve through the resulting points. If the effect of the spring rate proves to be negligible, this curve is the retarded velocity curve.
3. Integrate under the curve drawn in step 2 to obtain the displacement curve.
4. Assume that the curve drawn in step 3 represents the actual bolt displacement curve and use this curve to determine the retardation due to the spring rate K. Ordinarily, it will be found that this retardation is so small that it will not have any effect worthy of consideration.
5. If the retardation determined in step 4 is sufficient to affect the velocity, use it to modify the curve drawn in step 2, and then integrate under the new curve to obtain a corrected displacement curve.
6. Steps 4 and 5 can be repeated as often as is necessary until no significant change occurs in the displacement curve. Actually, this process of successive approximation should never be necessary and satisfactory results should be achieved in the first three steps or at least in the first five steps.

Fig. 1–16 shows the curves obtained for the gun of the example. In this particular design, the spring is so weak that its retardation effects are entirely negligible during the first 0.010 second. To illustrate this point, the loss in velocity due to F_o over this interval is

$$V=\frac{F_o t}{M_r}=\frac{17.2\cdot .01\cdot 32.2}{500}=.0111\left(\frac{\text{ft.}}{\text{sec.}}\right)$$

The loss due to K, as determined by the method of step 4 is only about 0.0004 feet per second. Thus, in this gun the retarded velocity curve for the first 0.010 second is practically identical with the free velocity curve.

The remainder of the bolt displacement curve can now be determined analytically by using equation 1–10:

$$d=\frac{KD+F_o}{K}\sin\left[\sqrt{\frac{K}{M_r}}\,t+\sin^{-1}\frac{F_o}{KD+F_o}\right]-\frac{F_o}{K}$$

However, since some bolt travel (d′) occurred during the first 0.010 second, the values of F_o, D, and t must be changed to take this motion into account and d′ must be added to the resulting values obtained for d. The changed values to be used in equation 1–10 are:

$$F_o'=F_o+Kd'$$

$$D'=D-d'$$

$$t'=t-.010$$

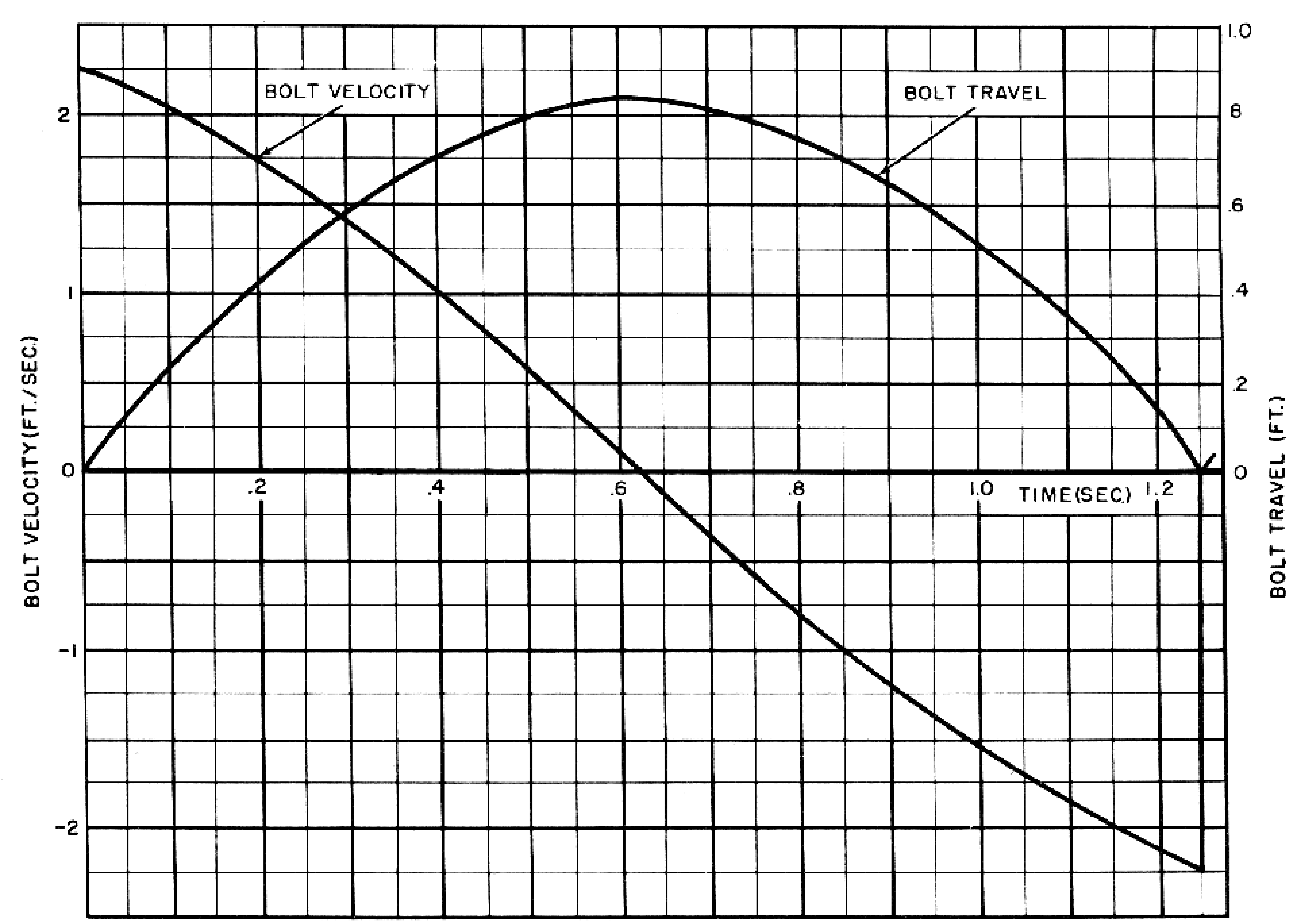

Figure 1–17. Time-Travel and Time-Velocity Curves (Complete Cycle).

The modified form of equation 1–10 is now:

$$d=\frac{K(D-d')+F_o+Kd'}{K}\sin\left[\sqrt{\frac{K}{M_r}}(t-.010)+\sin^{-1}\frac{F_o+Kd'}{K(D-d')+F_o+Kd'}\right]-\frac{F_o+Kd'}{K}$$

$$d=\frac{KD+F_o}{K}\sin\left[\sqrt{\frac{K}{M_r}}(t-.010)+\sin^{-1}\frac{F_o+Kd'}{KD+F_o}\right]-\frac{F_o+Kd'}{K}+d'$$

This equation is employed to complete the bolt displacement curve. The ordinates of the displacement curve are then multiplied by K and increased by F_o to obtain a curve showing the variation of the total spring force with time. Integrating under this curve and dividing by M_r in accordance with equation 1–15 will give a graph of the loss in velocity due to the spring force. Subtracting this curve from the free bolt velocity curve will give the complete graph for the retarded bolt velocity.

Fig. 1–17 shows the displacement and velocity curves obtained by this method for the gun of the example. After the necessary substitutions are made in equation 1–10, the final form of the equation to be used after the first 0.010 second is:

$$d=1.072\sin[2.15t+.223]-.239$$

The spring force curve obtained from the displacement curve of fig. 1–17 is shown in fig. 1–18.

If so desired in the course of a design, the effects of friction and loads incident to operating the gun mechanism may be taken into account in plotting the displacement and velocity curves. These forces are handled in the same way as the spring force. For example, the friction force resisting bolt motion will be essentially constant and therefore can be taken into account by increasing F_o in equation 1–10. A constant or varying load which exists for only a small portion of the cycle (such as the force

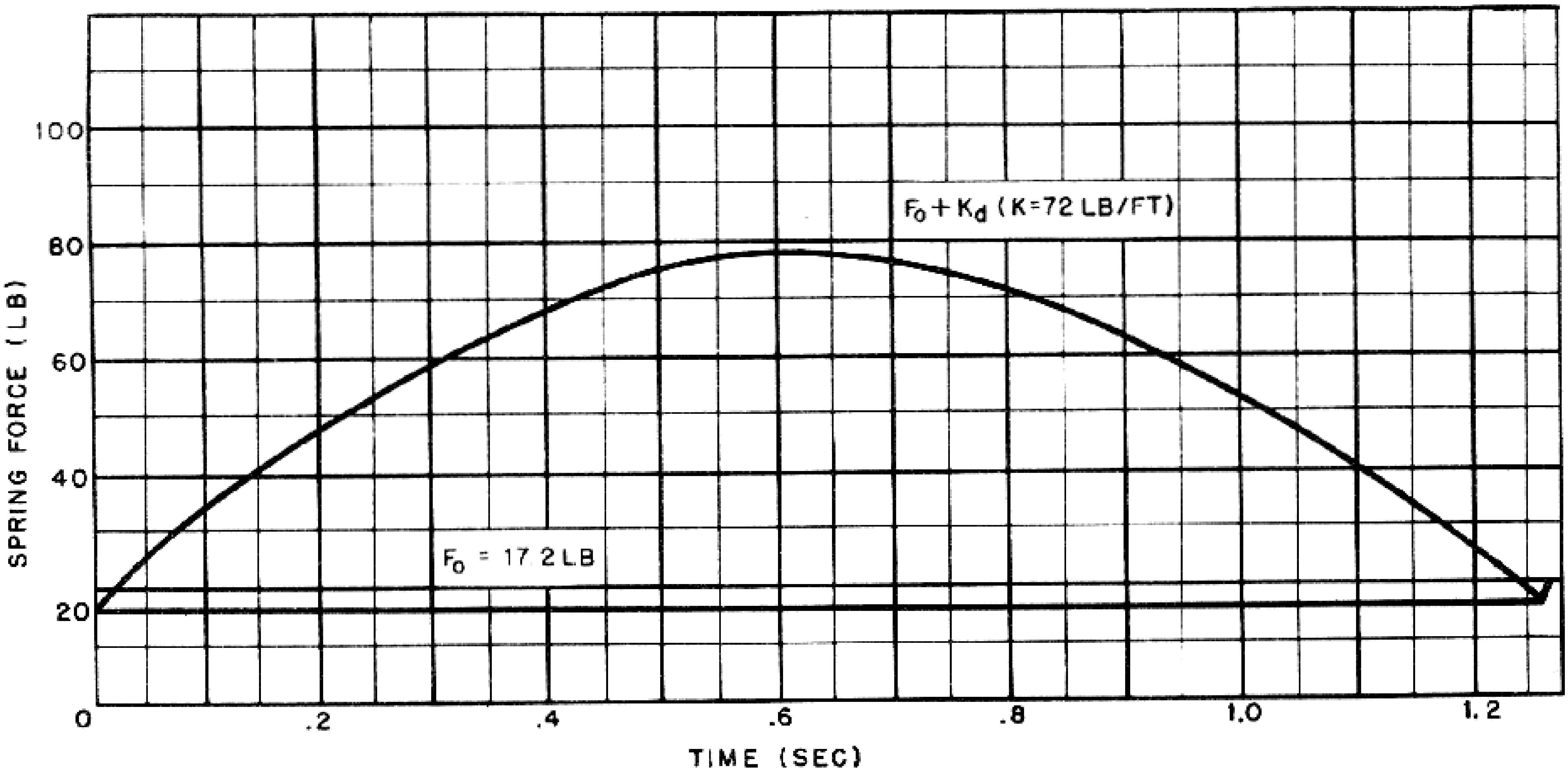

Figure 1–18. Variation of Spring Force With Time.

required to remove a cartridge from the feeder) can be treated in a like manner providing that the problem is considered in stages by methods similar to those described in the preceding paragraphs.

Another useful curve for design and analysis purposes may be obtained by plotting bolt velocity versus displacement. This curve may be drawn easily because the velocity and displacement curves can be used to determine the velocity corresponding to any displacement. Fig. 1–19 shows the velocity-displacement curve for the gun of the example.

5. *Note concerning driving springs*

In paragraph 2, it was pointed out that the selection of F_o and K for a driving spring will have a significant effect on the rate of fire. This may be seen by considering the time to recoil for the extreme conditions in which (a) the initial compression is zero, and (b) the spring constant is zero and only a constant force retards the recoil.

The expression for the time to recoil when the initial compression is zero can be obtained directly from equation 11 by setting $F_o=0$. This gives:

$$(1\text{–}16) \qquad T=\sqrt{\frac{M_r}{K}}\,\frac{\pi}{2}$$

The expression for the time to recoil when the spring constant is zero can not be obtained from equation 1–11 because substituting K=0 yields an indeterminate expression. However, the expression can be derived by substituting K=0 in equation 1–8 and solving the resulting differential equation. This gives the relation between recoil distance and time as:

$$(1\text{–}17) \qquad T=\sqrt{\frac{2M_r}{F_o}}\,[\sqrt{D}-\sqrt{D-d}]$$

When t=D, d=D and therefore:

$$(1\text{–}18) \qquad T=\sqrt{\frac{2M_rD}{F_o}}$$

For the conditions of equation 1–16, $K=2\,F_{av}/D$, where F_{av} is the average spring force over the distance D. For the conditions of equation 1–18 $F_o=F_{av}$. Making these substitutions in equations 1–16 and 1–18 gives the following results:

For $F_o=0$	For $K=0$
$T=\sqrt{\frac{M_rD}{2F_{av}}}\,\frac{\pi}{2}$	$T=\sqrt{\frac{2M_rD}{F_{av}}}$
$=\sqrt{\frac{M_rD}{F_{av}}}\,\frac{\pi}{2\sqrt{2}}$	$=\sqrt{\frac{M_rD}{F_{av}}}\,\sqrt{2}$

Since that average spring force must be the same in both cases, the time to recoil is greater for the condition when K=0 by a factor of

$$\frac{\sqrt{2}}{\pi/2\sqrt{2}}=\frac{4}{\pi}=1.27.$$

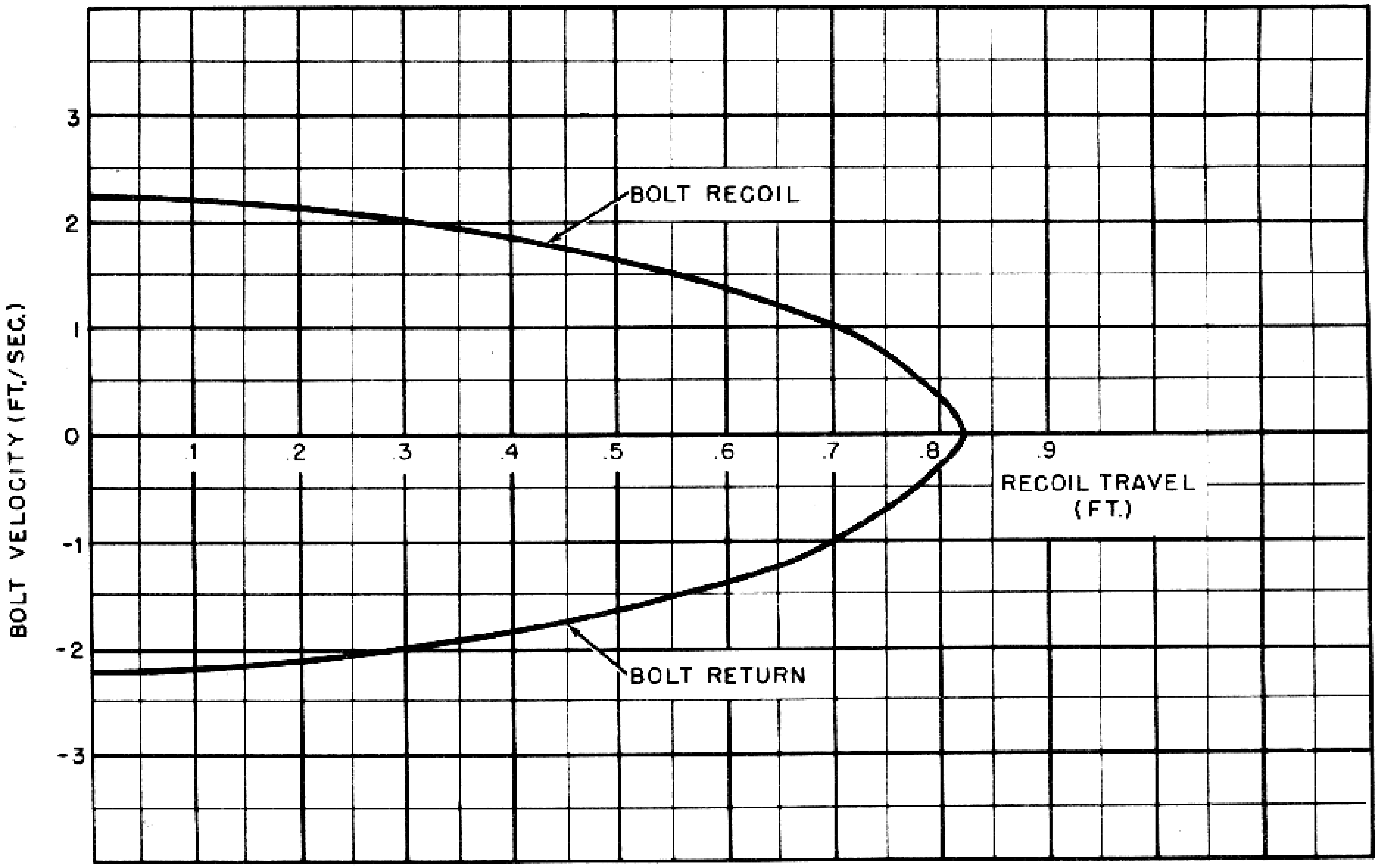

Figure 1–19. Velocity-Displacement Curve.

The condition in which neither K nor F_0 is zero will give a time to recoil somewhere between these two extremes, depending on the combination selected. This indicates that in the design of the driving spring, F_0 should be made as small as possible in order to improve the rate of fire.

BLOWBACK SYSTEM WITH ADVANCED PRIMER IGNITION

In the plain blowback system, the bolt returns to the firing position with relatively low velocity but with considerable kinetic energy and this energy is absorbed by impact before the next cycle starts. Since the bolt is stationary when the new round is fired, all of the explosive force of the round is effective in accelerating the bolt to the rear. As has been explained, this condition requires the use of an extremely heavy bolt in order to keep the bolt velocity within safe limits.

A substantial saving in bolt weight and other advantages can be realized by making use of the kinetic energy of the returning bolt. Instead of permitting this energy to be dissipated by impact before the next round is fired, it is possible to time the ignition so that the new round is fired just before the bolt reaches its fully forward position. In this method of operation, known as "advanced primer ignition," the impulse of the propellant explosion must first slow and stop the returning bolt before it can propel the bolt to the rear. With this action, only a portion of the explosive impulse is effective in blowing back the bolt and the interval of time during which the pressure of the powder gases acts to produce a rearward acceleration of the bolt is also reduced. Both of these effects permit the use of a much lighter bolt and produce a condition in which higher bolt velocities are allowable. Thus, not only can the gun be lighter, but it is also possible to achieve a higher rate of fire.

The form of the mechanism for a blowback gun employing advanced primer ignition (fig. 1–20) is basically the same as for a plain blowback gun except that the firing device shown in the figure

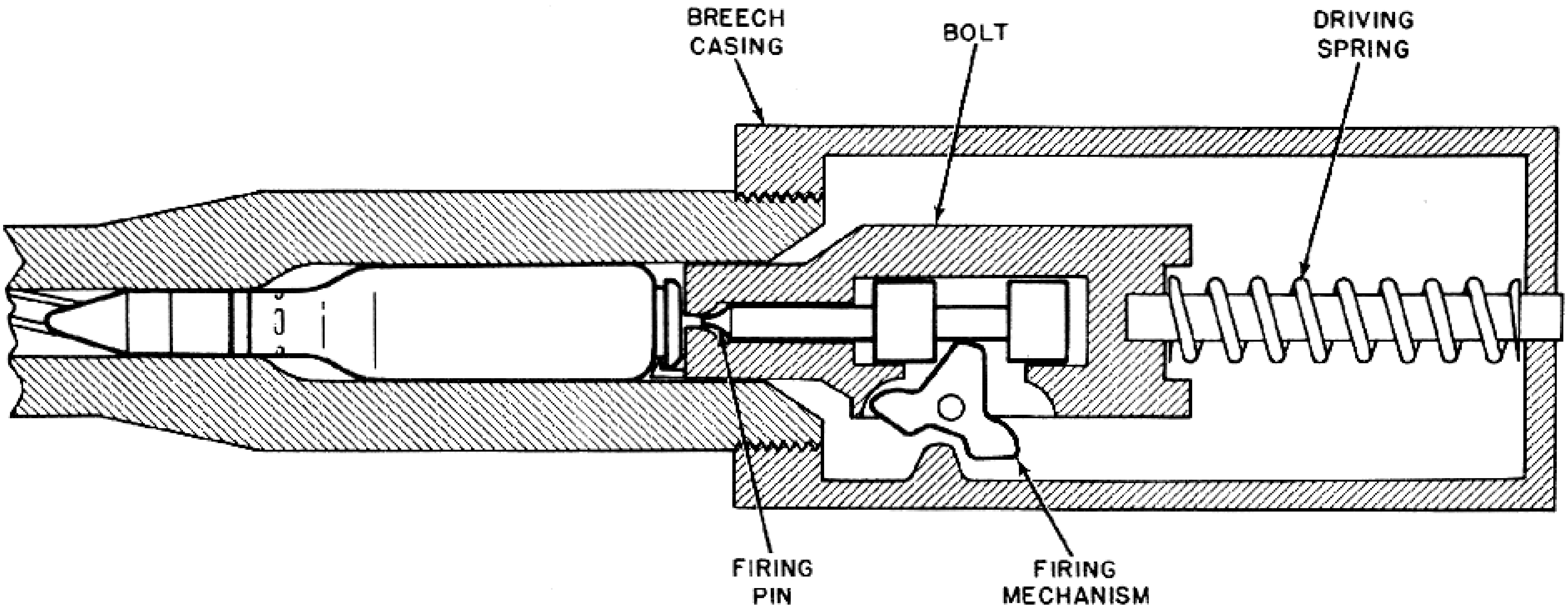

Figure 1–20. Simplified Schematic of Blowback Mechanism With Advanced Primer Ignition.

is arranged to ignite the primer of the fresh cartridge just before the bolt reaches its fully forward position. Although the details of an actual gun of this type may be considerably different in form from the schematic representation shown in fig. 1–20, the basic mechanism shown illustrates the essential mechanical function. The fundamental parts of the mechanism are the bolt (which backs up the cartridge case and is free to slide in the breech casing) and the driving spring (which absorbs the kinetic energy of the bolt when the bolt is blown back and then drives the bolt back to the firing position).

Cycle of Operation

The automatic cycle for a blowback gun with advanced primer ignition occurs as follows:

The cycle starts with the bolt seared to the rear and with the driving spring compressed. When the sear is released, the bolt is thrust forward by the driving spring and as it moves forward, the bolt picks up a fresh cartridge from the feed mechanism and carries this cartridge into the chamber. When the cartridge has entered the chamber sufficiently that the case walls are adequately supported but before the bolt has reached its fully forward position, the firing device is actuated to ignite the primer.

The pressure resulting from the explosion of the propellant charge drives the projectile through the barrel of the gun and at the same time immediately exerts a force which acts through the base of the cartridge case to slow down the forward motion of the bolt, bring the bolt to a stop, and then propel the bolt to the rear. At the time the bolt is driven to the rear, the only significant resistance to the acceleration of the bolt is due to the inertia of the bolt mass.

The force exerted by the pressure of the powder gases lasts for only about 0.008 or 0.009 second after ignition of the primer. After this point, there is no further force driving the bolt to the rear but the recoiling parts continue to move of their own momentum. As the bolt moves back, the spent cartridge case is extracted from the chamber and ejected. The resistance of the driving spring gradually slows the bolt down until it has reduced the bolt velocity to zero. At this point, the cycle of operation is complete and a new cycle begins as the energy stored in the driving spring starts the bolt moving forward.

Analysis of Advanced Primer Ignition

The most important factor to be considered in analyzing the effects of using advanced primer ignition is the manner in which the energy of the returning bolt is utilized. If the relatively small losses to friction and to operating the mechanism are ignored, the driving spring will return the bolt with a final velocity which is almost equal to the initial velocity of recoil. The amount of impulse which must be supplied by the propellant explosion to stop the forward motion of the bolt will then be approximately equal to the amount of impulse required to produce the initial recoil velocity, or in other words, only about one-half the impulse produced by the explosion is effective in causing the recoil velocity. Therefore, when advanced primer ignition is employed, the momentum imparted to the bolt is only one-half of that which would be obtained with plain blowback. This means that from this standpoint alone, the bolt weight can be reduced by a factor of two.

In addition to the advantage mentioned in the preceding paragraph, the use of advanced primer ignition in a blowback gun results in other advantages which are related to the manner in which the cartridge case moves under the pressure of the powder gases. The general nature of this movement is as follows:

Immediately after ignition of the primer, that is, in the very early stage of the propellant explosion, the bolt is still moving forward and is thrusting the case into the chamber. Any frictional force which results from the high pressure inside the case and which tends to resist the forward movement will result in compression stresses in the case walls. These stresses are not troublesome because they do not tend to cause case separation and, in addition, the case is well inside the chamber so that its walls are adequately supported. On the other hand, when the forward motion has been stopped and the case starts to move to the rear, the factors which limit blowback operation become effective and they must be taken into account. These factors give rise to two considerations:

1. If no lubrication is provided, the peak chamber pressures will cause the cartridge case to seize in the chamber and therefore separation of the case will occur unless the bolt movement is limited so that the elongation of the case material is not exceeded while the case is stuck. As explained in the analysis of plain blowback, the precise elongation permissible for a specific cartridge case can be determined only by careful experimentation under actual firing conditions, but a good rule to follow for the brass cases of 20-mm rounds is that the bolt movement to the rear should not exceed 0.015 inch during the first 0.0015 second of the propellant explosion. With advanced primer ignition, the first 0.0009 second (approximately) of the explosion is utilized to stop the forward motion of the bolt so that the critical time during which case separation can occur endures for only 0.0006 second. Since a bolt movement of 0.015 inch is permissible during this time, the average allowable bolt velocity for the same time is 25 inches per second, or about 2 feet per second. This is twice as great as the velocity permissible with plain blowback but is still a very low value.
2. If the ammunition is lubricated in order to avoid chamber seizure, case separation will not occur but the motion of the bolt must still be limited to prevent the case from moving so far out of the chamber that the thin walls near the base are unsupported while there is any considerable residual powder gas pressure. As for plain blowback, this means that for a case of the type shown in fig. 1–6A, the travel in the first 0.010 second of the propellant explosion should not exceed 0.250 inch. Since the rearward motion does not start until 0.0009 second has elapsed, this movement will occur in 0.0091 second and therefore the allowable average velocity is only 27.3 inches per second, or at the most 2.5 feet per second (instead of 2 feet per second as is allowable with plain blowback).

From the foregoing it is apparent that although the use of advanced primer ignition permits slightly higher bolt velocities than are attainable with plain blowback, the advantage in this direction is not very great with the type of ammunition shown in fig. 1–6A. The increase in permissible bolt velocity will produce a somewhat greater rate of fire and will also result in a further decrease in the bolt weight necessary. This saving in bolt weight, coupled with the fact that the bolt weight is reduced by a factor of two because only one-half the explosive impulse is effective in producing recoil, will give a total weight reduction factor of somewhere between 2 and 2.5. In other words, instead of the 500-pound bolt required for the 20-mm gun used as an example in the analysis of plain blowback, the bolt weight for a 20-mm blowback gun with advanced primer ignition would be somewhat over 200 pounds. Although this represents a great improvement over plain blowback, a gun having such a heavy bolt would still not be practical, particularly since the rate of fire will not be much greater than the 48-round-per-minute rate attainable with the plain blowback gun used as an example.

To make full use of the potentialities of advanced primer ignition, it is necessary to use lubricated cartridge cases having the special base form shown in fig. 1–6B. With this form, the diameter of the base is smaller than the maximum case diameter so

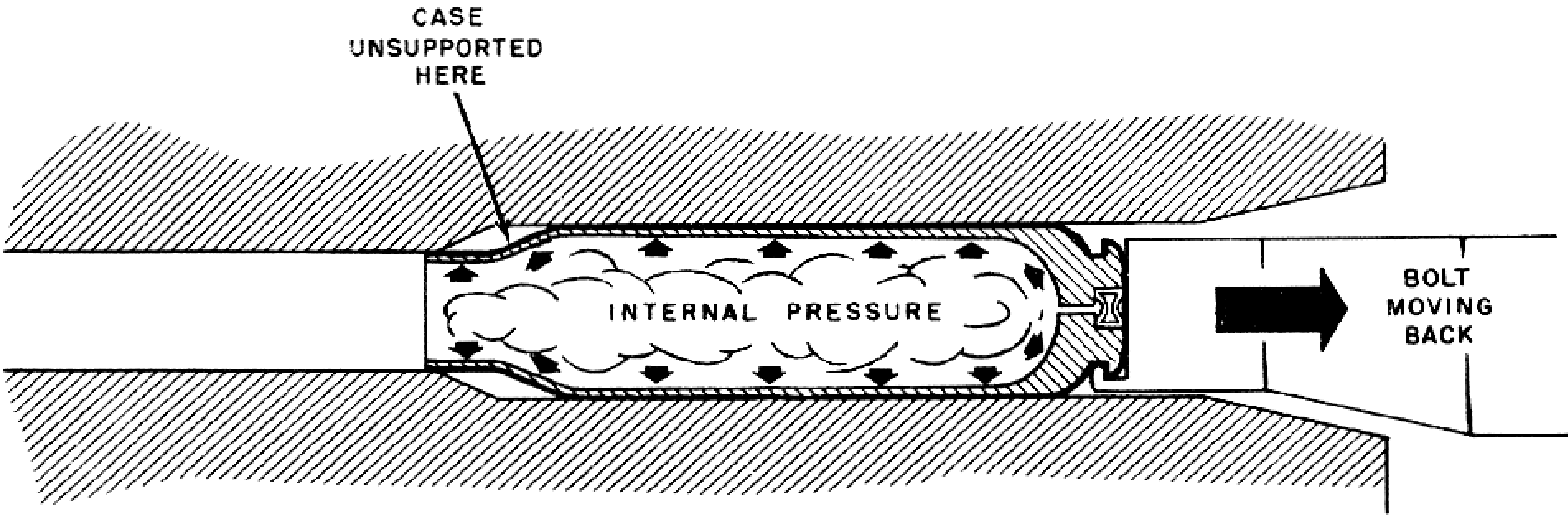

Figure 1–21. Deformation of Bottle-Necked Case.

that the bolt and extractor can follow the case into the chamber, which is made especially long. When the case is blown back, it can travel a considerable distance before the walls near its base become unsupported and therefore a higher bolt velocity is permissible. In an existing 20-mm gun employing advanced primer ignition, the walls near the base of the cartridge case are quite heavy and the case is thrust deeply into the chamber with the result that the case can be blown back nearly two inches in the first 0.010 second without causing rupture near the base. Since the time for this movement is approximately 0.0091 second, the allowable average recoil velocity for this interval is about 220 inches per second or approximately 18 feet per second. This recoil velocity results in a weight of less than 30 pounds for the recoiling parts and in a rate of fire of between 400 and 500 rounds per minute. Although this is not an exceptionally high cyclic rate for a 20-mm gun, a design having the characteristics mentioned is thoroughly sound and practical for some applications.

It is appropriate here to mention some general points concerning the use of ammunition of the type considered in the preceding paragraph. With a cartridge case of the form shown in fig. 1–21, the bottle-necked portion at the front of the case is not supported by the chamber while the case moves under the pressure of the powder gases. Therefore, the internal pressure will tend to push the neck forward and will also tend to expand the mouth of the case. This tendency is so pronounced in some guns that the extracted cases are deformed to the point where the bottle-neck is entirely gone and the cases become practically cylindrical. Because of this extreme deformation, the mouth of the case will sometimes split open. It also should be noted that the use of ammunition which can move well inside the chamber makes the problem of obtaining precisely timed ignition of the primer less critical than it would be for conventional ammunition of the form shown in fig. 1–6A. With a 20-mm cartridge of this conventional type, only a 0.250-inch rearward travel is permissible during the action of the gas pressure and to obtain satisfactory performance the ignition must be timed so that the forward motion of the case will be stopped very close to the position shown in the figure. If ignition is too late, the bolt will strike the rear face of the barrel. If ignition is too early, the case will not enter the chamber far enough and when blown back it will not receive support for the full 0.250 inch. Since the total permissible travel under pressure is only 0.250 inch, a difference of only a few hundredths of an inch in the point at which ignition occurs can have a serious effect on performance and the ignition must therefore be timed very precisely. With ordinary percussion primers and simple firing devices, such precision is difficult to obtain. However, with ammunition of the form shown in fig. 1–6B (for which the permissible movement under pressure can be nearly two inches), extreme precision in timing is not necessary and a variation even as great as ⅛ inch in the position at which ignition occurs for successive rounds will not have any unfavorable effect on performance.

All things considered, the use of advanced primer ignition is an effective means for obtaining satisfactory performance in an action based on the blow-

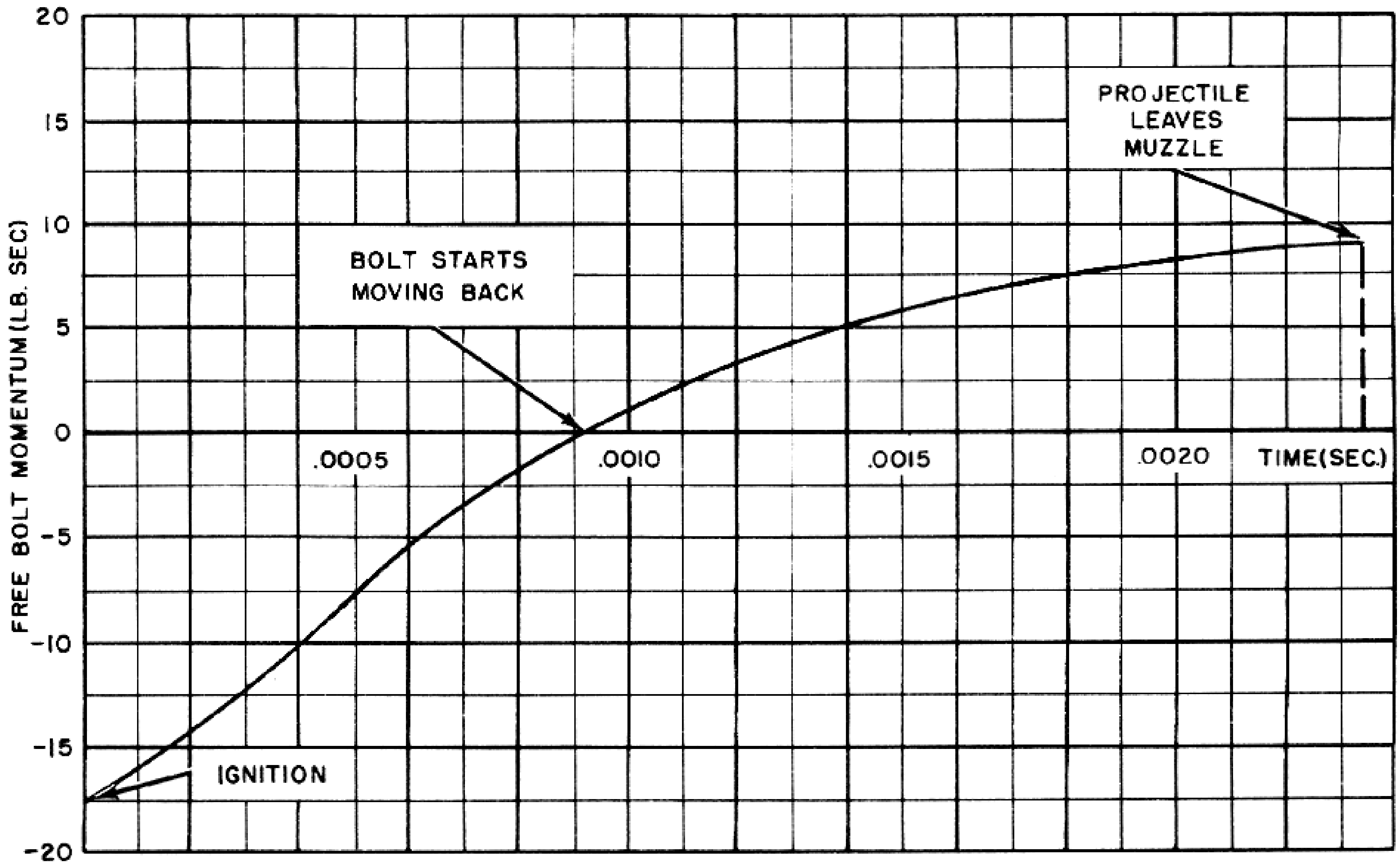

Figure 1–22. Free Bolt Momentum for First 0.00234 Second.

back principle. However, when comparing advanced primer ignition with plain blowback it must be emphasized that the advantages gained by making use of the momentum of the returning bolt are somewhat limited when this factor alone is considered. With all other things being equal, these advantages are as follows: First, the weight of the recoiling parts in an advanced primer ignition gun can be less than half of that in a plain blowback gun. Second, slightly higher bolt velocities are allowable in an advanced primer ignition gun and therefore a somewhat greater rate of fire can be attained than with plain blowback.

It should be realized that these advantages alone are not sufficient to permit the design of a practical gun employing conventional ammunition. Reasonable performance can be obtained only by using ammunition with the special base form previously described. Of course, if this ammunition were used in a plain blowback gun, the bolt weight could be considerably reduced and a higher rate of fire could be obtained but the weight would still be too great and the cyclic rate would still be too low for the design to be practical. The use of advanced primer ignition, however, further reduces the bolt weight and further increases the rate of fire to the point where a practical design can be achieved.

Mathematical Analysis of Advanced Primer Ignition

The following mathematical analysis of advanced primer ignition is based on the same general principles used for the analysis of plain blowback. In this analysis, it is assumed that the same ballistic data used for plain blowback are available. (See figs. 1–9, 1–10, and 1–11.) Since many of the methods and formulas employed in this analysis are the same or are very similar to those used for plain blowback, the derivations of the formulas and the explanation of the procedures will not be repeated here. However, as they arise, any new concepts or new formulas will be explained.

1. *Determination of bolt weight*

The free momentum imparted to the bolt by the impulse created in the explosion of the propellant is

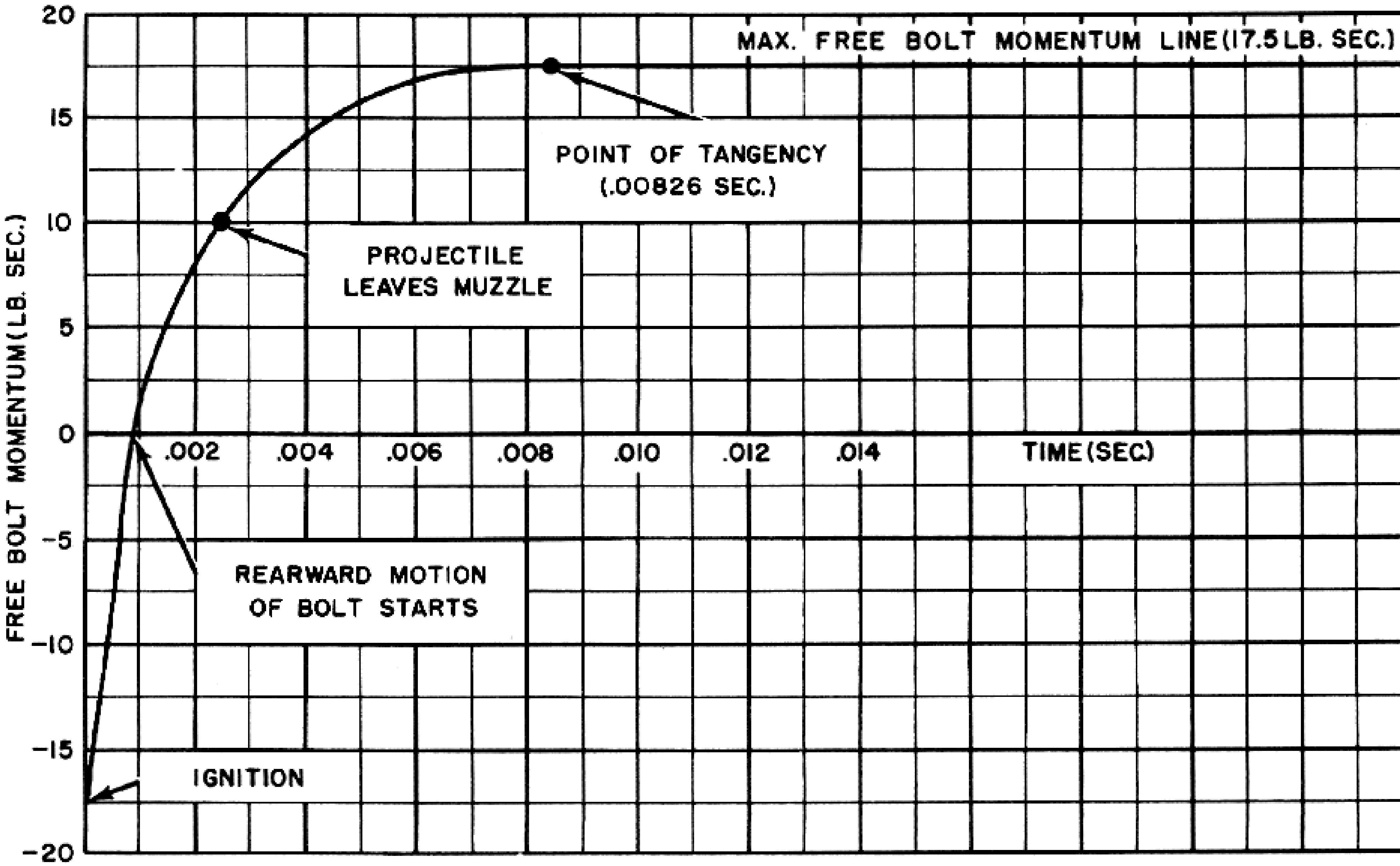

Figure 1–23. Free Bolt Momentum for First 0.010 Second.

exactly the same for advanced primer ignition as for plain blowback. However, it must be remembered that at the instant the propellant charge is ignited, the bolt is moving forward and has a momentum equal to one half the total change in momentum which is produced by the propellant explosion. At any instant after ignition of the propellant, the free momentum of the bolt will be the sum of its initial momentum and the change in momentum produced by the impulse of the propellant explosion.

As has been shown previously, the total change in momentum produced by the propellant explosion is expressed by equation 1–2 as:

$$M_p V_p + 4700\ M_c$$

Therefore the initial forward momentum of the bolt is

$$\frac{1}{2}\left(M_p V_p + 4700\ M_c\right)$$

Since this momentum is directed forward, its sign is negative. Before the projectile leaves the muzzle, the momentum change produced by the impulse of the propellant explosion is:

$$\left(M_p + \frac{M_c}{2}\right) v_p$$

Accordingly, the free momentum of the bolt at any instant during this time will be the sum of its initial momentum and the change in momentum resulting from the impulse of the propellant explosion. That is:

$$(1\text{–}19)\quad M_r v_{r_f} = \left(M_p + \frac{M_c}{2}\right) v_p - \frac{1}{2}\left(M_p V_p + 4700\ M_c\right)$$

Equation 1–19 can be used to plot a graph of free bolt momentum versus time for the period before the projectile leaves the muzzle. For the cartridge and barrel on which fig. 1–10 is based, the equation is evaluated as follows:

$$M_r v_{r_f} = \frac{1}{32.2}\left[\left(.29 + \frac{.070}{2}\right) v_p - \frac{1}{2}\left(.29 \times 2750 + 4700 \times .070\right)\right]$$

$$= .00101\, v_p - 17.5$$

The curve obtained by using this relation is shown in fig. 1–22. The same curve is also shown in

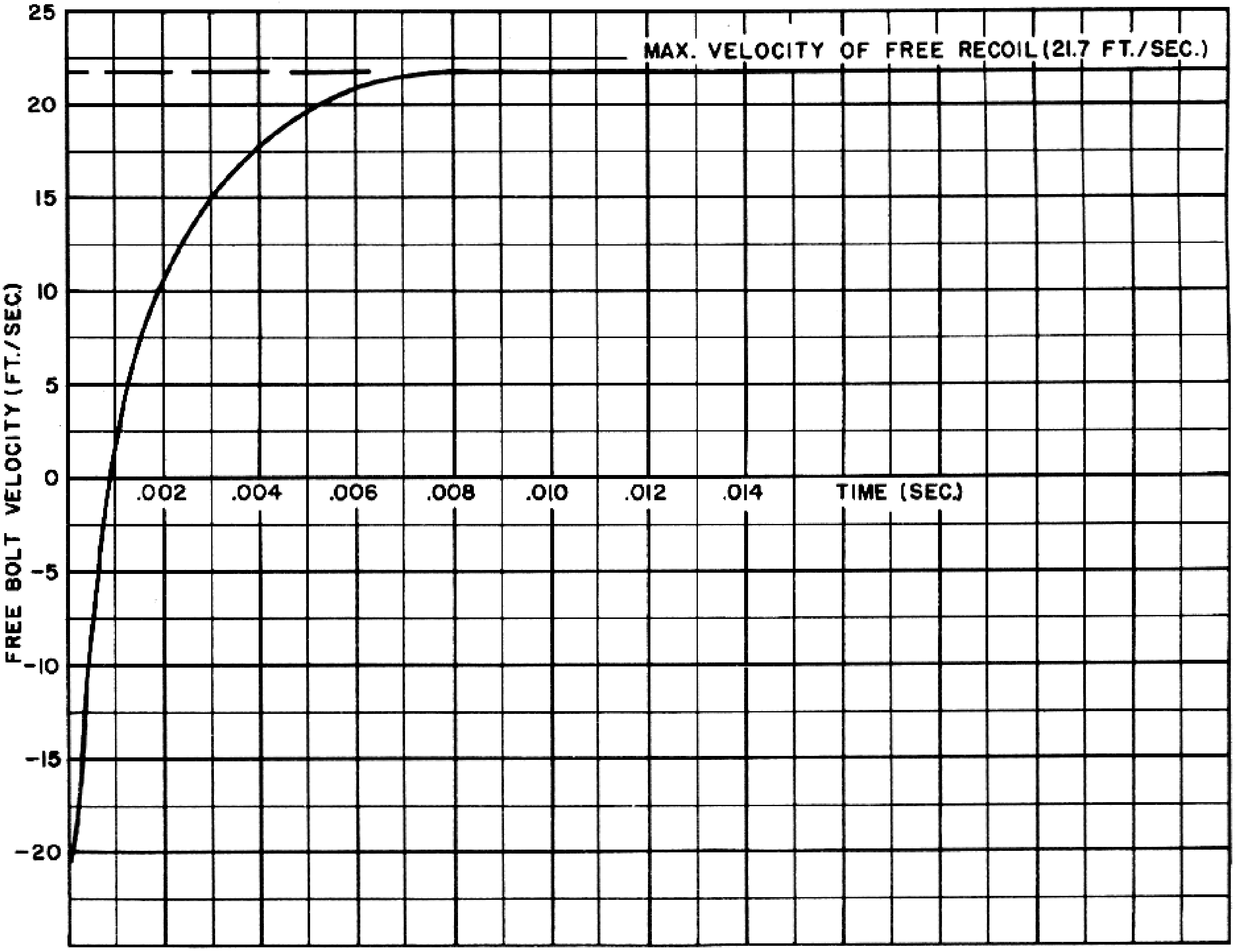

Figure 1–24. Free Bolt Velocity Curve for First 0.014 Second.

fig. 1–23 as the portion between t=0 and t=0.00234 second. Note that these curves have the same form as the corresponding curves for plain blowback (figs. 1–12 and 1–13) except that the zero axis is shifted upward by 17.5 (lb. sec.) which is half the total change in momentum produced by the impulse of the propellant explosion.

The momentum curve for the time after the projectile leaves the muzzle is completed in the same way as for plain blowback. In this case the maximum free bolt momentum is given by the expression:

(1–20) $$M_r V_{r_f} = \frac{1}{2}\,(M_p V_p + 4700\, M_c)$$

For the conditions of the example:

$$M_r V_{r_f} = \frac{1}{2}\left(\frac{.29}{32.2}\,2750 + 4700\,\frac{.070}{32.2}\right) = 17.5 \text{ (lb. sec.)}$$

Fig. 1–23 is used to determine the bolt weight by using the relation expressed by equation 1–4:

$$M_r = \frac{\int_{t_1}^{t_2} (M_r v_{r_f})\,dt}{(t_2 - t_1)\, v_{r_{f(all)}}}$$

In this case, it will be assumed that the special ammunition shown in fig. 1–6B is to be used and that the allowable movement during the first 0.010 second is two inches. As fig. 1–23 shows, the rearward movement does not start until 0.0009 second has elapsed and therefore the time over which the two-inch movement can occur is 0.0091 second. This gives the allowable average velocity for the interval from t=0.0009 to t=0.0010 as:

$$v_{r_{f(all)}} = \frac{2}{12 \times .0091} = 18.30 \text{ (ft./sec.)}$$

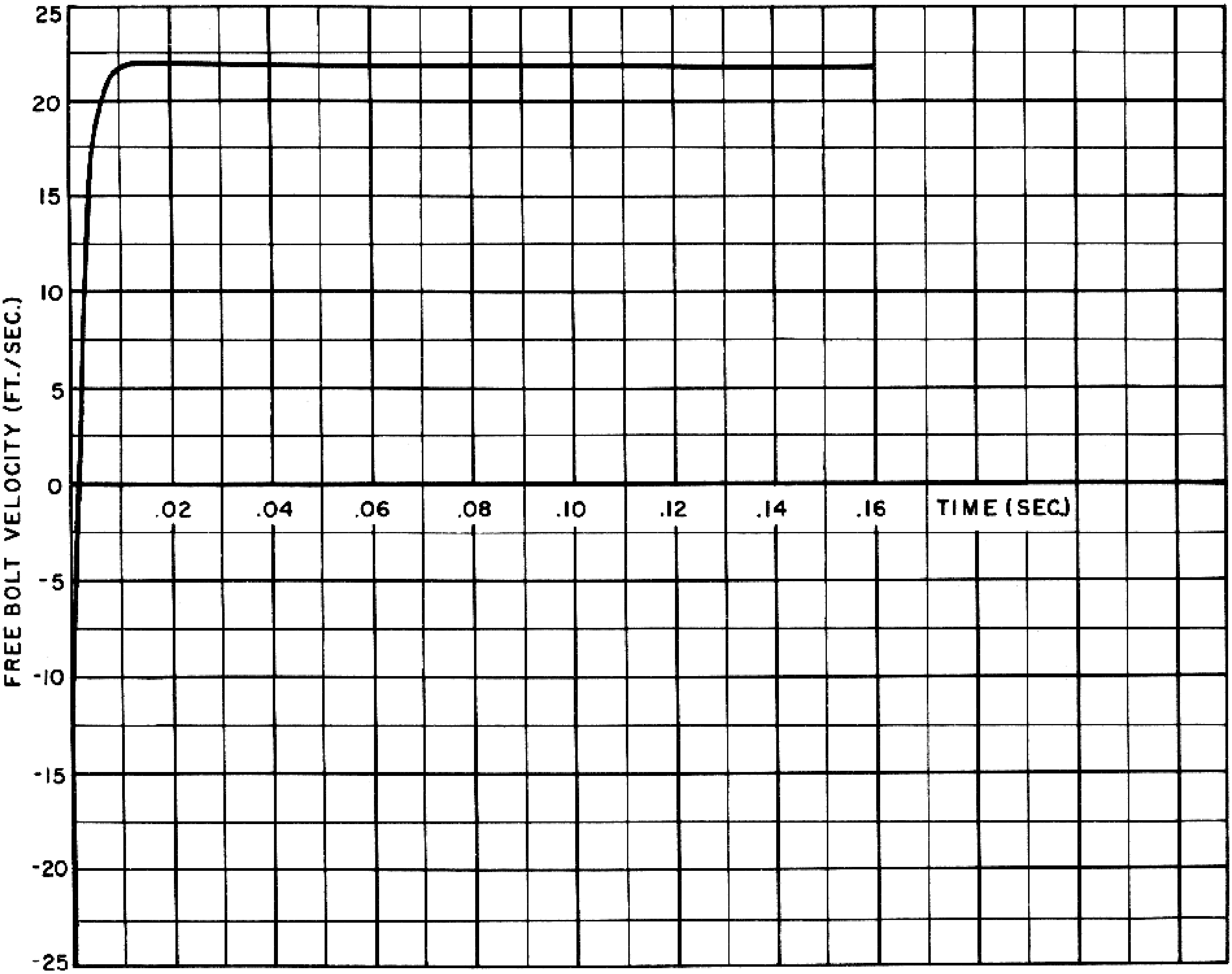

Figure 1–25. Free Bolt Velocity for 0.160 Second.

Integrating under the curve of fig. 1 23 from t= 0.0009 to t=0.0091 gives a total area of 0.1310 (lb.-sec.²). Using equation 1–4 to evaluate M_r gives:

$$M_r = \frac{.1310}{.0091 \times 18.3} = .789 \left(\frac{\text{lb. sec.}^2}{\text{ft.}}\right)$$

Therefore the required weight is:

$$W_r = gM_r = 32.2 \times .789 = 25.5 \text{ (lbs.)}$$

Accordingly, the weight of the recoiling parts will be taken as 26 pounds for the remainder of the analysis.

2. *Determination of driving spring design data*

The maximum velocity of free recoil is found in the same way as for plain blowback by using the equation expressing the maximum free recoil momentum to solve for the velocity.

$$\text{(1-21)} \qquad M_r V_{r_f} = \frac{1}{2}\,(M_p V_p + 4700\, M_c)$$

$$V_{r_f} = \frac{M_p V_p + 4700\, M_c}{2\, M_r} = \frac{W_p V_p + 4700\, W_c}{2\, W_r}$$

For the 26-pound bolt and the conditions of the example:

$$V_{r_f} = \frac{.29 \times 2750 + .070 \times 4700}{2 \times 26} = 21.9 \left(\frac{\text{ft.}}{\text{sec.}}\right)$$

Again assuming that this velocity is imparted instantaneously to the bolt, the initial bolt energy is given by equation 1–6:

$$E_r = \frac{1}{2}\, M_r V_{r_f}^2 = \frac{W_r V_{r_f}^2}{2g} \text{ (ft. lb.)}$$

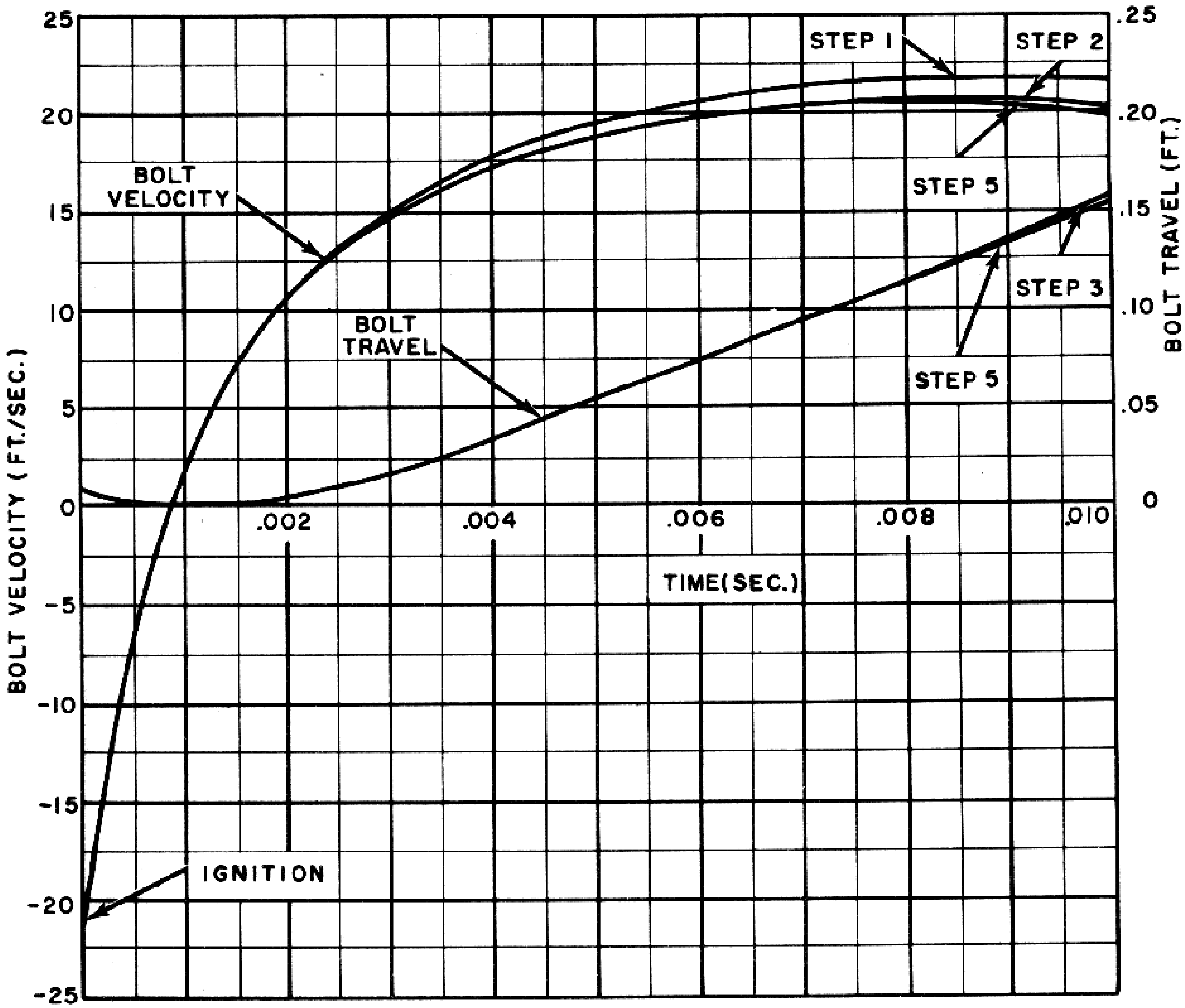

Figure 1–26. Time-Travel and Time-Velocity Curves for First 0.010 Second.

Evaluating this expression for the conditions of the example gives:

$$E_r = \frac{26 \times 21.9^2}{2 \times 32.2} = 194 \text{ (ft. lb.)}$$

The bolt driving spring must be proportioned so that it will absorb this amount of energy over the entire distance through which the bolt moves in recoil. The energy absorbed by a spring is equal to the distance through which it is compressed times the average force required to produce this deflection. That is:

$$E_r = F_{av}D \text{ or } F_{av} = \frac{E_r}{D}$$

If it is assumed that the bolt in the example must open 10 inches (0.833 feet) in order to permit feeding of a 20-mm cartridge, the average force exerted by the spring must be:

$$F_{av} = \frac{194}{.833} = 233 \text{ (lb.)}$$

In designing the spring so that it will produce this average force, the same factors described in the analysis of plain blowback should be considered. However, an arbitrary choice of spring characteristics will suffice for present purposes. If the initial compression is taken as 130 pounds, a maximum force of 336 pounds will produce the required average force of 233 pounds. Since the difference between the maximum force and the initial compres-

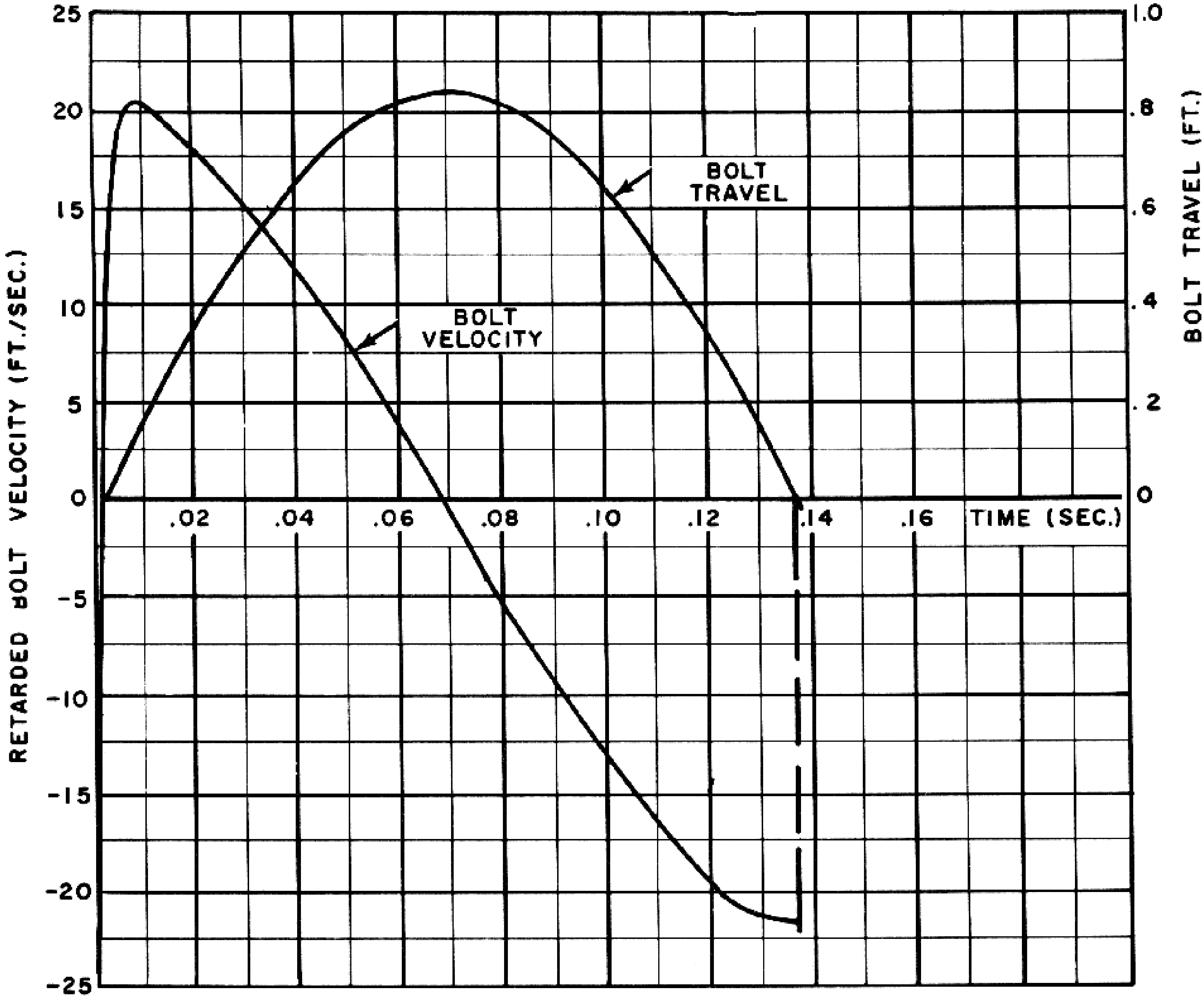

Figure 1–27. Time-Travel and Time-Velocity Curves (Complete Cycle).

sion is 206 pounds and the recoil distance is 10 inches, the spring rate will be 20.6 pounds per inch or 247 pounds per foot. Realizing that this choice is arbitrary, it will be assumed here that the selected values of $F_o=130$ pounds and $K=247$ pounds per foot will result in a satisfactory spring.

Since the bolt weight and the characteristics of the driving spring have been determined, the basic design of the gun is now complete and the remaining task is to consider what performance this design may be expected to give.

3. *Bolt motion equations*

Since the bolt motion equations derived for plain blowback are all based only on the amount of bolt energy and on the characteristics of the driving spring, these equations are not affected by the use of advanced primer ignition. (Of course, the values to be substituted in the equations are different, but the relationships between these values are not changed.) Therefore, the equations will not be derived again here but they are listed for ready reference:

$$t=\sqrt{\frac{M_r}{K}}\left[\sin^{-1}\frac{Kd+F_o}{KD+F_o}-\sin^{-1}\frac{F_o}{KD+F_o}\right] \tag{1–9}$$

$$d=\frac{KD+F_o}{K}\sin\left[\sqrt{\frac{K}{M_r}}\,t+\sin^{-1}\frac{F_o}{KD+F_o}\right]-\frac{F_o}{K} \tag{1–10}$$

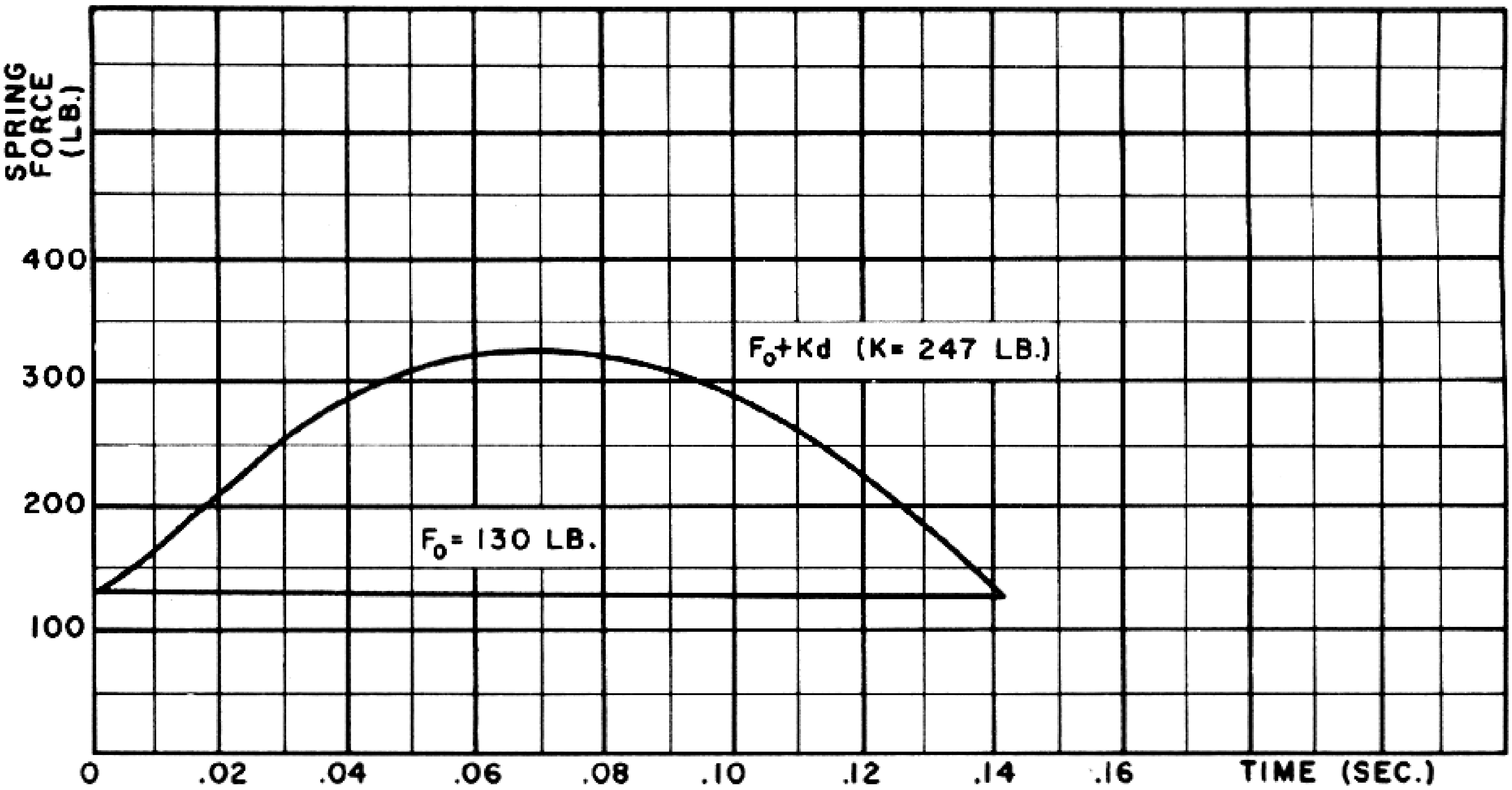

Figure 1–28. Variation of Spring Force With Time.

(1–11) $$T=\sqrt{\frac{M_r}{K}}\left(\cos^{-1}\frac{F_o}{KD+F_o}\right)$$

(1–12) $$N=\frac{30}{T}=\frac{30\sqrt{\frac{K}{M_r}}}{\cos^{-1}\frac{F_o}{KD+F_o}}$$

(It should be noted that these equations are all based on the simplifying assumption that the maximum velocity of free recoil is transferred instantaneously to the bolt. A more thorough analysis of the actual occurrences during the progress of the propellant explosion is given in the following description of the methods used for developing the theoretical time-travel and time-velocity curves.)

On the basis of equation 1–12, the rate of fire for the gun of the example is:

$$N=\frac{30\sqrt{\frac{247\times 32.2}{26}}}{\cos^{-1}\frac{130}{247\times .833+130}}=446\text{(rounds per minute)}$$

With the rate of fire and bolt energy known, the power absorbed by the bolt can be computed by means of the formula:

(1–13) $$HP=\frac{E_rN}{33{,}000}$$

The horsepower absorbed by the bolt in the gun of the example will be:

$$HP=\frac{194\times 446}{33{,}000}=2.62$$

This should be adequate power for operating the gun mechanism.

4. *Development of theoretical time-travel and time-velocity curves*

The theoretical curves showing bolt travel and bolt velocity with respect to time for a gun using advanced primer ignition are developed according to the same general principles employed for plain blowback but there are certain differences in the details as a result of the fact that ignition of the primer occurs while the bolt is still moving forward.

The development of the curves starts with the free bolt velocity curves (figs. 1–24 and 1–25) which are derived directly from the free bolt momentum curve previously plotted (fig. 1–23) by dividing each ordinate of the momentum curve by the mass of the bolt. (Bolt weight is 26 pounds.)

Fig. 1–26 shows the time-travel and time-velocity curves obtained for the gun of the example for the period from t=0 to t=0.010 second. These curves

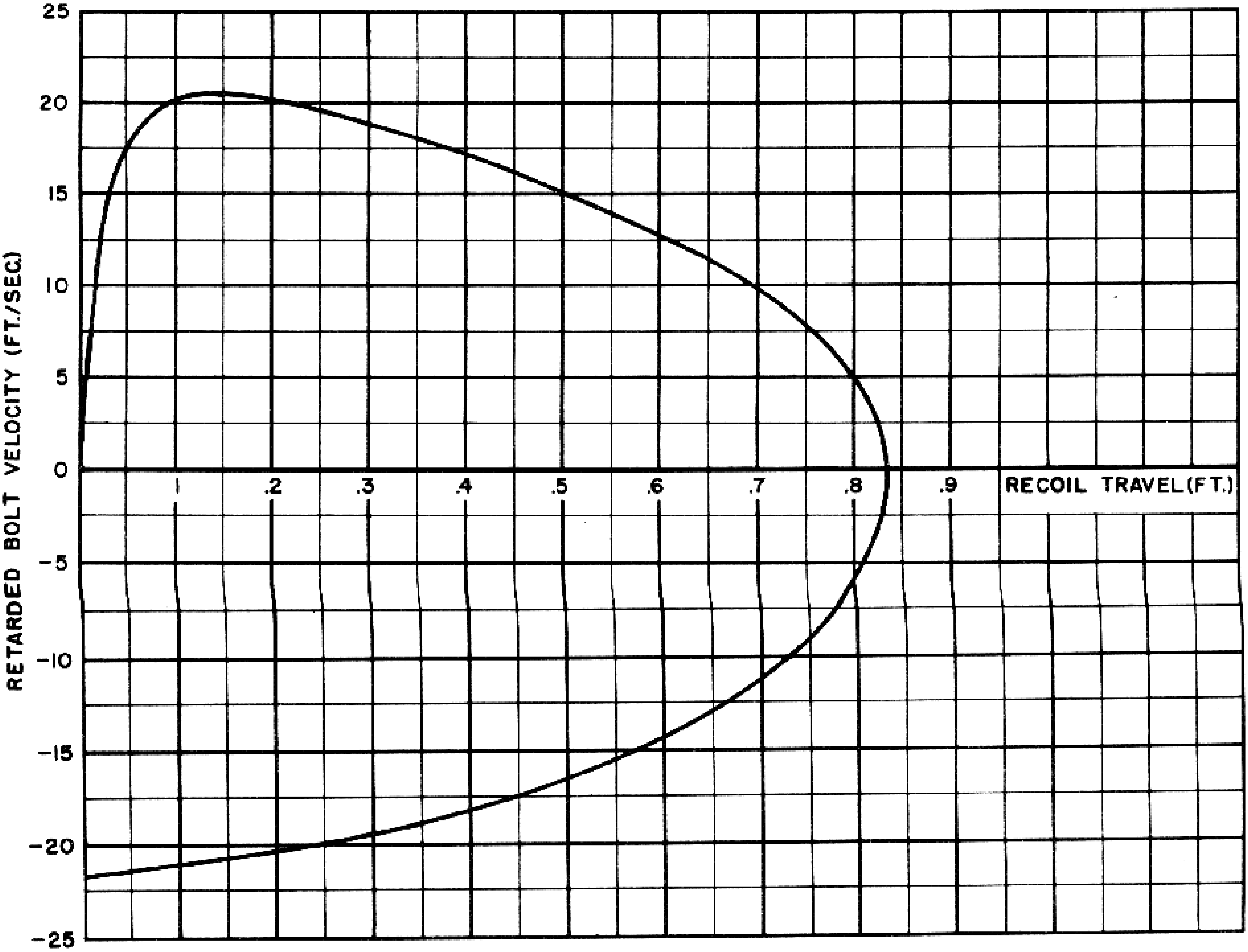

Figure 1–29. Velocity-Displacement Graph.

were derived by the step-by-step system described under plain blowback and the steps referred to in the figure are those in the procedure described for plain blowback. Note that for the first 0.0009 second the bolt travel curve dips downward to zero and then starts to rise as the bolt moves back, indicating that the bolt travel is measured from the most forward position reached during the propellant explosion. In this particular design the total velocity loss resulting from the effect of the initial spring compression during the time interval between t=0.0009 to t=0.010 is equal to 1.47 feet per second, computed as follows:

$$V=\frac{F_o t}{M_r}=\frac{130\times.0091\times32.2}{26}=1.47\left(\frac{\text{ft.}}{\text{sec.}}\right)$$

The loss due to the spring constant K, as determined by the method of step 4 is only about 0.19 feet per second. This loss is so slight that it is not necessary to continue the process of successive approximation any further than step 5.

The remainder of the bolt displacement curve can now be determined analytically by using equation 1–10, modified as necessary to account for the displacement d′ during the first 0.010 second. The changed values to be used in equation 1–10 are the following:

$$F_o'=F_o+Kd'=130+247\times.156=168.5$$

$$D'=D-d'=D-.156$$

$$t'=t-.010$$

Making the required substitutions as explained for plain blowback gives the final form of the equation to be used after the first 0.010 second as:

$$d=1.361\sin[17.49\,t+.351]-.527$$

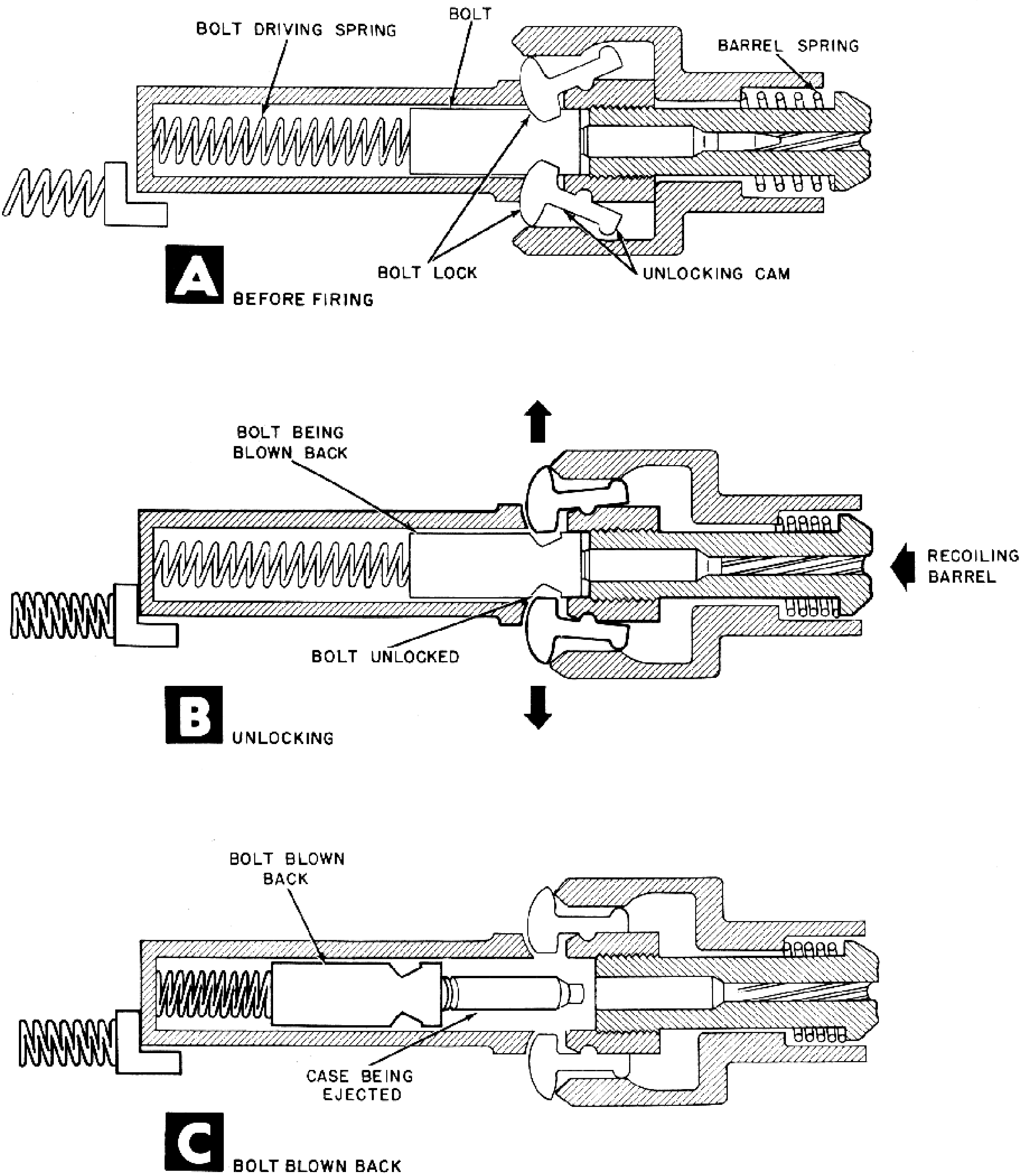

Figure 1–30. Simplified Schematic of Delayed Blowback Mechanism (Recoil-U nlocking).

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This equation is used to complete the bolt displacement curve and gives the result shown in fig. 1–27. The ordinates of the displacement curve are then multiplied by K and increased by F_0 to obtain a curve showing the variation of the spring force with time (fig. 1–28). Integrating under this curve and dividing the results by M_r in accordance with equation 1 15 will give a graph of the velocity loss due to the spring force. Subtracting this curve from the free bolt velocity curve will give the complete graph for the retarded bolt velocity, which is also shown in fig. 1–27. Fig. 1–29 shows the velocity versus displacement curve for the gun of the example as derived from the curves of fig. 1–27.

DELAYED BLOWBACK SYSTEM

All of the major difficulties associated with the design of blowback machine guns stem from excessive movement of the cartridge case during the time of action of the powder gas pressure. The preceding paragraphs show how the use of advanced primer ignition causes the initial high-pressure phase of the propellant explosion to be expended in stopping the forward motion of the bolt, with the resulting advantages of a lighter bolt and a slightly higher rate of fire than would be permissible with plain blowback. These advantages are attributable to the fact that the rearward motion of the bolt is delayed for approximately one-thousandth of a second, thus halving the impulse which is effective in blowing back the bolt and also reducing the time during which the bolt is accelerated to the rear. Since this time is reduced, the average rearward velocity of the bolt can be higher during the interval without exceeding the allowable movement.

The beneficial effects of the delayed rearward bolt movement obtainable with advanced primer ignition lead to the conclusion that still greater benefits could be achieved by further delaying the movement. Unfortunately, the delay which can be obtained with advanced primer ignition is more or less fixed and amounts to the time required for the propellant explosion to produce approximately one-half of its total impulse. (In other words, for a 20-mm gun such as used in the examples previously discussed, the delay is approximately 0.0009 to 0.0010 second.) To delay the rearward motion of the bolt beyond this time, it is necessary to resort to a special operating system referred to as "delayed blowback".

Delayed blowback may be defined as the system of operation in which the bolt remains locked until the peak powder gas pressures have passed and a safe operating limit is reached after the projectile clears the muzzle. The bolt is then unlocked by some means so that it can be blown back by the residual pressure with sufficient energy to perform the remainder of the cycle of operation. In this system, the time at which the bolt is unlocked can be controlled in the design so that any desired portion of the residual pressure can be utilized. Of course, the bolt must be unlocked while there is still sufficient impulse available from the residual pressure to produce the required operating energy.

Any gun in which the bolt is unlocked while there is still some residual pressure is subject to some blowback and partakes of some of the characteristics of the delayed blowback system. Such guns include certain gas-operated and short-recoil-operated weapons in which the bolt is unlocked almost immediately after the projectile has left the muzzle. However, in guns of this type, the operating energy does not come primarily from blowback but is derived mainly from the action of the gas piston or from the motion of the recoiling parts; therefore these guns will not be described at this time. The present analysis is concerned only with guns in which delayed blowback is the main source of energy.

The methods which have been used to unlock the bolt in delayed blowback guns are very numerous. Some are relatively simple and some quite elaborate but all are intended to keep the breech rigidly locked for a portion of the time of action of the powder gases. In some guns, the barrel and locked bolt are permitted to recoil together for a short distance and this motion is then utilized to perform the operation of unlocking. In other guns, the barrel is tapped so that a portion of the expanding powder gases can be by-passed to operate a piston or lever which actuates a mechanism so arranged that the breech is unlocked shortly after the projectile leaves the muzzle. Another method, known as primer actuation, uses an arrangement whereby the chamber pressure causes the primer of the cartridge to move to the rear in its pocket. As the primer is set back, it impinges on a sliding member and drives this member to the rear. The mechanism is devised so that the sliding member will unlock the bolt after a sufficient delay to permit the projectile to clear the muzzle. Still another method, known as the "booster principle", uses a device at the muzzle to trap the muzzle blast. The muzzle device is moved by the expanding gases and this movement is transferred to the breech mechanism through a mechanical connection which unlocks the bolt. After unlocking occurs, the trapped gas pressure blows back the bolt.

The basic point to remember is that a delayed blowback gun is one in which the bolt remains locked until after the projectile leaves the muzzle and is then unlocked so that the residual pressure can blow the bolt back. Whether the delayed unlocking is accomplished through recoil actuation, gas actuation, setback of the primer, booster actuation, or any other method is not of critical importance in considering what effects the delay has on the blowback action. Accordingly, in the following description and analysis of delayed blowback, it should be understood that, although recoil actuation is used to illustrate the principles, these principles apply regardless of what method of actuation is employed.

Cycle of Operation

Fig. 1–30 shows, in schematic form, a typical recoil-actuated delayed blowback mechanism. The cycle of operation is as follows:

The cycle starts with a cartridge in the chamber and with the bolt locked (fig. 1–30A). When the gun is fired, the reaction to the forward momentum imparted to the projectile and powder gases causes the barrel and locked bolt to recoil together. This recoil movement continues for a short distance until the projectile has cleared the muzzle and the bolt unlocking device is actuated (fig. 1–30B). When the bolt is unlocked, the residual pressure drives the cartridge case to the rear against the resistance offered by the inertia of the bolt.

After unlocking occurs, the barrel is stopped by a buffer and returned to battery by the barrel spring. When the residual pressure has dropped to zero, the bolt continues to move to the rear of its own momentum (fig. 1–30C). As the bolt moves back, the spent cartridge case is extracted and ejected and the bolt driving spring is compressed. When the driving spring and buffer system has absorbed all of the kinetic energy in the bolt and brought the bolt to a stop, the energy stored in the spring drives the bolt forward. The bolt picks up a fresh cartridge from the feeder as it moves forward, loads this cartridge in the chamber, and then relocks to the barrel, thus completing the cycle of operation.

Analysis of Delayed Blowback

In a delayed blowback gun, the blowback action occurs under the relatively low residual pressure which exists after the projectile has left the muzzle and therefore case separation does not present a serious problem. However, it should be realized that the residual pressure can be considered to be relatively "low" only when it is compared with the peak chamber pressure. In a typical 20-mm gun with a barrel length of nearly 60 inches, the initial value of the residual pressure is approximately 5000 pounds per square inch and this pressure may be considered to decrease exponentially with time as shown in fig. 1–31, until it reaches zero approximately 0.008 second after ignition of the propellant charge. Pressures of the magnitudes which exist for the major portion of the time shown in the figure are great enough to cause rupture of the thin walls near the base of the case if the case is permitted to move too far out of the chamber while these pressures are acting. Therefore, it is necessary in a delayed blowback gun to limit the bolt movement so that the cartridge case does not move too quickly out of the chamber.

The exact limit for movement of a specific cartridge case during the action of the residual gas pressure in a given gun can be determined only by experimentation under actual firing conditions. However, a fair estimate for present purposes can be obtained by considering the pressures shown in fig. 1–31 in relation to the strength of a typical 20-mm cartridge case. If it is assumed that after the thin portions of the case walls become unsupported the maximum internal pressure that can be safely allowed is 750 pounds per square inch, the period during which rupture of the case can occur is shown by the shaded portion of fig. 1–31. If it is further assumed that the bolt is unlocked 0.001 second after the projectile leaves the muzzle, the critical time extends from $t=0.00334$ to $t=0.00500$ second or lasts approximately 0.00166 second. Now as previously explained, a cartridge of the conventional type shown in fig. 1 6A should not be permitted to move out of the chamber by more than approximately one-

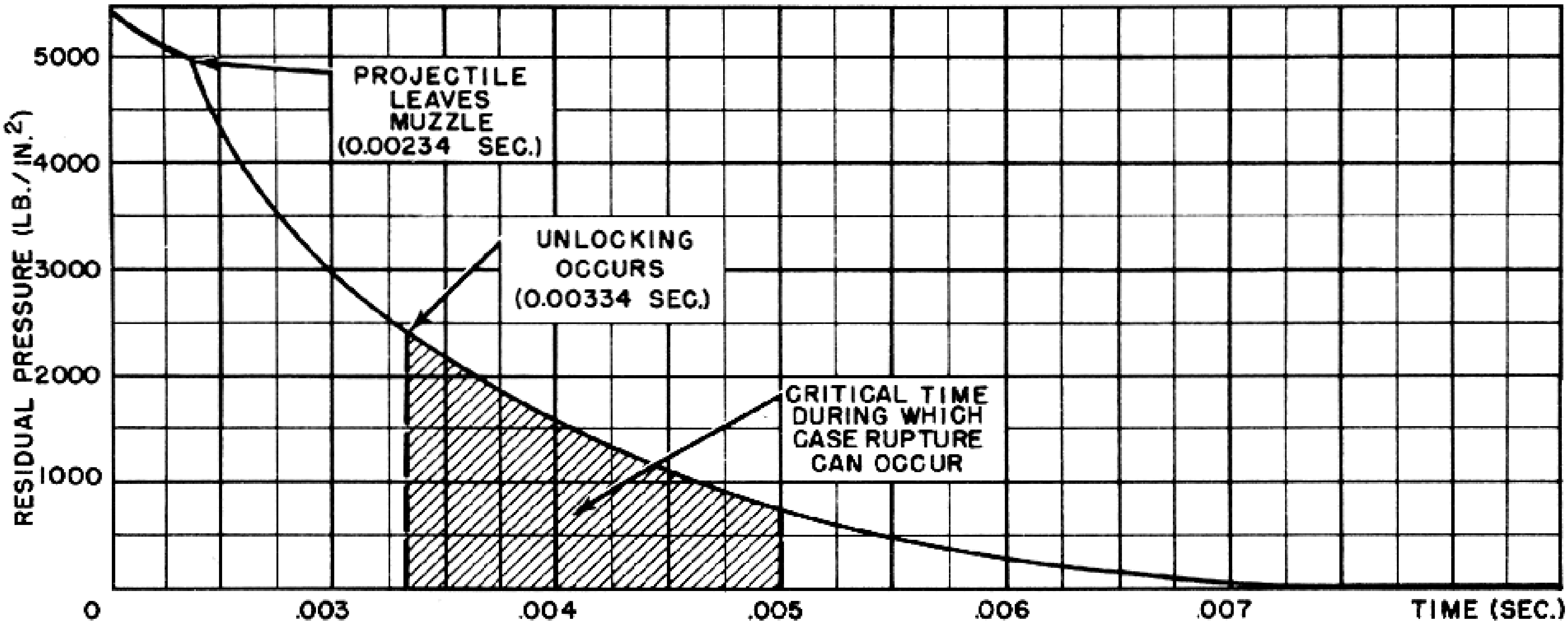

Figure 1–31. Residual Pressure Curve and Critical Period for Case Rupture (20 mm Gun of Example).

quarter inch during the time for which the residual pressure is high enough to cause rupture of the case near its base. Since a one-quarter inch movement is permissible and the time during which this movement can occur is about 0.00166 second, the allowable average bolt velocity during this interval is equal to

$$\frac{0.250}{12\times.00166}=12.5\left(\frac{\text{ft.}}{\text{sec.}}\right)$$

As shown in fig. 1–31, the residual pressure continues to act for some time after 0.00500 second and therefore the final velocity reached by the bolt can be considera ly higher than the 12.5 (ft./sec.) average value allowable for the first 0.00166 second after the bolt is unlocked. The foregoing considerations show that the use of delayed blowback permits the attainment of relatively high bolt velocities with conventional ammunition so that it is not necessary to use the special ammunition described for advanced primer ignition.

When delayed blowback is used, only a very small portion of the total impulse of the propellant explosion is available for operating the gun mechanism. The relative magnitude of the available portion of the total impulse can be visualized by examining fig. 1–32, which shows the variation of the chamber pressure with time. Assuming that the bolt is unlocked 0.001 second after the projectile leaves the muzzle, the shaded area in this figure (when multiplied by the bore cross-section area) would represent the impulse which produces the relative velocity between the bolt and the barrel. The unshaded area under the curve (also multiplied by the bore cross-section area) would represent the impulse applied to the barrel and bolt while these parts are locked together.

The points made in the preceding paragraph indicate that the bolt must be relatively light in order for the small available impulse to produce a high bolt velocity and sufficient bolt energy. Also, since such a great impulse is applied before the barrel and bolt are unlocked, some means must be provided to account for the recoil reactions which occur before unlocking. Of course, in a delayed blowback gun employing recoil unlocking, the impulse before unlocking is utilized to produce the recoil motion of the barrel and bolt. In guns employing gas unlocking, primer actuation, booster actuation, or some other form of unlocking, it is usually also necessary to mount the barrel so that it can recoil to the rear and thus provide a means for controlling the magnitude of the trunnion reaction.

It should be pointed out here that the barrel and bolt, while locked together, can acquire a considerable recoil velocity with respect to the breech casing of the gun. After unlocking occurs, the blowback action drives the bolt to the rear and imparts an additional velocity to the bolt. Therefore, the actual velocity of the bolt measured with respect to the breech casing is the sum of the velocity of the barrel at the instant of unlocking and the velocity imparted by blowback. For this reason the bolt

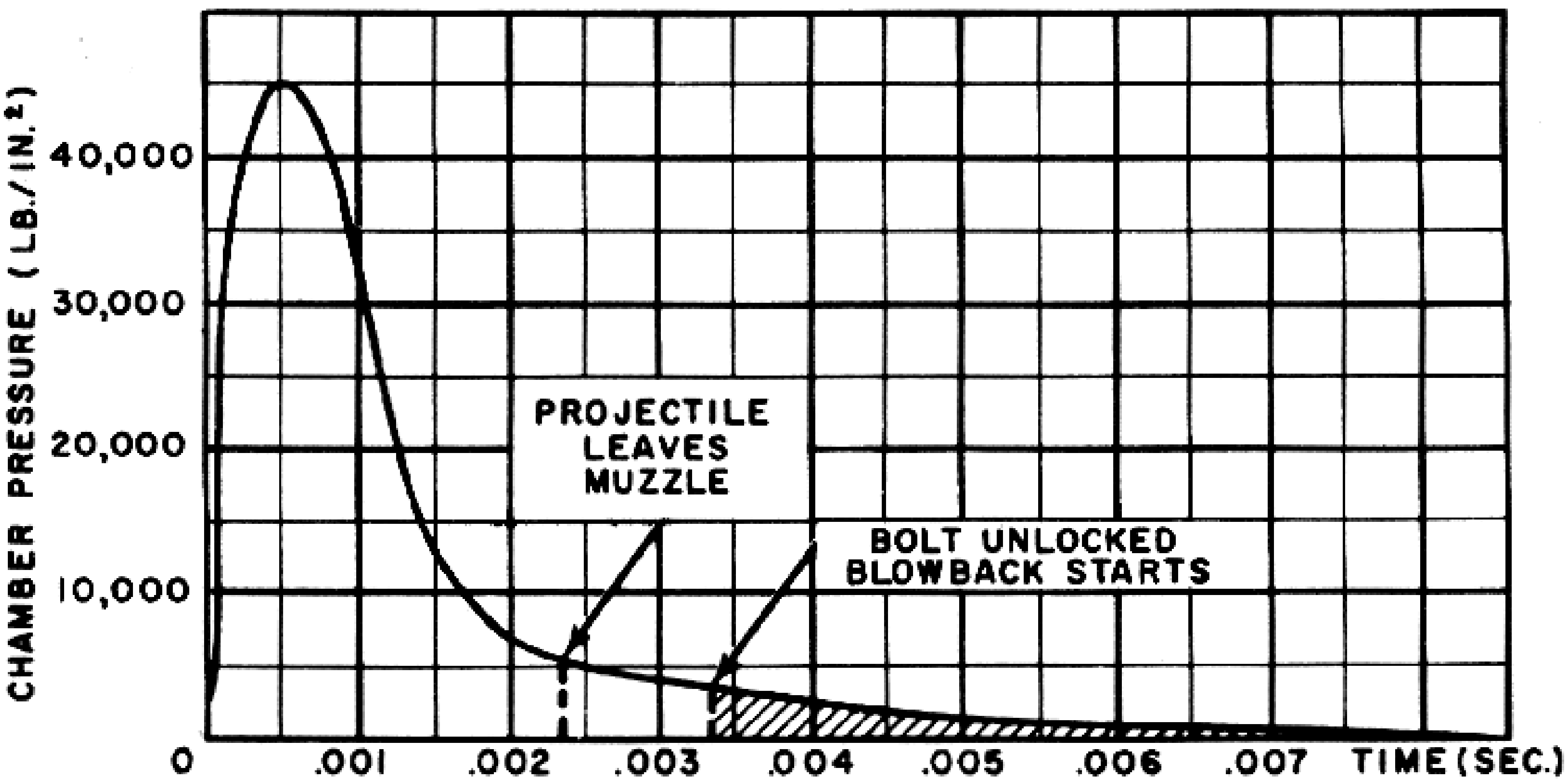

Figure 1–32. Variation of Chamber Pressure With Time Showing Proportion Available for Blowback (Breech Unlocked 0.001 Second After Projectile Leaves Muzzle).

velocities obtained with delayed blowback are fairly great and accordingly guns employing this principle are capable of relatively high rates of fire.

Mathematical Analysis of Delayed Blowback

The following mathematical analysis of delayed blowback is based on the same general principles used for the analysis of plain blowback except that the problem must be considered in two stages. These stages cover the conditions which exist before unlocking and the conditions which exist during and after blowback occurs. In this analysis it will be assumed that the same ballistic data used for plain blowback are available. (See figs. 1–9, 1–10, and 1–11.) Since many of the methods and formulas employed in this analysis are the same as or very similar to those used for plain blowback, the derivations of the formulas and the explanations of the procedures will not be repeated here. However, as they arise, any new concepts or new formulas will be explained.

In order to perform an analysis of delayed blowback, it is necessary to assume certain definite characteristics of the gun to be used as an example. First, it will be assumed that recoil unlocking will be employed. Since both the barrel and bolt move in recoil before unlocking, the weight of these parts must be known in order that their motion characteristics may be determined. In an actual design problem, it would first be necessary to design the barrel and plan the mechanism sufficiently at least to permit making a preliminary estimate of the weight of the recoiling parts. For purposes of the present analysis it will be assumed that the barrel and its related parts weigh 40 pounds and the effective weight of the bolt will be taken as 10 pounds, giving a total weight of 50 pounds for the recoiling parts. It will also be assumed that unlocking occurs 0.001 second after the projectile leaves the muzzle of the gun. After the analysis is completed in an actual problem, it may be desirable to modify the assumed values to adjust the performance of the gun. However, the same method of analysis will apply and the assumed values will serve here to illustrate the method.

1. *Conditions of free recoil before unlocking*

Before unlocking occurs, the combined mass of the barrel and bolt moves in recoil. For the condition of free recoil the momentum relation for the time before the projectile leaves the muzzle is the same as expressed by equation 1–1:

$$M_r v_{r_f} = \left(M_p + \frac{M_c}{2}\right) v_p$$

Solving for v_{r_f}:

$$v_{r_f} = \frac{.29 + \frac{.070}{2}}{50} \, vp = .00650 \, v_p$$

Using the projectile velocities shown in fig. 1–10, this relation can be used to plot the curve of free

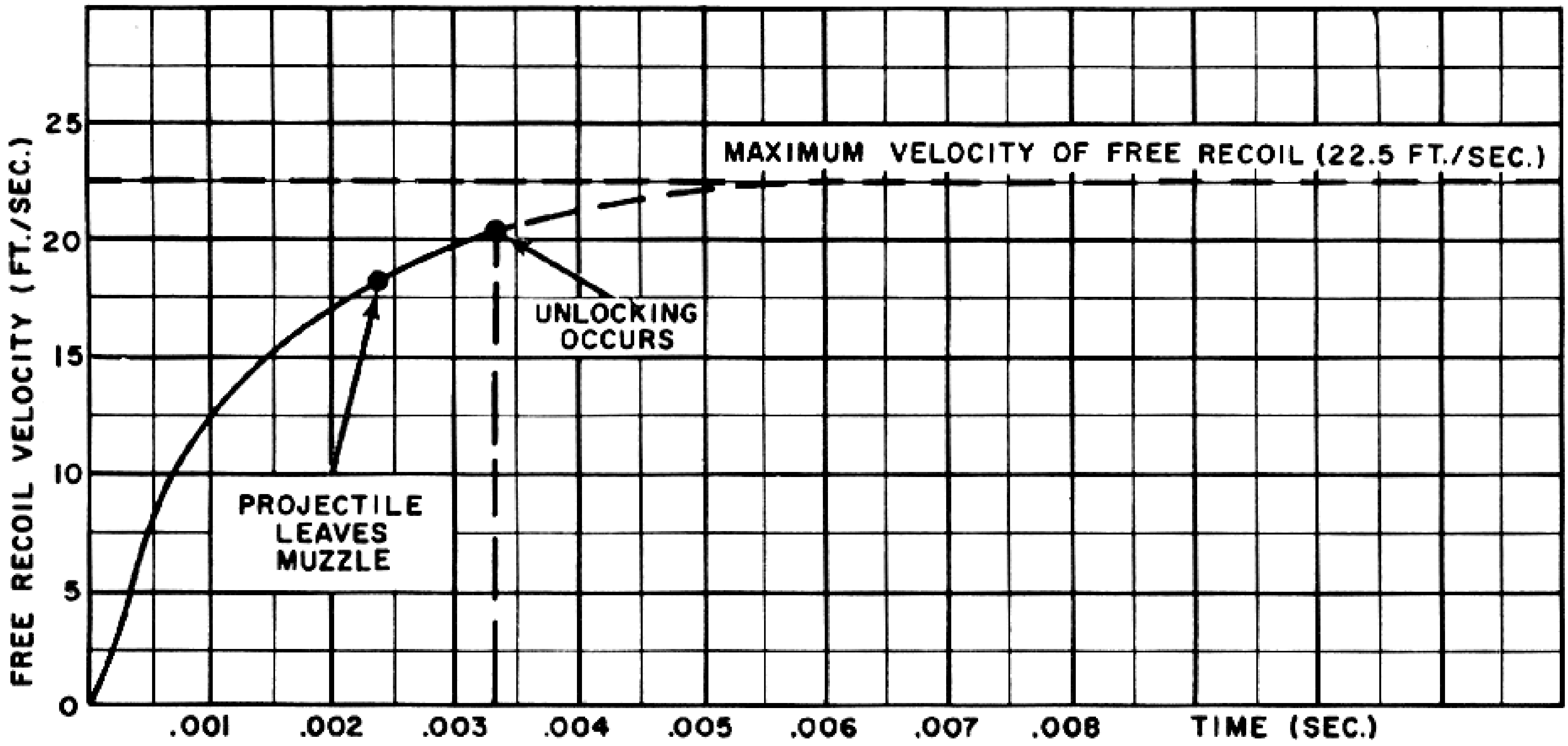

Figure 1–33. Free Recoil Velocity Before Unlocking.

recoil velocity versus time for the period before the projectile leaves the muzzle. The curve so obtained is shown in fig. 1–33 as the portion between t=0 and t=0.00234 second. In order to plot the remainder of the curve, it is necessary to determine the maximum velocity of free recoil and extrapolate the curve by the methods previously described. Actually the extrapolated curve will apply only until unlocking occurs, 0.001 second after the projectile leaves the muzzle. The dotted portion of the curve in fig. 1–33 after t=0.00334 second is used only for purposes of extrapolation and does not relate to the conditions of recoil.

2. *Effect of springs before unlocking*

Immediately after unlocking, the rearward motion of the barrel is stopped by a buffer and the bolt is blown back by the residual pressure. Since the barrel is stopped by the buffer, the only real functions of the barrel spring are to assist the barrel to return to battery and to hold the barrel firmly in the battery position. Therefore the value of the force exerted by the barrel spring is not critical and the characteristics of the spring may be selected arbitrarily. To return the barrel quickly to battery, a fairly strong spring is desirable. As will appear, such a spring will not have any great effect on the recoil motion while the powder gas pressures are acting and therefore, the resistance of the spring can be made quite high. On this basis, the initial compression of the spring will be selected as 400 pounds and the spring constant as 400 pounds per inch.

Since the bolt is light (10 pounds) and receives a relatively low impulse from blowback, the driving spring for the bolt will necessarily be relatively light in order to permit the bolt to open the 10 inches assumed necessary for feeding a 20-mm round. The actual characteristics of the bolt spring can not be determined at this time but it can be safely assumed that the bolt spring will have an initial compression of approximately 120 pounds and a spring constant of about 20 pounds per inch.

3. *Theoretical time-travel and time-velocity curves before unlocking*

The theoretical time-travel and time-velocity curves for the time before unlocking are developed according to the same general principles used for plain blowback. Fig. 1–34 shows the curves obtained for the gun of the example for the period of time from t=0 to t=0.00334 second. These curves were derived by the step-by-step system described under plain blowback and the steps referred to in the figure are those in the procedure described for plain blowback. In drawing these curves, the combined resistances of the barrel and bolt springs were taken into account. In this case, the total

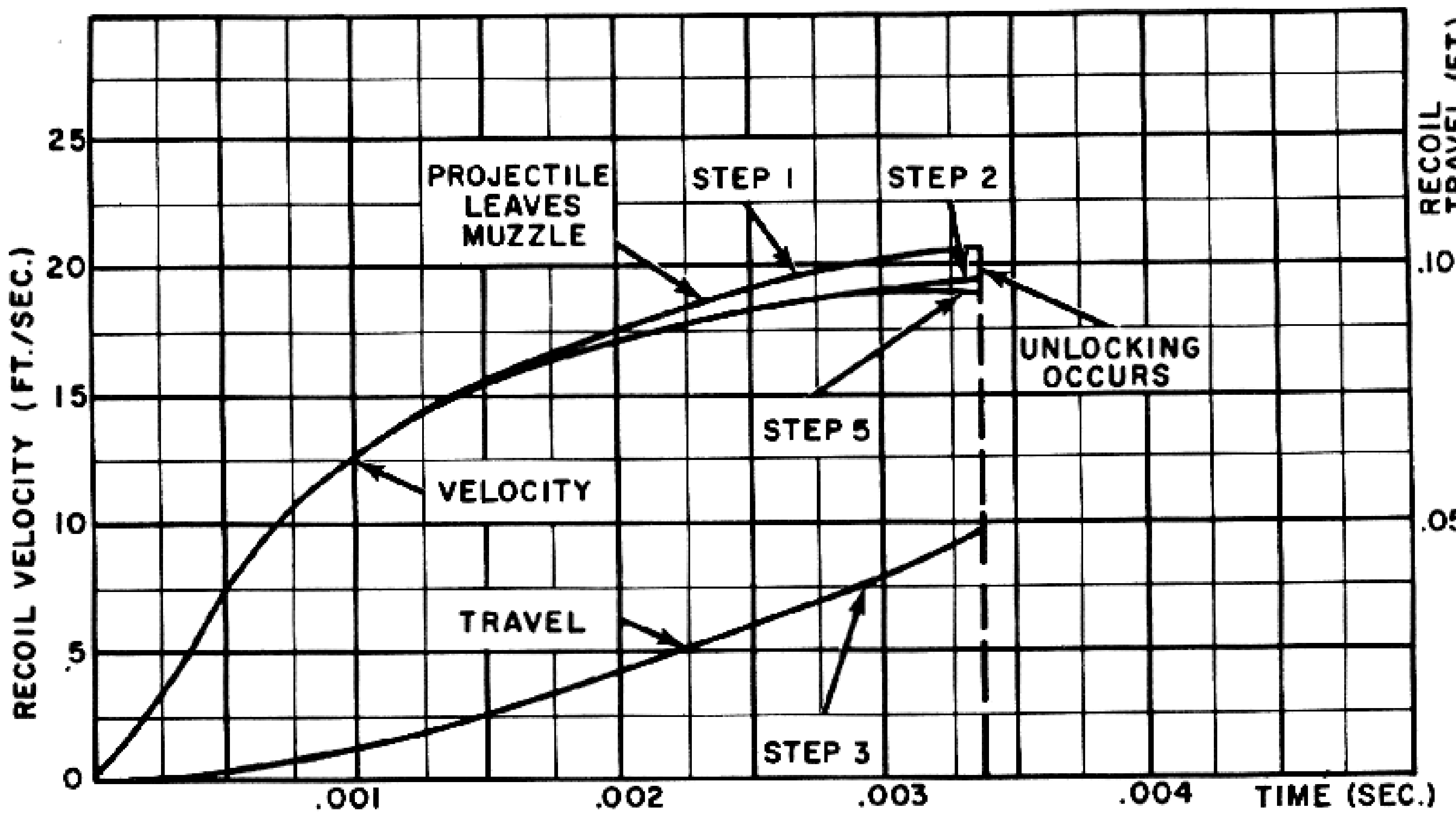

Figure 1–34. Time-Travel and Time-Velocity Curves Before Unlocking.

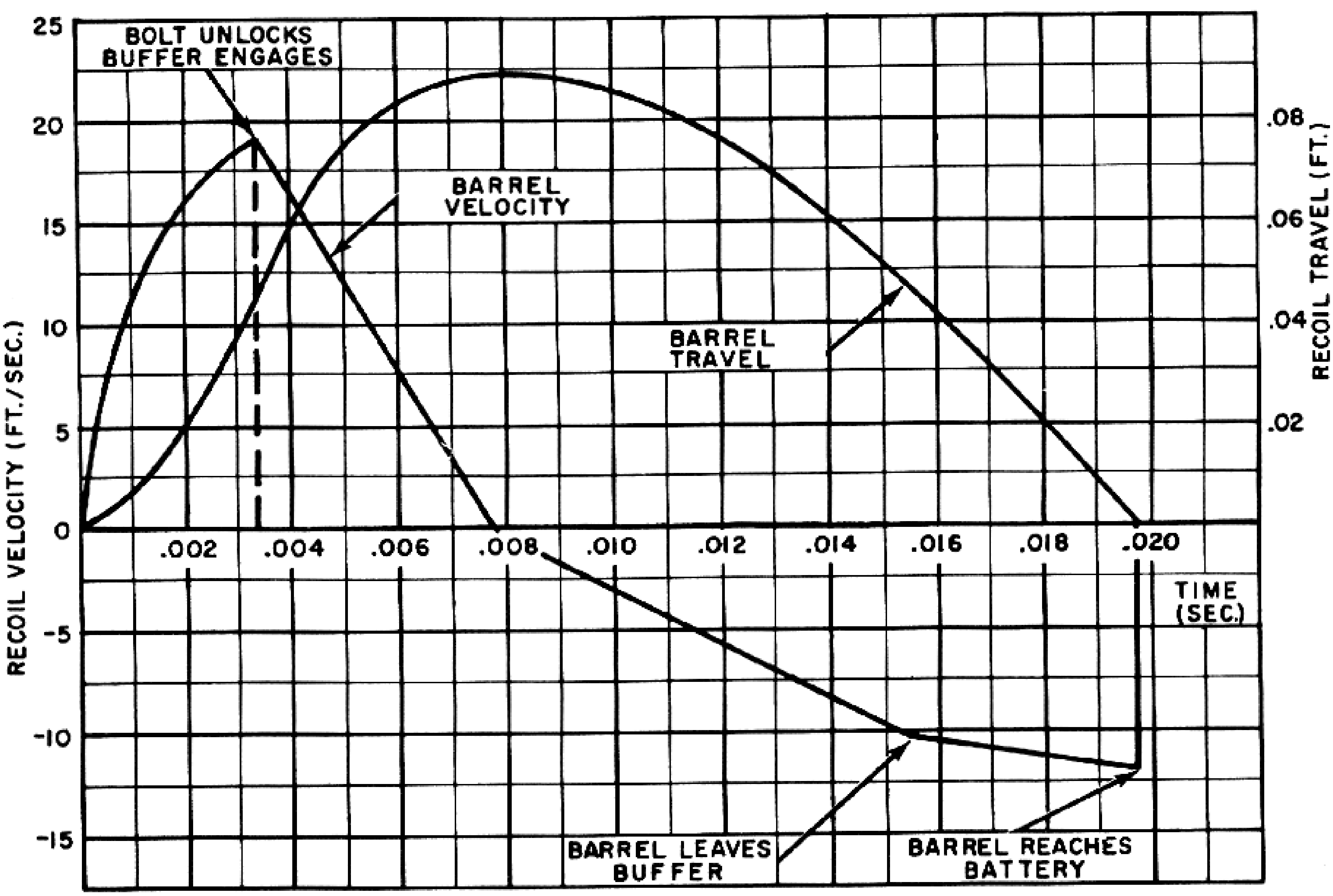

Figure 1–35. Time-Travel and Time-Velocity Curves for Barrel.

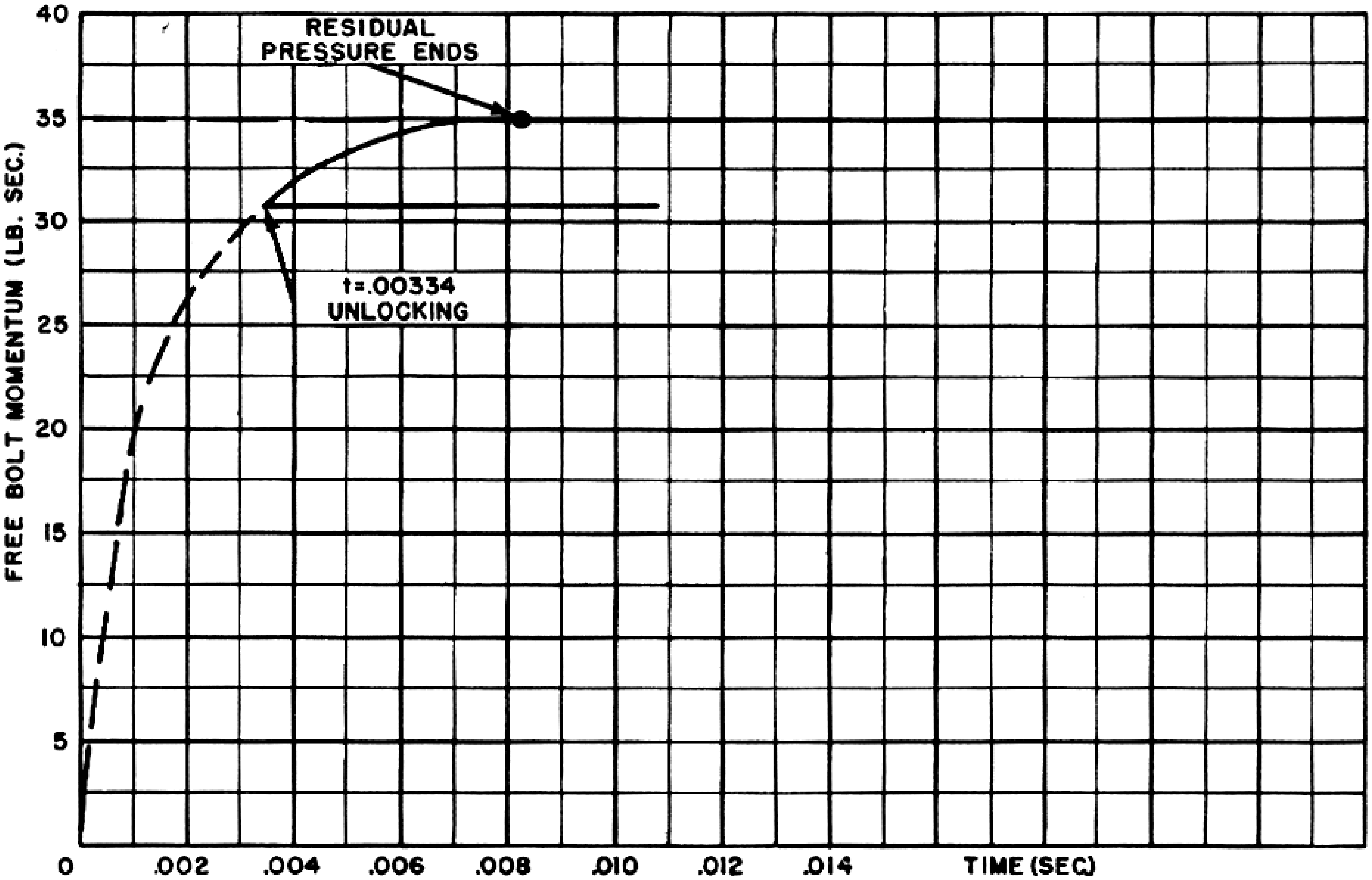

Figure 1–36. Free Bolt Momentum Imparted After Unlocking.

velocity loss resulting from the effect of the combined initial compression of the barrel and bolt springs for the first 0.00334 second is equal to 1.118 feet per second, computed as follows:

$$V=\frac{F_0 t}{M_r}=\frac{520\times.00334\times32.2}{50}=1.118\left(\frac{\text{ft.}}{\text{sec.}}\right)$$

The loss due to the combined spring constant K, as determined by the method of step 4 is only about 0.26 foot per second. This loss is so slight that it is not necessary to continue the process of successive approximation any further than step 5. Examination of the curves of fig. 1–34 reveals that the total recoil movement before unlocking is 0.0470 foot (0.565 inch) and the recoil velocity at the instant of unlocking is 19.2 feet per second.

4. *Barrel motion after unlocking*

Immediately after unlocking, the barrel strikes the buffer and its rearward motion is halted. Since the barrel weighs 40 pounds and is moving at a velocity of 19.2 feet per second, its kinetic energy is equal to

$$E_r=\frac{1}{2}MV^2=\frac{1}{2}\frac{40}{32.2}(19.2)^2=229\text{ (ft. lb.)}$$

In order to bring the barrel to a stop, this kinetic energy must be absorbed by a buffer. If it is assumed that the motion of the barrel is stopped within one-half inch after engaging the buffer, the average force exerted on the buffer must be:

$$229\times\frac{12}{.50}=5500\text{ (lb.)}$$

This serves to indicate that the barrel buffer must be constructed very ruggedly. Buffers for applications of this sort are usually constructed intentionally so that there will be a considerable energy loss during the buffing action. This is done in order to damp out undesired motion of the barrel. In a well-designed buffer, the energy loss can be as high as 70 percent; that is, the kinetic energy of the barrel after its motion is reversed will be only 30 per cent of the energy it contained upon first striking the buffer.

The motion of the barrel during the time of action of the buffer will depend largely on the particular characteristics of the buffer used. It should be noted that while the buffer is acting, the effect of the barrel spring is so small by comparison that

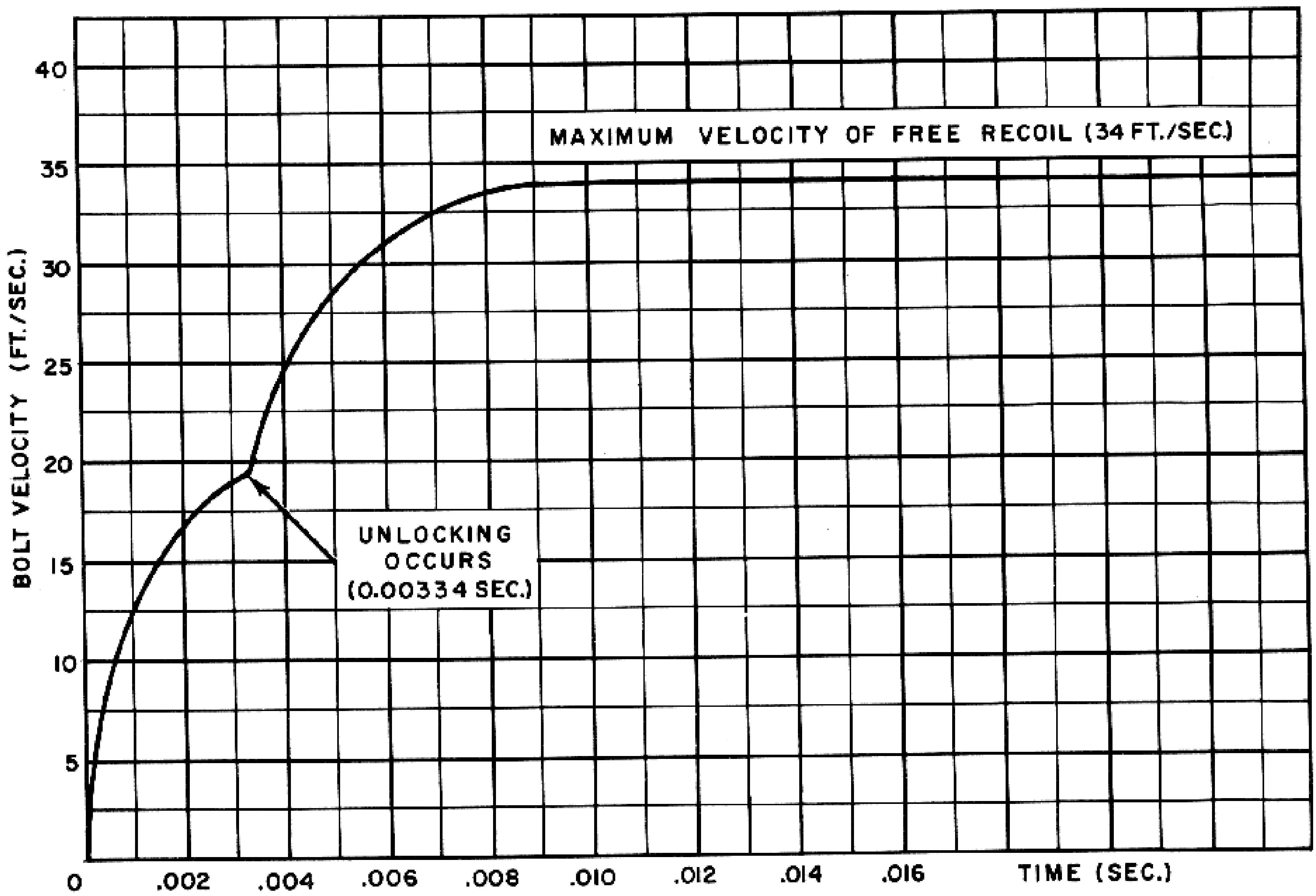

Figure 1–37. Free Bolt Velocity Curve for First 0.010 Second.

it is negligible. For purposes of illustrations, it will be assumed here that the resistance offered by the buffer to compression is constant at 5500 pounds for the full compression of one-half inch and it will also be assumed that the expansion force of the buffer is 30 per cent of this value, or 1,800 pounds. On this basis and using equation 15, the barrel motion is as shown in fig. 1–35. The velocity loss due to the buffer is given as:

$$V=\frac{Ft}{M}=\frac{5500\times 32.2}{40}\,t=4420\,t$$

In this expression t is measured from the time the buffer engages. The forward velocity imparted to the barrel by the buffer is given as:

$$V=\frac{Ft}{M}=\frac{1650\times 32.2}{40}\,t=1330\,t$$

where t is measured from the time the forward motion of the barrel starts. This relation holds until the barrel has moved forward one-half inch. Since the barrel is subjected to a uniform acceleration during this interval, the time required for the one-half inch movement can be determined by solving for t in the expression

$$\frac{.5}{12}=\frac{1}{2}\,1330\,t^2$$

$$t=.00792\ \text{(sec.)}$$

After the barrel leaves the buffer it is further accelerated forward by the barrel spring. The movement remaining to the battery position is 0.0470 foot (fig. 1–34) and it may be assumed with little error that the average force exerted by the barrel spring over this distance will be the initial compression (400 pounds) plus approximately one-half the force resulting from the spring constant for the 0.0470-foot deflection

$$\left(\frac{226}{2}=113\ \text{pounds}\right)$$

The gain in velocity due to this force will be:

$$V=\frac{Ft}{M}=\frac{513\times 32.2}{42}\,t=393\,t$$

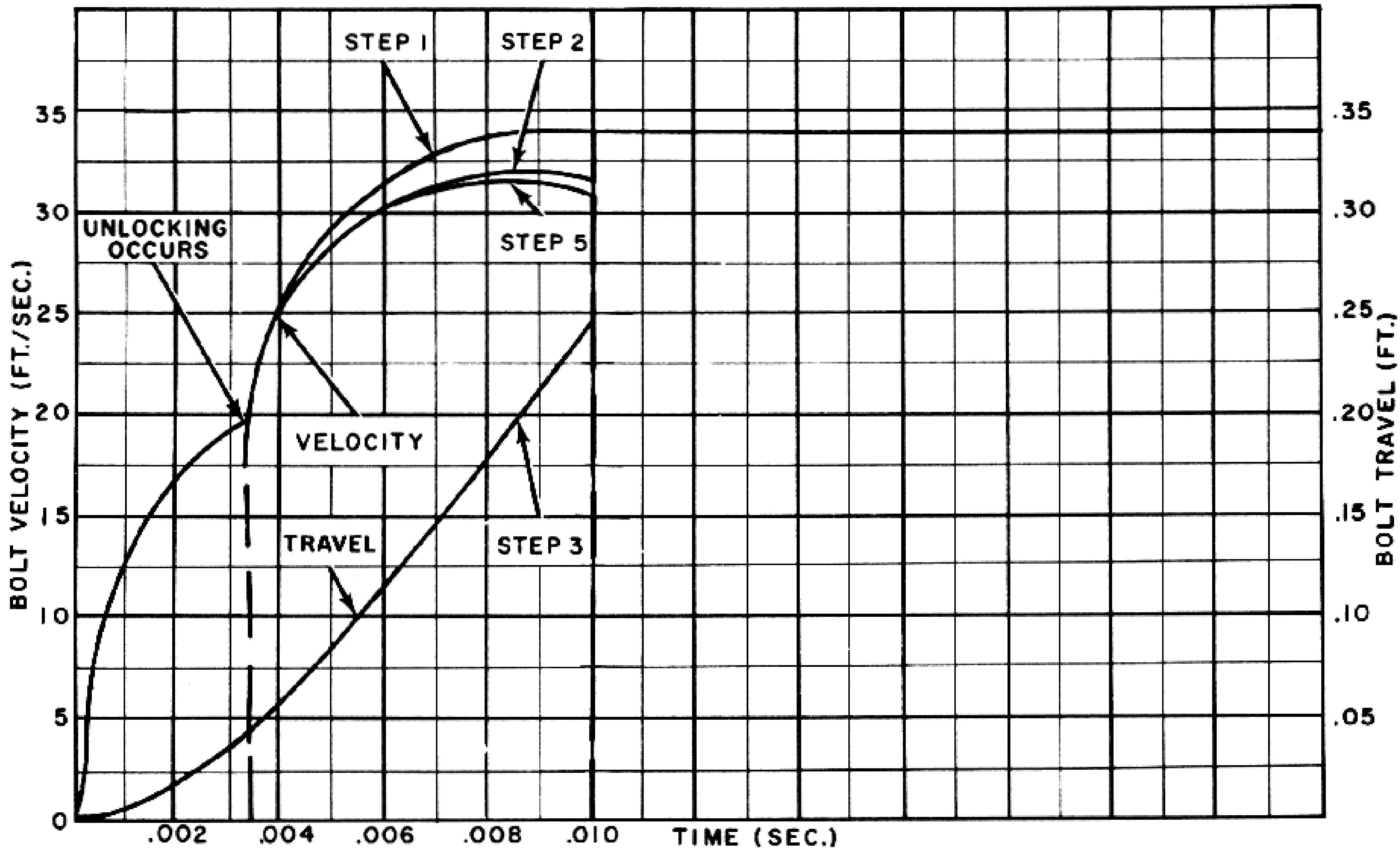

Figure 1–38. Time-Travel and Time-Velocity Curves for Bolt for First 0.010 Second.

Since the velocity of the barrel upon leaving the buffer was equal to 10.52 feet per second, the velocity for the last 0.0470 foot of this return to battery is given by the expression:

$$v = 10.52 + 393\ t$$

The time required to move this distance can be determined by solving the t in the following equation:

$$.0470 = \left[10.52 + \frac{393\ t}{2}\right] t$$

$$t = .00490 \text{ sec.}$$

The curves resulting from the above analysis are shown in fig. 1–35. As shown in the figure, the barrel reaches the battery position with a velocity of 12.0 feet per second at 0.0198 second after the ignition of the propellant. The barrel is brought to rest by a buffer and remains in this position until the bolt returns and a new cycle is started.

5. *Bolt motion after unlocking*

At the instant of unlocking, the barrel and bolt are both moving at the same recoil velocity. After unlocking, the bolt retains this velocity and acquires additional velocity from blowback. The methods used for analyzing the bolt movement after unlocking are generally the same as those used for plain blowback and employ the momentum relation expressed by the curve shown in fig. 1–13. In this case, the applicable portion of the curve is the part after 0.00334 second, at which time unlocking occurs. This portion of the curve is reproduced in fig. 1–36. The values of bolt momentum read above the horizontal line which crosses the curve at 0.00334 second represent the after unlocking. Dividing these values by the mass of the 10-pound bolt for the gun of the example gives the additional velocity imparted by blowback. Fig. 1–37 shows the complete curve of velocity for the bolt. (Up to 0.00334 second, the curve shows the retarded velocity curve from fig. 1–34 as obtained for both the barrel and bolt. After 0.00334 second, the curve shows the additional free velocity imparted by blowback.) The theoretical curves of bolt travel and bolt velocity versus time are then obtained by the same methods used for plain blowback.

Before the time-travel and time-velocity curves can be drawn, it is necessary to determine the char-

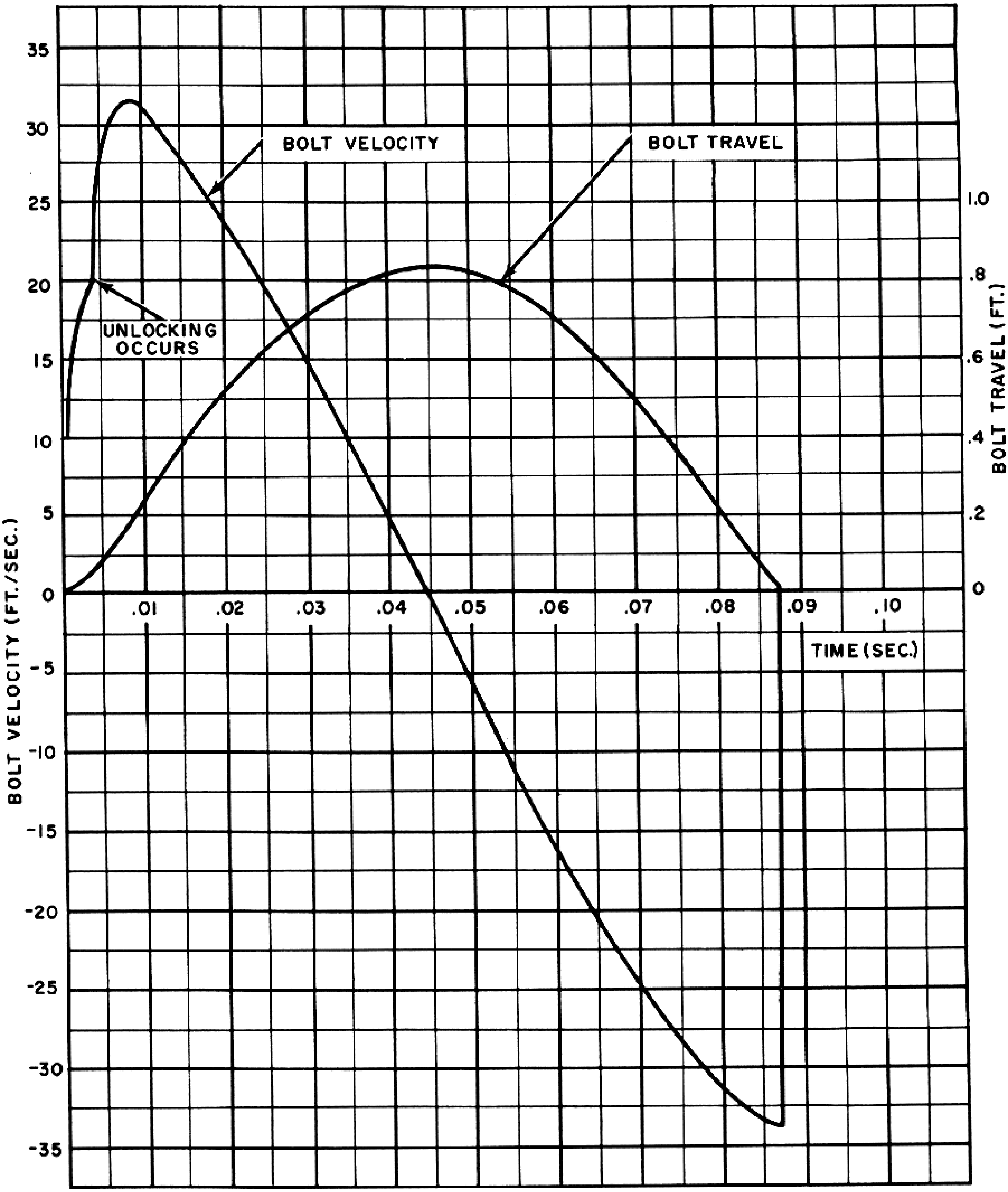

Figure 1–39. Time-Travel and Time-Velocity Curves for Bolt (Complete Cycle).

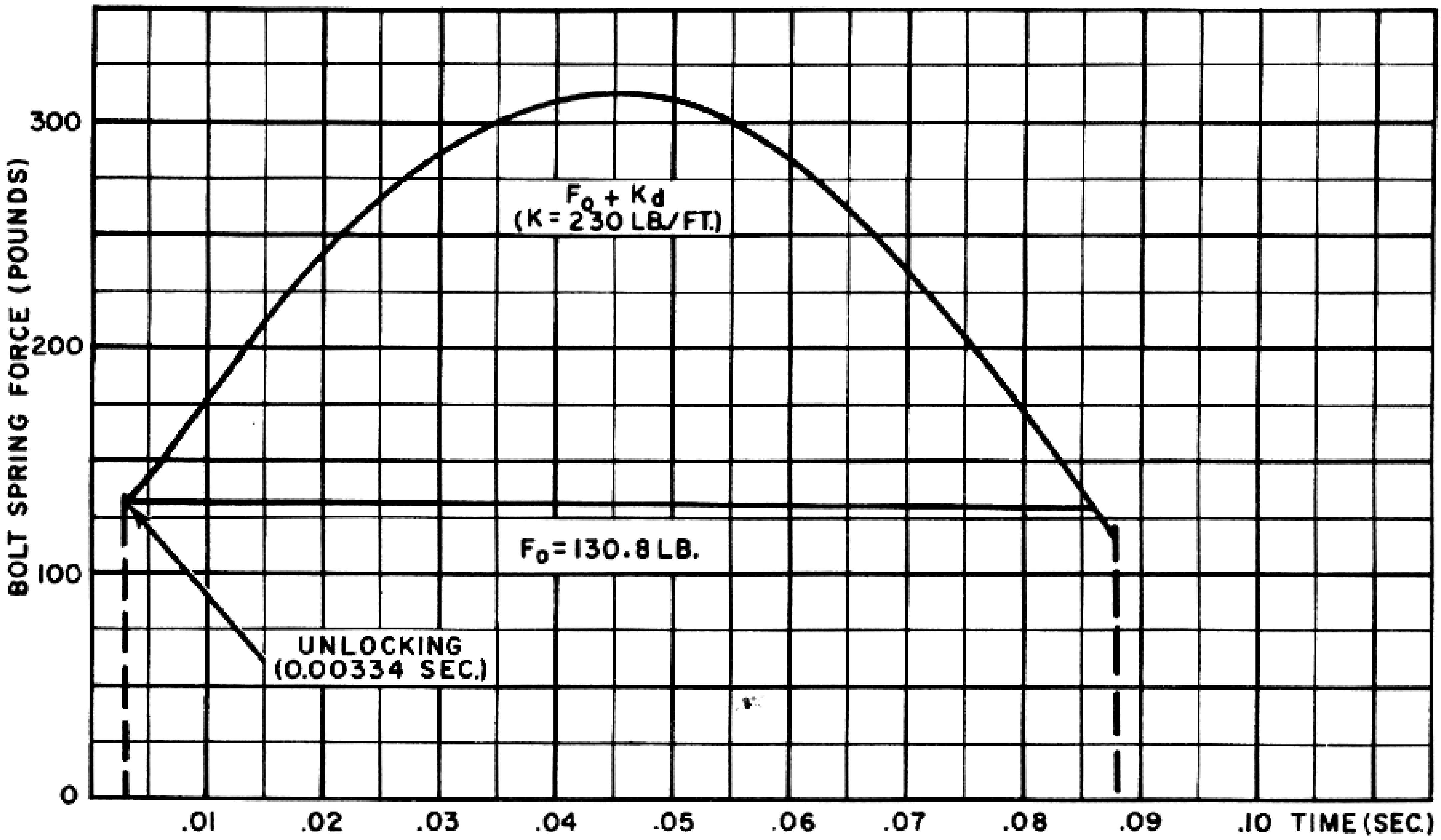

Figure 1–40. Variation of Spring Force With Time (Bolt Spring Only After Unlocking).

acteristics of the bolt driving spring so that the bolt will open the required distance of 10 inches to permit feeding. Fig. 1–37 shows that the maximum free recoil velocity of the bolt is 34 feet per second. Since this velocity is imparted within 0.010 second, it may be assumed that the initial bolt energy is imparted instantaneously. The value of this energy is given by equation 1–6:

$$E_r = \frac{1}{2} M_r V_{r_t}^2 = \frac{W_r V_{r_t}^2}{2g} \text{ (ft. lb.)}$$

Evaluating this expression for the conditions of the example gives:

$$E_r = \frac{10 \times 34^2}{2 \times 32.2} = 180 \text{ (ft. lb.)}$$

Since the bolt driving spring must absorb this amount of energy over a distance of 10 inches (0.833 feet), the average force exerted by the spring must be:

$$F_{av} = \frac{180}{.833} = 216 \text{ lb.}$$

In designing the spring so that it will produce this average force, the same factors described in the analysis of plain blowback should be considered. However, an arbitrary choice of spring characteristics will suffice for present purposes. If the initial compression is taken as 120 pounds, a maximum force of 312 pounds will produce the required average force of 216 pounds. Since the difference between the maximum force and initial compression is 192 pounds and the recoil distance is 10 inches, the spring constant will be 19.2 pounds per inch or 230 pounds per foot. Realizing that this choice is arbitrary, it will be assumed here that the selected values of $F_o = 120$ pounds and $K = 230$ pounds per foot will result in a satisfactory spring.

Having the characteristics of the bolt driving spring and the free recoil velocity curve of fig. 1–37, the time-travel and time-velocity curves for the bolt can be constructed using the same general approach used for plain blowback. At the instant unlocking occurs, the bolt driving spring has been compressed 0.0470 foot (fig. 1–34). This means that for considering the period of blowback, the initial compression of 120 pounds must be increased by the effect of the spring constant for this deflection. That is:

$$F_o = 120 + .047 \times 230 = 130.8 \text{ (pounds)}$$

Fig. 1–38 shows the time-travel and time-velocity curves obtained for the bolt of the gun used as ex-

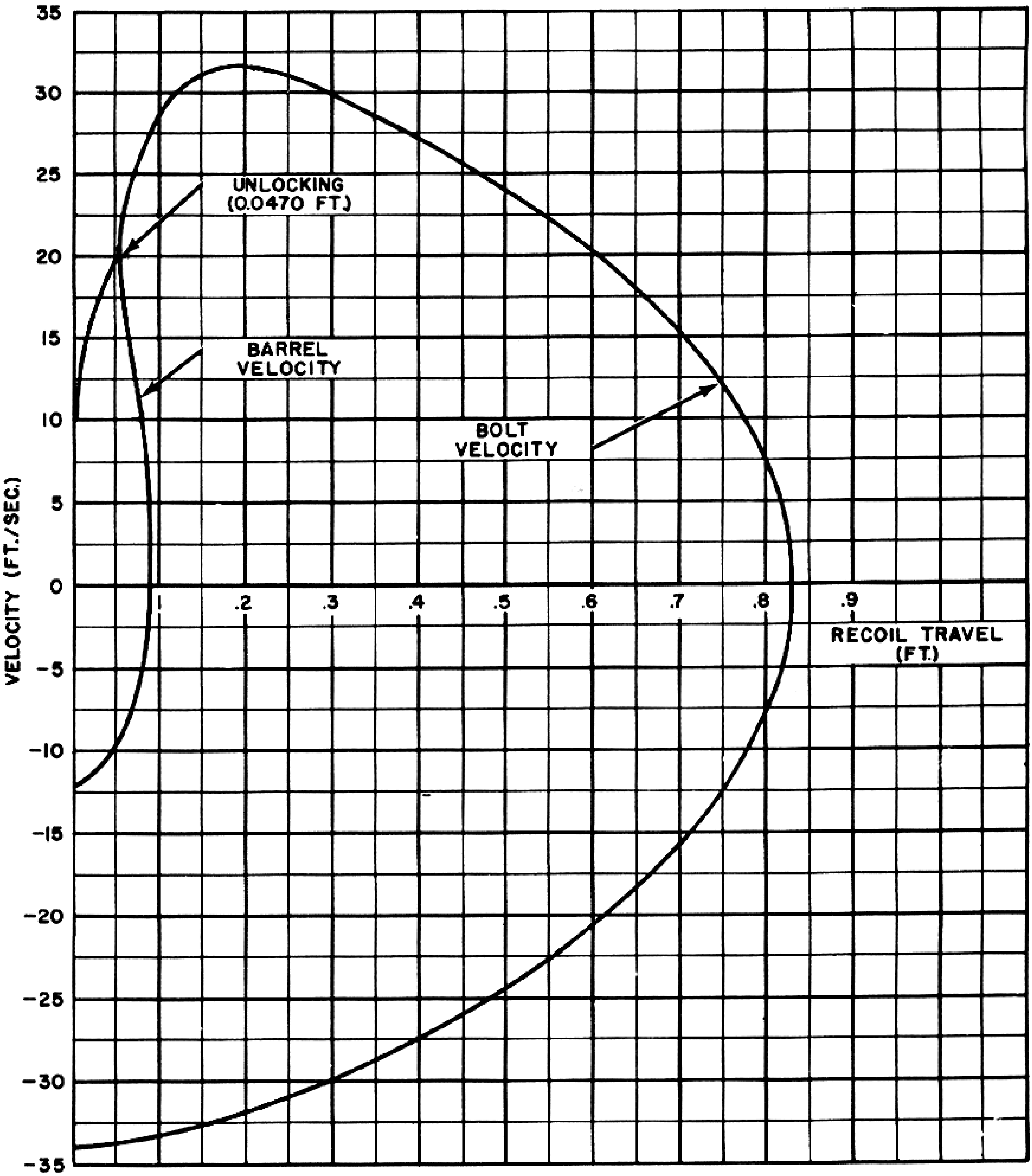

Figure 1–41. Velocity-Displacement Graph (Barrel and Bolt).

ample for the period from t=0 to t=0.010 second. These curves, for the time after t=0.00334 second were obtained by the step-by-step system described under plain blowback and the steps referred to in the figure are those in the procedure described for plain blowback. The velocity loss resulting from the initial compression of the bolt driving spring for the time interval between t=0.00334 and t=0.010 second is equal to 2.81 feet per second, computed as follows:

$$V=\frac{F_o t}{M_1}=\frac{130.8\times.00666\times32.2}{10}=2.81\left(\frac{\text{ft.}}{\text{sec.}}\right)$$

The loss due to the spring constant K, as determined by the method of step 4 is only about 0.697 foot per second. This loss is so slight that it is not necessary to continue the process of successive approximation any further than step 5.

The remainder of the bolt displacement curve can be determined analytically by using equation 1–10, modified as necessary to account for the displacement d′ during the first 0.010 second. The changed values to be used in equation 1–10 are the following:

$$F_o'=F_o+Kd'=120+230\times.245=176.3$$

$$D'=D-d'=D-.245$$

$$t'=t-.010$$

Making the required substitutions as explained for plain blowback gives the final form of the equation to be used after the first 0.010 second as:

$$d=1.353\sin[27.2t+331]-.521$$

This equation is used to complete the bolt displacement curve and gives the result shown in fig. 1–39. The ordinates of the displacement curve are then multiplied by K and increased by F_o to obtain a curve showing the variation of spring force with time (fig. 1–40). (Note that the initial compression used is 130.8 pounds which takes into account the compression resulting from the recoil movement before unlocking.) Integrating under this curve and dividing the results by M_r in accordance with equation 1–15 will give a graph of the velocity loss due to the spring force. (All computations start at the time of unlocking, 0.00334 second.) Subtracting this curve from the free bolt velocity curve of fig. 1–37 will give the complete graph for the retarded bolt velocity, which is also shown in fig. 1–39. Fig. 1–41 shows the velocity versus displacement curves for the gun of the example as derived from the curves of figs. 1–35 and 1–39.

From fig. 1–39, the time for the complete cycle is given as 0.0875 second. This gives the rate of fire for the gun of the example as:

$$N=\frac{60}{.0875}=686 \text{ (rounds per minute)}$$

RETARDED BLOWBACK SYSTEM

One of the principal disadvantages of the plain blowback system is the excessive bolt weight required to limit the movement of the cartridge case to a safe value during the action of the powder gas pressure. This particular difficulty can be circumvented by employing the "retarded" blowback system—a system in which a special type of retarding mechanism is operated by the movement of the bolt. The mechanism itself is composed of relatively light parts and the inertia forces which result when these parts are set in motion by the bolt are therefore relatively small. However, the mechanism is arranged so that the bolt must act through a tremendous mechanical disadvantage to overcome the inertia forces and is accordingly subjected to a very high resistance to motion. In other words, although the bolt and the associated mechanism may be quite light, the effective resistance to bolt acceleration can be made just as great as that which would be obtained by the use of a very heavy bolt.

The mechanism of a retarded blowback gun is similar to that of a plain blowback gun except for the presence of the retarding mechanism. This mechanism can take many forms but the basic principle underlying all of these forms is that the bolt must overcome the inertia forces in the mechanism by acting through a high mechanical disadvantage. One such mechanism is illustrated schematically in fig. 1–42. This mechanism is essentially a toggle joint and when the bolt is closed, the angle "a" indicated in the figure is nearly 180 degrees. Under these conditions, the linkage acts like a crank mechanism which is slightly off dead center and most of the blowback force acting on the linkage is not effective in opening the bolt but is transmitted directly through the links to the breech

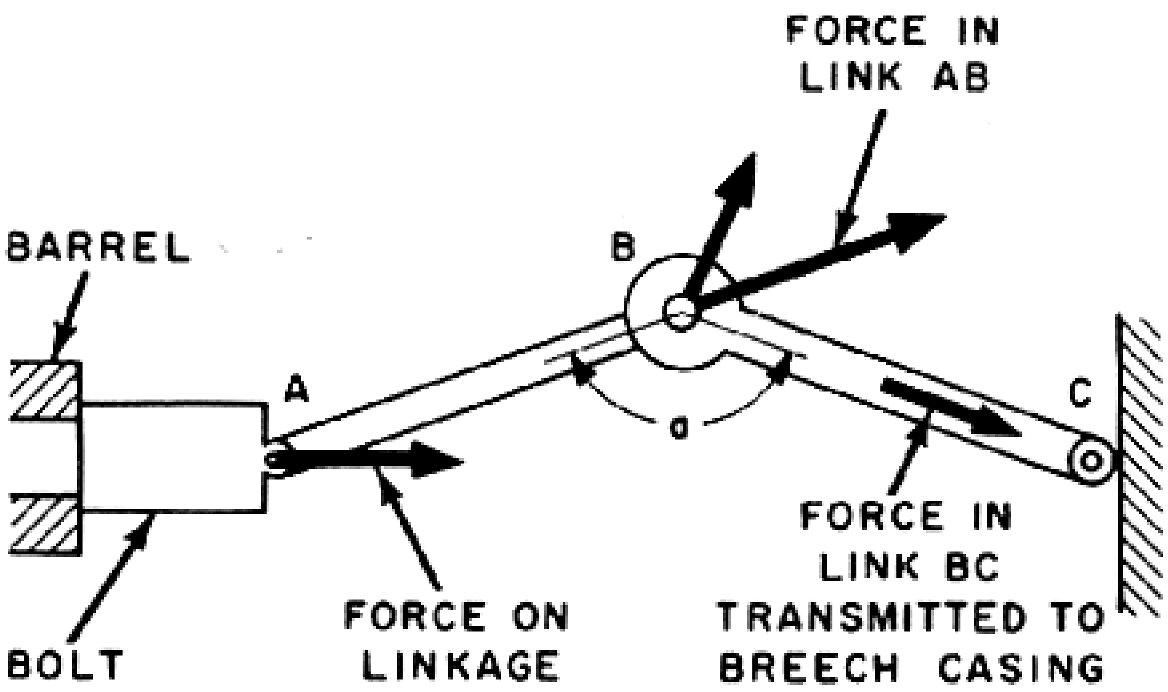

Figure 1–42. Straight Toggle Linkage.

casing. Only a very small part of the blowback force acts on the linkage mass at point B in the direction necessary to overcome its inertial resistance to rotation about point C. The result of this action is that the relatively small inertial resistance of the linkage mass is effectively multiplied so that it produces the same resistance to bolt acceleration as a very heavy mass located at point A. In this mechanism, the retardation offered by the linkage does not remain constant. As the bolt opens and angle "a" decreases, the bolt acts at a smaller disadvantage and the mass multiplying effect of the linkage decreases. The effect of this change is that the more the bolt opens, the less resistance it encounters.

The toggle linkage described in the preceding paragraph can be arranged in many different ways. For example, fig. 1–43 shows a linkage which operates on the same principle but for some applications may be more economical of space. A mechanism of this type, as used in the Schwarzlose machine gun, is shown in fig. 1–44. In some cases, the links may not pivot on hinge pins as indicated schematically in figs. 1–42 and 1–43 but may have cam-shaped ends which make rolling contact with each other as the links move with respect to each other.

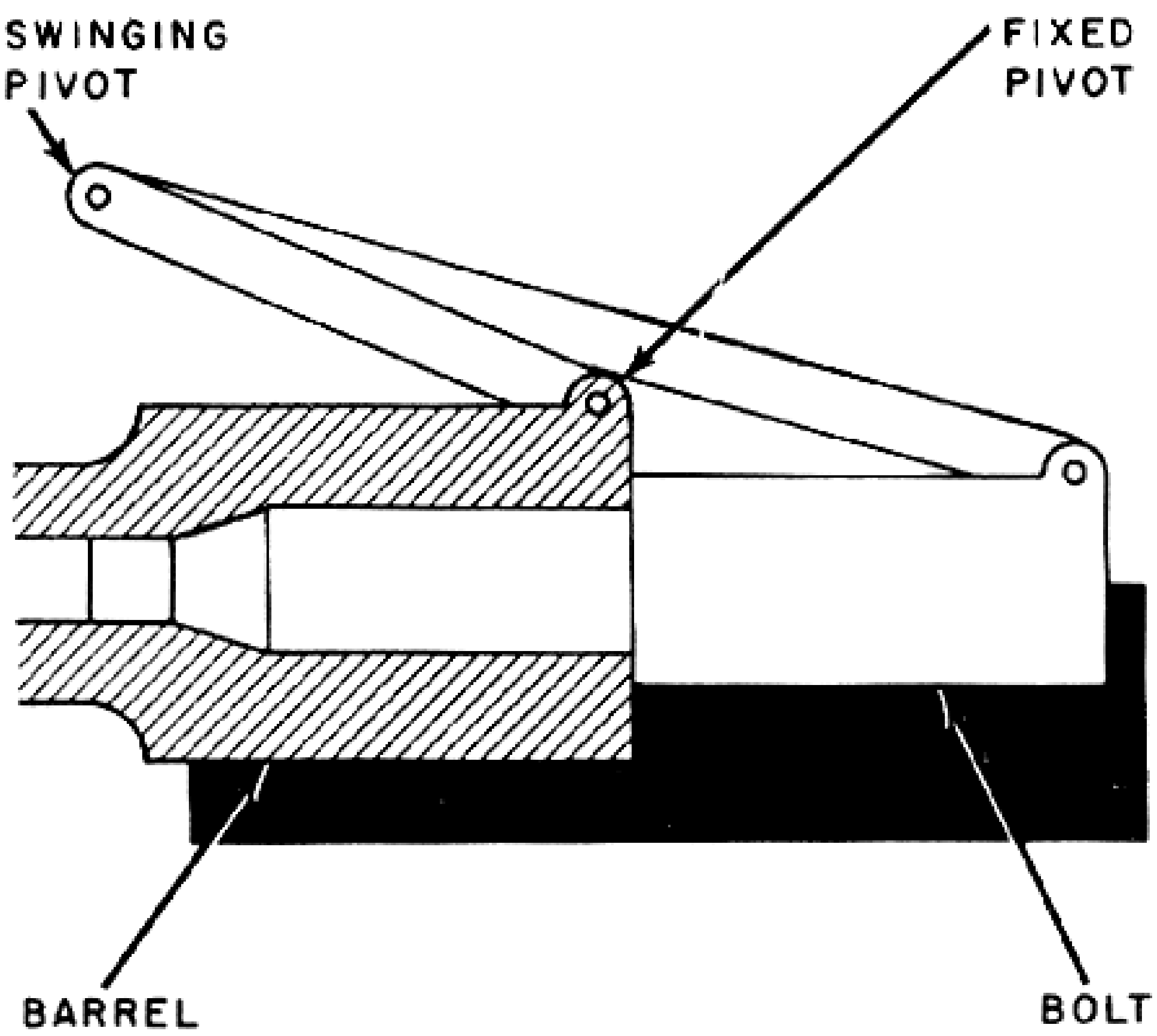

Figure 1–43. Compact Form of Toggle Linkage.

Linkages represent only one of many types of mechanisms that can be used to produce retardation by causing the bolt to operate against a high mechanical disadvantage. A wide variety of inclined surfaces, cams, spirals, wedges, screw threads, and other devices can be employed in such a manner that only a small component of the blowback force is effective in causing sliding or rotating motion of the mechanism. Many such devices are illustrated in part XI of this publication and therefore will not be described here.

Cycle of Operation

The cycle of operation for a retarded blowback gun is essentially the same as for a plain blowback gun. When the cartridge is fired, the pressure of the powder gases drives the cartridge case to the rear against the resistance offered by the bolt and the associated retarding device. After the powder gas pressure has fallen to zero (in less than 0.010 second for a typical 20-mm gun), the bolt continues to move to the rear by virtue of the momentum imparted to the recoiling parts by the explosion. During the rearward motion of the bolt, the spent cartridge case is extracted and ejected and the bolt driving spring is compressed. When the driving spring and buffer have absorbed all of the kinetic energy of the recoiling parts, the bolt is pushed forward to pick up a fresh cartridge from the feed mechanism and load this cartridge into the chamber. After the cartridge is fully chambered, it is fired and a new cycle begins.

Analysis of Retarded Blowback

From the standpoint of performance with high-powered ammunition, the most significant characteristic of a retarded blowback gun is that the rearward motion of the cartridge case starts immediately after ignition of the propellant charge, which is exactly what happens in a plain blowback gun. Thus, if the retardation is constant so that the effect of the retarding mechanism is exactly the

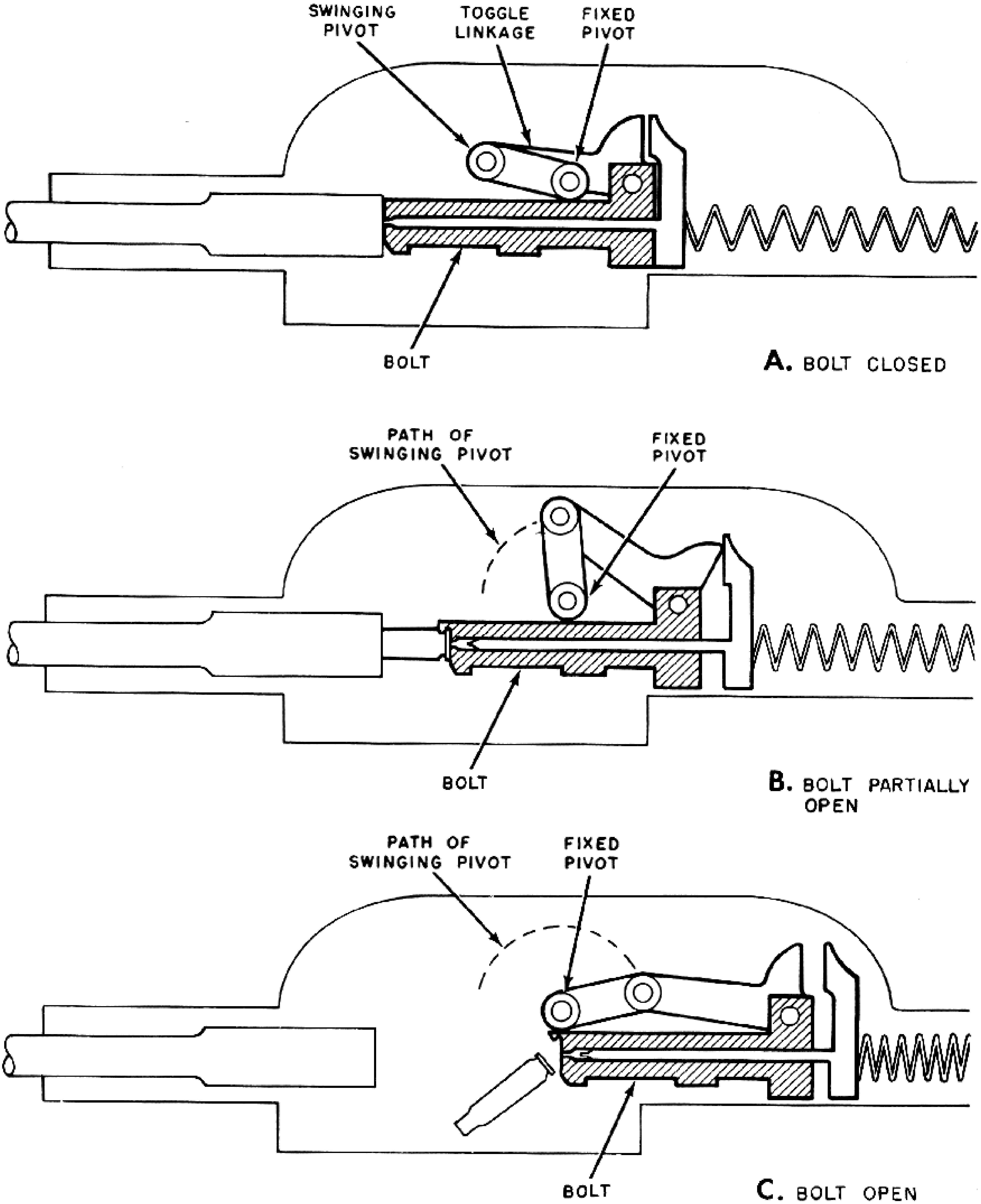

Figure 1–44. Breech Mechanism of Schwarzlose Machine Gun.

same as that of a very heavy bolt, a retarded blowback gun would suffer from all of the disadvantages of a plain blowback gun (except for the disadvantage of excess weight). These disadvantages, which are explained in detail under "Plain blowback system," are principally a very low rate of fire and insufficient bolt energy for operating the gun mechanism. Therefore, it appears that there is little point in using the retarded blowback system merely as a means of saving weight.

The real advantage of using retarded blowback can be obtained only if the retardation characteristics of the mechanism are *not* uniform. The ideal type of retarded blowback mechanism would be one in which a very high resistance to bolt movement is encountered during the period of high chamber pressure which exists until after the projectile has left the muzzle. This high resistance would result in a very low bolt velocity and a very small bolt movement during the period of high pressure. It would then be desirable for the last part of the small bolt movement to cause a change in the characteristics of the retarding mechanism so that the resistance is decreased by a substantial amount a millisecond or so after the projectile has left the muzzle and the residual pressure has dropped to a safe operating limit. The bolt, being subjected to greatly decreased resistance, would then be blown back safely at a relatively high velocity. An examination of the preceding requirements will indicate that an ideal retarding mechanism approximates the effect of a delay mechanism except that the bolt is not rigidly locked at any time. (Cf. "Delayed blowback system".)

It is important to note that effective use of retarded blowback requires a high degree of precision of mechanism and timing of operation. For safety and proper functioning, the change in the resistance offered by the retarding device must occur at exactly the correct time during the propellant explosion. This fact makes barrel length the most critical factor to be taken into consideration. For example, it has been stated that in the Schwarzlose machine gun (which employs a toggle linkage for retardation) the barrel length is critical to an unbelievable degree. If the barrel were slightly longer, the residual pressure would be too high as the linkage rises. Since the retardation would then be too low for the existing pressure, this would create a condition of extremely violent recoil and possible explosive rupture of the cartridge case. If the barrel were slightly shorter, the residual pressure would drop excessively before the linkage has risen sufficiently. Since the retardation would then be too high for the available pressure, there would be insufficient recoil and the gun would fail to function.

The foregoing example serves to indicate that a retarded blowback gun for high-powered ammunition must be designed and developed with great care. The parts of the retarding mechanism must be well

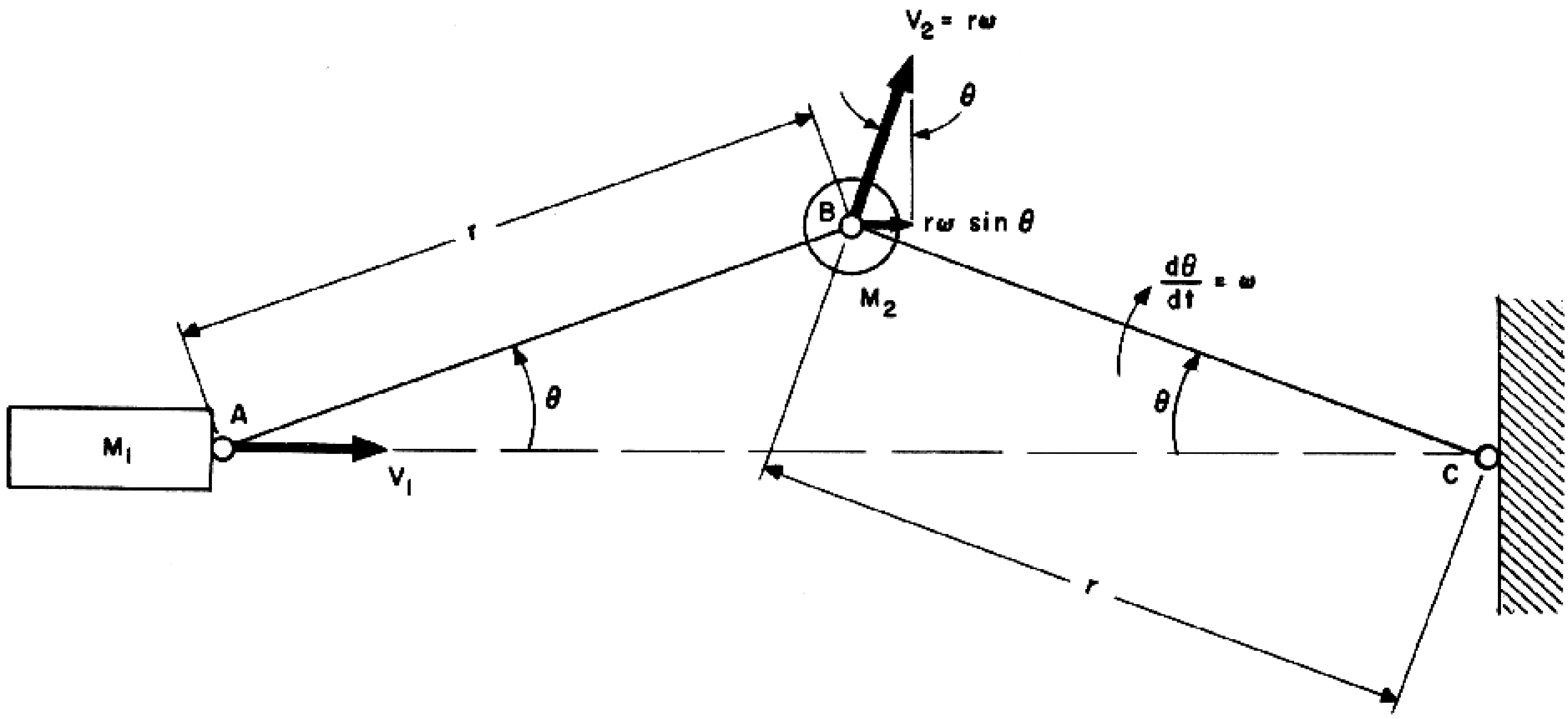

Figure 1–45. Relationship of Velocities in Toggle Linkage.

made and precisely fitted and the ammunition must be uniform in performance. Also, since the high forces resulting from the initial phases of propellant explosion are transmitted directly through the parts of the retarding mechanism, these parts must be of high-strength materials and carefully heat-treated. All things considered, mechanisms of this type are difficult and costly to manufacture and are at best suitable only for guns in which the recoil forces are not excessively great.

Mathematical Analysis of Retarded Blowback

The general character of the mass multiplying effects which can be obtained with a retarding device can be illustrated by considering a typical toggle linkage of the form shown in fig. 1–45. The linkage consists of two arms of equal length, r, pivoted at points A, B, and C. For purposes of analysis, the entire mass of the linkage M_2 is considered to be located at point B. The mass of the bolt itself is designated as M_1. The position of the linkage at any instant of time is defined by the angle θ between arm BC and the path of motion of the bolt.

1. *Initial retardation effect*

As arm BC rotates about point C, mass M_2 moves at a tangential velocity of $V_2 = r\omega$ where ω is the angular velocity of arm BC in radians per second. As indicated in the figure, the angle between the vector V_2 and the vertical is equal to θ and therefore the horizontal component of V_2 (in the direction of the bolt velocity V_1) is equal to $r\omega \sin \theta$. Since arm AB moves at the same angular velocity as arm BC, the bolt velocity V_1 is expressed by the relation:

$$V_1 = 2r\omega \sin \theta$$

Differentiating to obtain acceleration:

$$\frac{dV_1}{dt} = 2r \sin \theta \frac{d\omega}{dt} + 2r \cos \theta \frac{d\theta}{dt}$$

but:

$$\frac{d\omega}{dt} = \frac{d^2\theta}{dt^2} \text{ and, } r\frac{d^2\theta}{dt^2} = \frac{dV_2}{dt}$$

also:

$$\frac{d\theta}{dt} = \omega$$

Therefore:

$$\frac{dV_1}{dt} = 2 \sin \theta \frac{dV_2}{dt} + 2 r \cos \theta \, \omega^2$$

At the instant the bolt motion starts, $\omega = 0$. Hence, the relation between the initial accelerations of the masses reduces to:

$$\frac{dV_1}{dt} = 2 \sin \theta \frac{dV_2}{dt}$$

or

$$\frac{dV_2}{dt} = \frac{1}{2 \sin \theta} \frac{dV_2}{dt}$$

This relation shows that if θ is small, the acceleration of the linkage mass M_2 will be much greater than the acceleration of the bolt mass M_1. For example, if $\theta = 4°$, $\sin \theta = 0.0698$ and the acceleration of mass M_2 will be greater than the acceleration of mass M_1 by a factor of 7.17. In other words, the inertia reaction of a mass located at point B is 7.17 times greater than for the same mass located at point A.

Actually, the mass multiplying effect is further increased by the fact that the bolt acts through the linkage at a great mechanical disadvantage. Fig. 1–46 shows a vector diagram of the forces in the linkage. The inertia reaction of mass M_2 is equal to M_2 (dV_2/dt) directed perpendicular to arm BC. This force is in equilibrium with the indicated forces exerted at point B by the linkage arms. Taking component perpendicular to arm BC gives the force P_2 in arm AB as:

$$P_2 = \frac{M_2 \frac{dV_2}{dt}}{\sin 2\theta}$$

Taking horizontal components at point A gives the relation between P_2 and the force P_1 exerted on arm AB by the bolt

$$P_1 = P_2 \cos \theta$$

Substituting the value of P_2 into this expression gives:

$$P_1 = \frac{M_2 \frac{dV_2}{dt}}{\sin 2\theta} \cos \theta$$

As previously explained, at the instant the bolt motion starts:

$$\frac{dV_2}{dt} = \frac{1}{2 \sin \theta} \frac{dV_1}{dt}$$

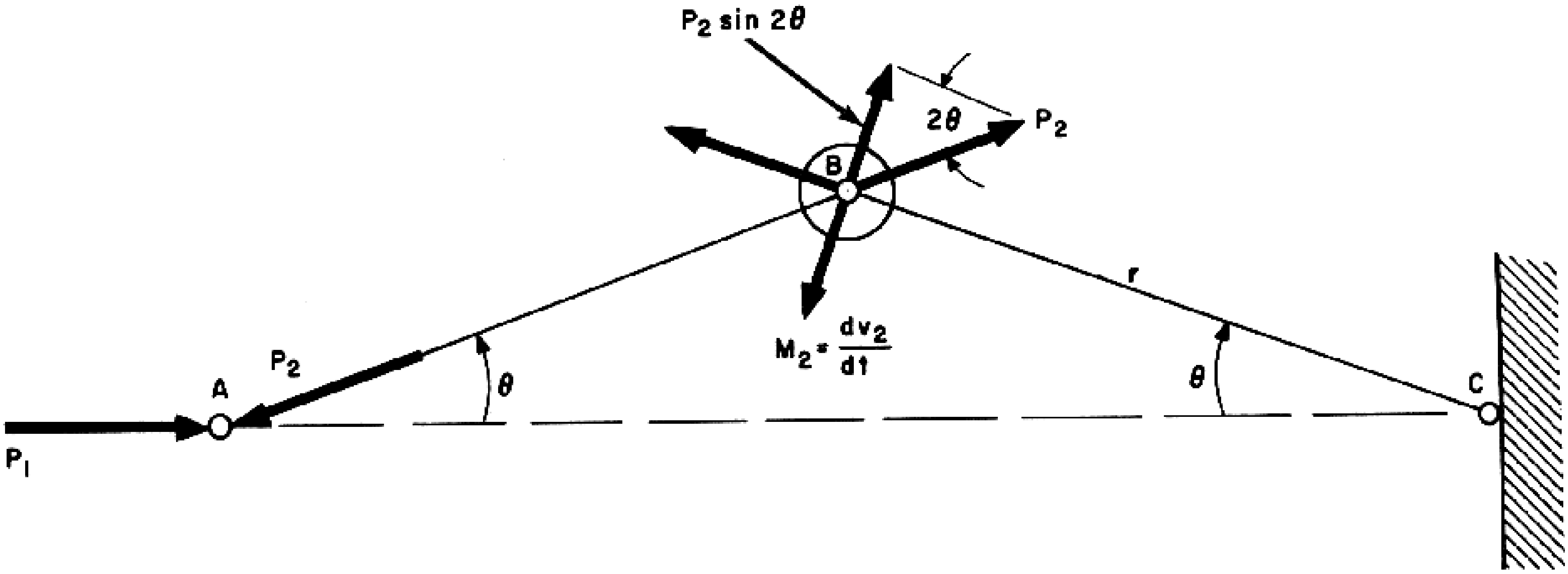

Figure 1–46. Effect of Inertia Reaction of Linkage.

Making this substitution in the expression for P_1 gives

$$P_1 = \frac{M_2 \dfrac{1}{2\sin\theta} \dfrac{dV_1}{dt}}{\sin 2\theta}\cos\theta$$

$$= \frac{\cos\theta}{2\sin\theta\sin 2\theta} M_2 \frac{dV_1}{dt}$$

Since $\sin 2\theta = 2\sin\theta\cos\theta$:

$$P_1 = \frac{1}{4\sin^2\theta} M_2 \frac{dV_1}{dt}$$

The factor, $1/(4\sin^2\theta)$ is the initial mass multiplying effect of the linkage and, for the instant the bolt motion starts, expresses the ratio by which the retardation offered by the linkage mass exceeds that of an equal mass located at point A. For example:

If $\theta = 4°$ $\dfrac{1}{4\sin^2\theta} = \dfrac{1}{4(.0698)^2} = 51.7$

$\theta = 1°$ $\dfrac{1}{4(.0175)^2} = 820$

$\theta = \dfrac{1°}{2}$ $\dfrac{1}{4(.00873)^2} = 3280$

Note that as θ is made smaller, the mass multiplying effect increases tremendously. (When $\theta = ½°$, a one-pound mass at point B would have the same initial retarding effect as a 3,280-pound mass located at point A.)

The foregoing analysis indicates that by means of a toggle linkage, the initial retardation can be made to be as great as desired merely by decreasing the initial angle. However, there are practical limitations on how small the initial angle should be.

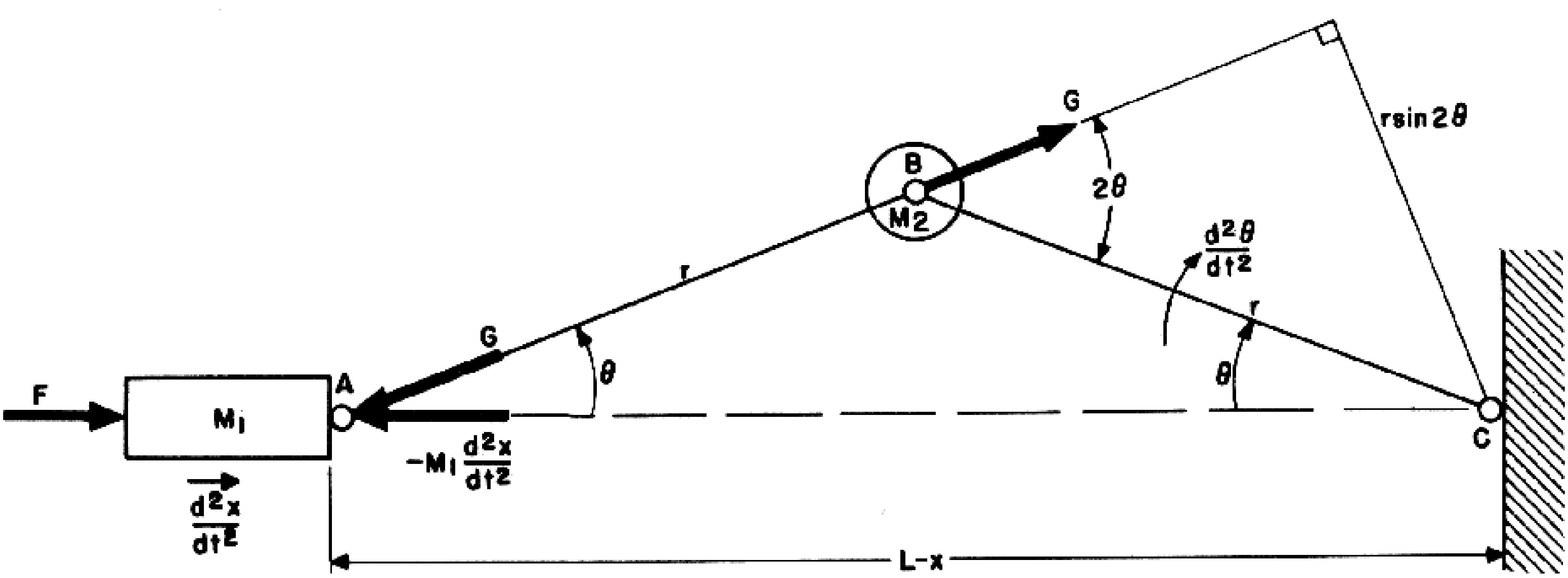

Figure 1–47. Forces in Toggle Linkage.

When angle θ is very small, proper functioning demands an extremely high precision in the dimensions of the parts. However, at small angles, tremendous forces are exerted on the links and the resulting deformation of the linkage will produce a condition in which the linkage will not act as effectively as theoretical analysis would indicate. For practical applications, the initial value of angle θ should not be much smaller than from 5 to 10 degrees.

2. *Analysis of bolt motion*

The analysis of the bolt motion in a retarded blowback gun employing a toggle linkage can not be conducted by the same methods as are described in this publication for other blowback guns. This is so because the mass effect of the linkage is not constant but varies as the parts of the linkage rotate, with the result that the motion can not be interpreted in terms of a simple relationship between impulse and momentum.

The differential equation expressing the free recoil conditions in the linkage may be derived from fig. 1–47. F is the force exerted on the bolt by the powder gas pressure at any instant of time. (F is an empirical function of time which may be derived from a graph of chamber pressure versus time of the type shown in fig. 1–9.) Considering mass M_2 and arm BC at angle θ, the torque resulting from the force G applied to M_2 by arm AB will be equal to the moment of inertia of arm BC times the angular acceleration of this arm about point C. That is:

$$Gr \sin 2\theta = I \frac{d^2\theta}{dt}$$

Since the entire mass of the linkage is assumed to be concentrated at point B, the moment of inertia is given by the relation

$$I = M_2 r^2$$

Making this substitution and solving for G gives:

$$G = \frac{M_2 r}{\sin 2\theta} \frac{d^2\theta}{dt^2}$$

Now considering the equilibrium of the horizontal forces on the bolt at point A gives the relation

$$F = M_1 \frac{d^2x}{dt^2} + G \cos\theta$$

Substituting the expression for G previously obtained gives:

$$F = M_1 \frac{d^2x}{dt^2} + \frac{M_2 r}{2 \sin\theta} \frac{d^2\theta}{dt^2} \cos\theta$$

But $\sin 2\theta = 2 \sin\theta \cos\theta$

Therefore:

$$F - M_1 \frac{d^2x}{dt^2} + \frac{M_2 r}{2 \sin\theta} \frac{d^2\theta}{dt^2}$$

Angle θ may be eliminated from this expression as follows: If L is the initial distance between point A and point C and x is the linear displacement of the bolt along line AC:

$$\theta = \cos^{-1} \frac{L-x}{2r}$$

Differentiating to obtain $d\theta/dt$ gives:

$$\frac{d\theta}{dt} = \frac{\frac{dx}{dt}}{2r\sqrt{1-\left(\frac{L-x}{2r}\right)^2}} = \frac{\frac{dx}{dt}}{\sqrt{4r^2-(L-x)^2}}$$

Differentiating to obtain $d^2\theta/dt^2$ gives:

$$\frac{d^2\theta}{dt^2} = \frac{\sqrt{4r^2-(L-x)^2}\frac{d^2x}{dt^2} - \frac{L-x}{\sqrt{4r^2-(L-x)^2}}\left(\frac{dx}{dt}\right)^2}{[4r^2-(L-x)^2]}$$

$$\frac{d^2\theta}{dt^2} = \frac{[4r^2-(L-x)^2]\frac{d^2x}{dt^2} - (L-x)\left(\frac{dx}{dt}\right)^2}{[4r^2-(L-x)^2]^{3/2}}$$

Also:

$$\sin\theta = \sqrt{1-\cos^2\theta} = \sqrt{1-\left(\frac{L-x}{2r}\right)^2} = \frac{1}{2r}\sqrt{4r^2-(L-x)^2}$$

Substituting the expressions for $d^2\theta/dt^2$ and $\sin\theta$ in the differential equation gives:

$$F = M_1 \frac{d^2x}{dt^2} + M_2 r^2 \left[\frac{[4r^2-(L-x)^2]\frac{d^2x}{dt^2} - (L-x)\left(\frac{dx}{dt}\right)^2}{[4r^2-(L-x)^2]^2}\right]$$

Unfortunately, the solution to this equation can not be expressed in finite form in terms of elementary functions of t. The situation encountered here is similar to that which arises in the mechanics of a simple pendulum. In the case of the simple pen-

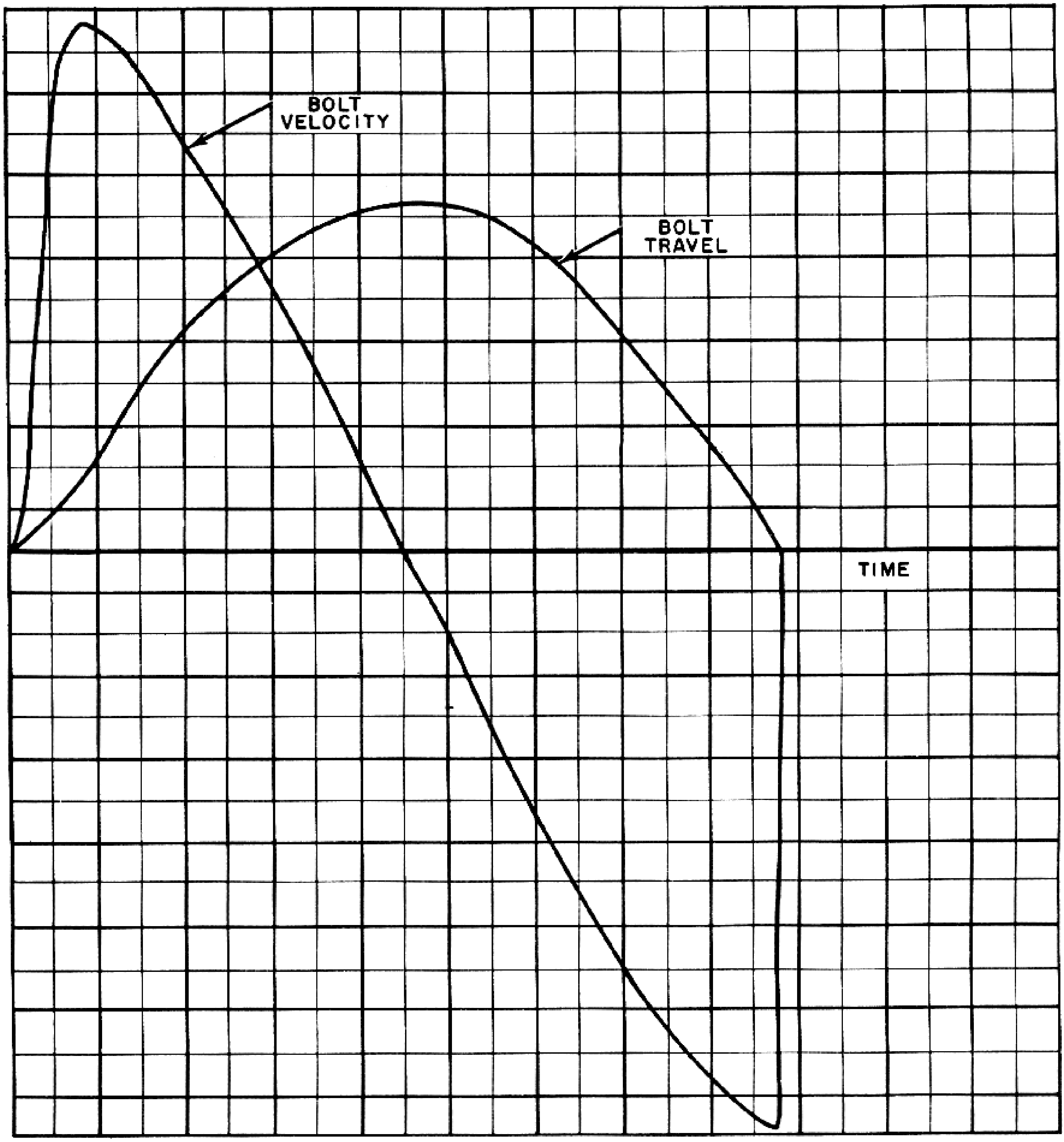

Figure 1-48. Time-Travel and Time-Velocity Curves for Complete Cycle of a Retarded Blowback Gun.

dulum, the relationship between the displacement of the bob and time involves an integral of a special type known as an "elliptic integral" which can be evaluated by the use of infinite series or by means of special tables. However, the equation derived above for the toggle linkage breech mechanism is further complicated by the fact that F is an empirical function of time and any attempt to obtain a solution by direct methods would involve extremely intricate manipulations. Probably the best method of attack would be to assign suitable values to M_1, M_2, r, and L and then (using a curve expressing the variation of F with time) to evaluate the integrals involved in the solution by one of the standard methods for numerical approximation. Because of the form of the differential equation and the fact that F varies with time, even this approach will be very laborious and much too tedious to demonstrate in this publication. Accordingly, the time-travel and time-velocity curves will not be developed here.

The general form of the time-travel and time-velocity curves for the complete cycle of a retarded blowback gun employing a toggle linkage (fig. 1–48) will closely resemble the form of the curves for a delayed blowback gun.

Chapter 2

RECOIL OPERATION

PRINCIPLES OF RECOIL

The principles of recoil can be understood best by considering the forces which result from firing a cartridge in an elementary gun. Such a gun (shown schematically in fig. 2–1) consists of a barrel having a chamber at its rear end for receiving the cartridge and a breech closure in the form of a bolt. The bolt is rigidly locked to the barrel after the cartridge is inserted, thus providing a firm support for the base of the cartridge case so that the case will not be blown out of the chamber by the explosion of the propellant charge.

When the cartridge is fired, the explosion of the propellant results in the rapid generation of extremely high gas pressure in the chamber and the expansion of this high-pressure gas drives the projectile forward through the bore. As the powder gases expand behind the projectile, the center of mass of the gases also moves forward. While the projectile is in the bore, the same pressure which causes the projectile and powder gases to move forward also acts simultaneously at the breech end of the gun to produce an equal and opposite reaction which tends to drive the entire gun to the rear. The force resulting from this reaction is called the "recoil force" and the magnitude of this force at any instant depends on the chamber pressure.

Fig. 2–2 shows how the chamber pressure varies with time in a typical 20-mm gun with a total barrel length of slightly less than five feet. The parts into which the curve is divided show the proportion of the pressure expended in producing the velocity of the projectile and in imparting motion to the powder gases. (A very small proportion of the total pressure is expended in overcoming bore friction and in imparting rotation to the projectile, but this proportion is too small to be shown in the figure.) The pressure producing the recoil force is the total of both parts of the curve. Fig. 2–2 shows that the recoil force does not immediately cease when the projectile leaves the gun after 0.00234 second but continues to act until the residual pressure falls to zero at approximately 0.008 second.

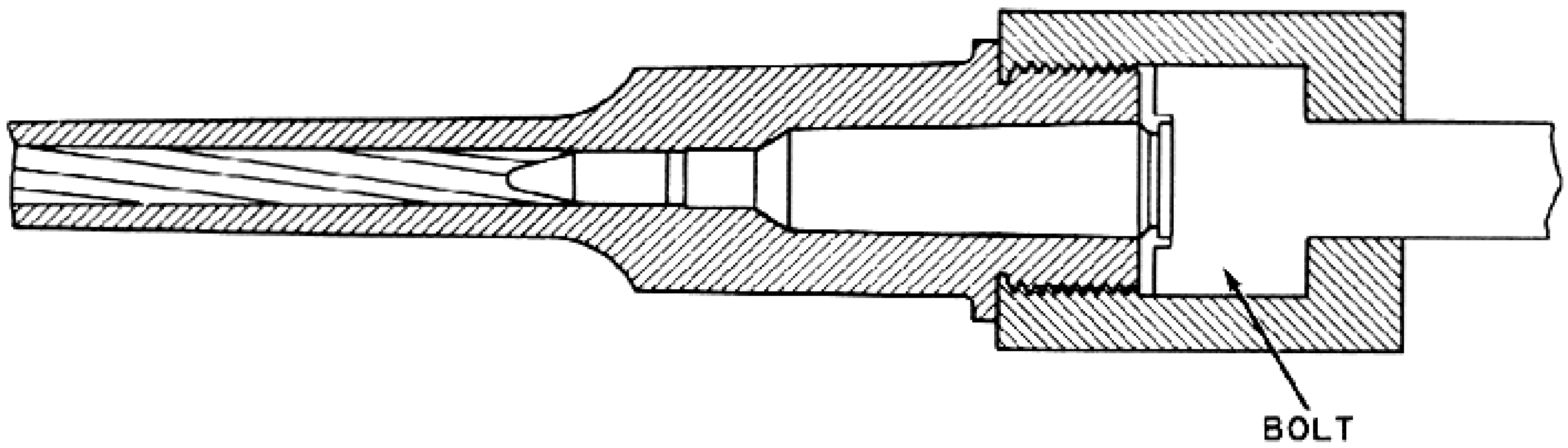

Figure 2–1. Elementary Gun.

The effect of the recoil force on the gun depends entirely on how the gun is mounted. If it is assumed that the gun is mounted so that it can move freely without friction or any other restraint, the impulse of the recoil force (acting over the entire 0.008 second) will impart to the gun a rearward momentum equal to the total forward momentum of the projectile and powder gases. The velocity of the gun will depend on its mass; the smaller the mass, the higher the velocity. When the residual pressure falls to zero at 0.008 second, the gun will have achieved its maximum velocity and since it is assumed that there are no external restraining forces, the gun will continue to move at this velocity. This hypothetical condition is referred to as the condition of "free recoil".

With any practical weapon, the rearward motion of the gun must be controlled and limited by the application of restraining forces, producing the con-

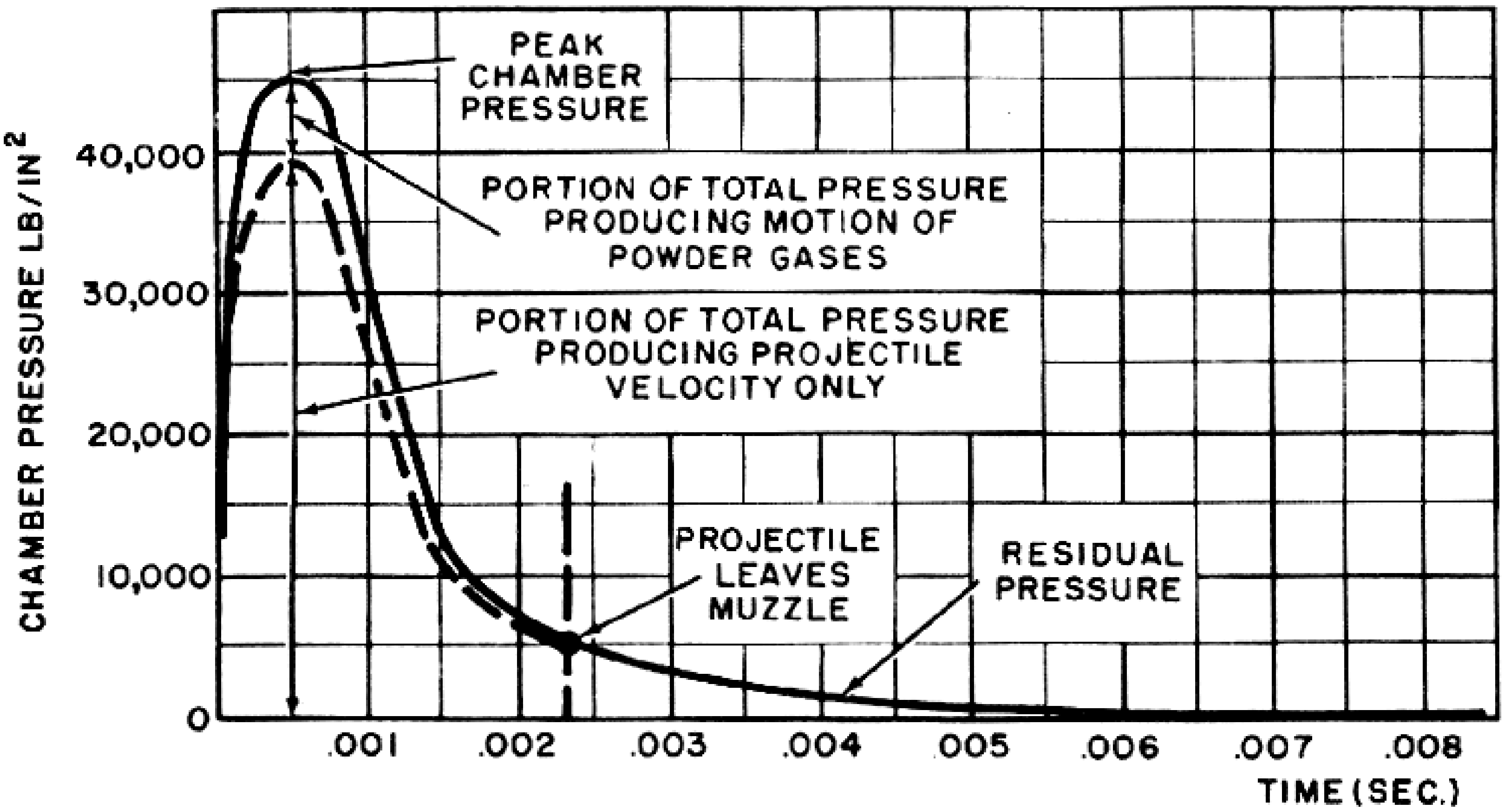

Figure 2–2. Variation of Chamber Pressure With Time.

dition known as "retarded recoil". In many guns, the effect of recoil is merely an inconvenience which must be tolerated since it can not be avoided. The primary source of difficulty in such cases is the tremendous magnitude of the recoil forces resulting from firing high-powered ammunition. (For example, it might be pointed out here as a matter of general interest that maximum recoil force in a 16-inch gun having a maximum chamber pressure of 38,000 pounds per square inch is the stupendous figure of almost 8,000,000 pounds. Even in a 20-mm gun, the maximum recoil force can amount to over 22,000 pounds.) While it might be possible to build a rigid mount capable of directly withstanding forces of this magnitude, such a mount would be entirely too heavy and cumbersome for any practical purpose. Accordingly, it is necessary to permit the gun to move during and after the action of the recoil force so that the momentum of the gun can be cancelled through the application of a smaller retarding force which acts over a considerable interval of time and distance. Since the gun moves in recoil, it acquires kinetic energy which must be absorbed in order to bring the gun to rest. For the above reasons, many guns (particularly those of heavier calibers) are mounted in a slide and are provided with a recoil brake and a recuperator, both of which absorb the recoil energy. Most of the energy is dissipated by the brake in the form of heat and the energy stored in the recuperator is utilized to return the gun to battery.

In hand-held weapons, the recoil momentum is cancelled by a force applied to the weapon through the arm or shoulder of the firer. For example, when a Springfield rifle is fired, the maximum force of recoil is about 3700 pounds. (The maximum chamber pressure of 52,000 psi times the bore cross-section area $(\pi/4)\ (.30)^2$ in., gives the maximum force as $52{,}000 \times .0707 = 3670$ pounds.) Actually, this force is not applied directly to the shoulder of the firer but produces the rearward acceleration of the gun known as "kick." The shoulder of the firer then acts as a recoil brake which absorbs the resulting kinetic energy of recoil over a travel of two or three inches. If it is assumed that the rifle moves three inches in recoil, the average force applied by the shoulder against the stock must be in the order of 60 pounds. If an attempt were made to limit the recoil distance to one-quarter inch, the average force would be 720 pounds. (This indicates why it is not a good idea to fire a high-powered rifle with the shoulder rigidly backed up against a solid support.)

Up to this point, recoil has been considered as undesirable because it creates forces and energies which must be absorbed and dissipated after each shot of an ordinary gun. However, in an automatic weapon, these same forces and energies represent a convenient source of power for operating the gun mechanism. Machine guns which utilize this source of power are said to employ the "recoil system" of operation.

The amount of operating energy available from recoil depends on the particular cartridge used and on the weight of the recoiling parts. The use of a powerful cartridge will result in a high total momentum imparted to the projectile and powder gases and the corresponding reaction will produce a high momentum of the recoiling parts. However, the velocity of recoil will depend on the weight of the recoiling parts; the greater the weight, the lower the velocity. Since the kinetic energy of a weight is directly proportional to its mass and the square of its velocity, the net result is that the energy contained in the recoiling parts will be inversely proportional to their weight. In other words, increasing the weight of the recoiling parts will not change the momentum imparted to them but will cause a decrease in both the recoil velocity and the recoil energy. Thus it is evident that the weight of the recoiling parts has an important effect on the performance of a recoil-operated gun.

All of the kinetic energy imparted to the recoiling parts is transferred to them in the period of less than 0.01 second during which the pressure of the powder gases is active. After this time, the parts continue to move of their own momentum and their energy is transferred to the gun mechanism for performing the various operations required in the automatic cycle. In various types of recoil systems, the energy may be employed in different ways. These systems will be described and analyzed in the following pages.

RECOIL OPERATION

In the recoil system of operation, provision is made for locking the bolt to the barrel and these parts are mounted in the receiver so that they can slide to the rear. The gun is fired with the bolt locked to the barrel and these parts remain locked together as they are thrust back by the pressure resulting from the explosion of the powder gases. In some guns, the energy derived from this motion is used to perform the entire cycle of operation; in other guns the energy derived from recoil may perform only certain functions in the cycle or may merely supplement the energy derived from another system of automatic operation.

The distinguishing characteristic of the recoil system is that energy used for operation is obtained from the recoil movement of the barrel and bolt while these parts are locked together. Any gun in which the bolt is locked to the barrel while there is pressure in the chamber will be subject to some recoil action, but unless the recoil is put to use in operating the gun mechanism, the gun does not employ the recoil system. For example, some gas-operated guns are arranged so that recoil can occur while the barrel and bolt are locked together but this motion is permitted only in order to obtain a reduced trunnion reaction. Since no energy for operating the gun mechanism is obtained from recoil, such guns can not be said to use the recoil system.

In the following description of recoil operation, it will be assumed that the bolt remains locked to the barrel during the entire time of action of the powder gas pressure. Some guns using the recoil system are designed so that the bolt is unlocked when the residual pressure has fallen to a safe operating limit but has not yet reached zero and are therefore subject to some blowback action.

In a gun operated purely by recoil the bolt remains locked to the barrel until the chamber pressure has become zero and therefore, there are no problems (such as are encountered in blowback) resulting from movement of the cartridge case under pressure and lubrication of the ammunition is unnecessary.

> NOTE: Of course, this statement is true only if the gun is adjusted for correct head space. If the head space is excessive, case separation will occur for reasons which are explained in detail under *Blowback*.

Since the use of recoil operation disposes of the limitations imposed by cartridge case movement, the main problem confronting the designer of a recoil weapon is how to make efficient use of the energy available for operating the mechanism.

RECOIL SYSTEMS

The number of different machine guns employing the recoil system of operation is very large and an examination of these weapons will reveal an extreme diversity of mechanical detail and functional arrangement. However, in spite of these dissimilarities, all recoil-operated weapons can be placed in one of two basic sub-classes: long recoil or short recoil.

Long recoil is defined as a system of operation in which energy for operating the gun mechanism is obtained from a recoil movement which is greater than the overall length of the complete cartridge. During this entire movement, the bolt remains locked to the barrel. At the end of the rearward movement, the bolt is unlocked from the barrel and is latched in its rearmost position while the barrel moves forward in counter-recoil, thus pulling the chamber off the empty cartridge case and ejecting the case. When the barrel has moved forward far enough to provide a sufficient opening for feeding, and just before its counter recoil movement is completed, the bolt is unlatched. The bolt then moves forward to perform the function of loading and the cycle is completed as the bolt relocks to the barrel.

In a short-recoil weapon, the bolt remains locked to the barrel for only a portion of the recoil stroke required to permit feeding. After unlocking occurs, the barrel may move a short distance with the bolt but it is then stopped. The bolt, on the other hand, continues to move to the rear and it may complete this movement by virtue of the momentum it had at the time of unlocking or it may receive additional momentum through the action of a mechanical device (known as an "accelerator") which transfers some of the energy of the barrel to the bolt. In either case, the rearward motion of the bolt continues until the opening is sufficient for feeding and the bolt is then moved forward to close and lock the breech. In some guns, the bolt may push the barrel back to the firing position but in others, the return motion of the barrel is accomplished independently before the bolt closes.

LONG RECOIL SYSTEM

In the following paragraphs the long recoil system of operation is described and analyzed by considering the sequence of events which occur in the automatic cycle of operation. As with other systems treated in this publication, this analysis is concerned only with the functioning of the mechanisms and with the general factors affecting design.

Because of its relatively simple functional characteristics, the long recoil system will be analyzed first. Actually, existing examples of guns using this system are far from simple when viewed from the standpoint of mechanical detail because of the complexities involved in actuating the locking and latching devices. However, these mechanical complexities are not directly concerned in an analysis of the basic motions and forces encountered in long recoil operation and therefore will not be considered here.

Fig. 2–3A shows schematically the essential elements of a gun which operates by the long recoil system. These elements consist of the bolt, an arrangement for locking the bolt to the barrel and unlocking it, a bolt driving spring for returning the bolt after recoil, a spring to return the barrel, and a latch to hold the bolt to the rear while the barrel is moving forward. The other portions of fig. 2–3 show different stages during the cycle of operation.

Cycle of Operation

The operating cycle of a typical long recoil gun occurs as follows:

The cycle starts with a cartridge in the chamber and with the bolt locked to the barrel (fig. 2–3A). When the cartridge is fired, the pressure of the powder gases drives the projectile and gases forward and at the same time drives the barrel and locked bolt to the rear in recoil. During the action of the powder gas pressure, the retardation offered by the springs is relatively small and the only really significant factor in limiting the recoil acceleration is the mass of the recoiling parts.

The force exerted by the powder gases exists for a relatively very short time. In a typical 20-mm gun with a barrel length of about five feet, the projectile leaves the muzzle after approximately 0.0023 second and the residual pressure continues to act until 0.008 or 0.009 second after ignition of the primer. After this point, the powder gas pressure is zero and the recoil force is also zero but the barrel and bolt continue to move of their own momentum. As the barrel and bolt move back, the barrel spring and bolt driving spring are compressed and the resistance of these springs gradually slows down the recoil parts until their velocity is zero at the extreme recoil position shown in fig. 2–3B. (The

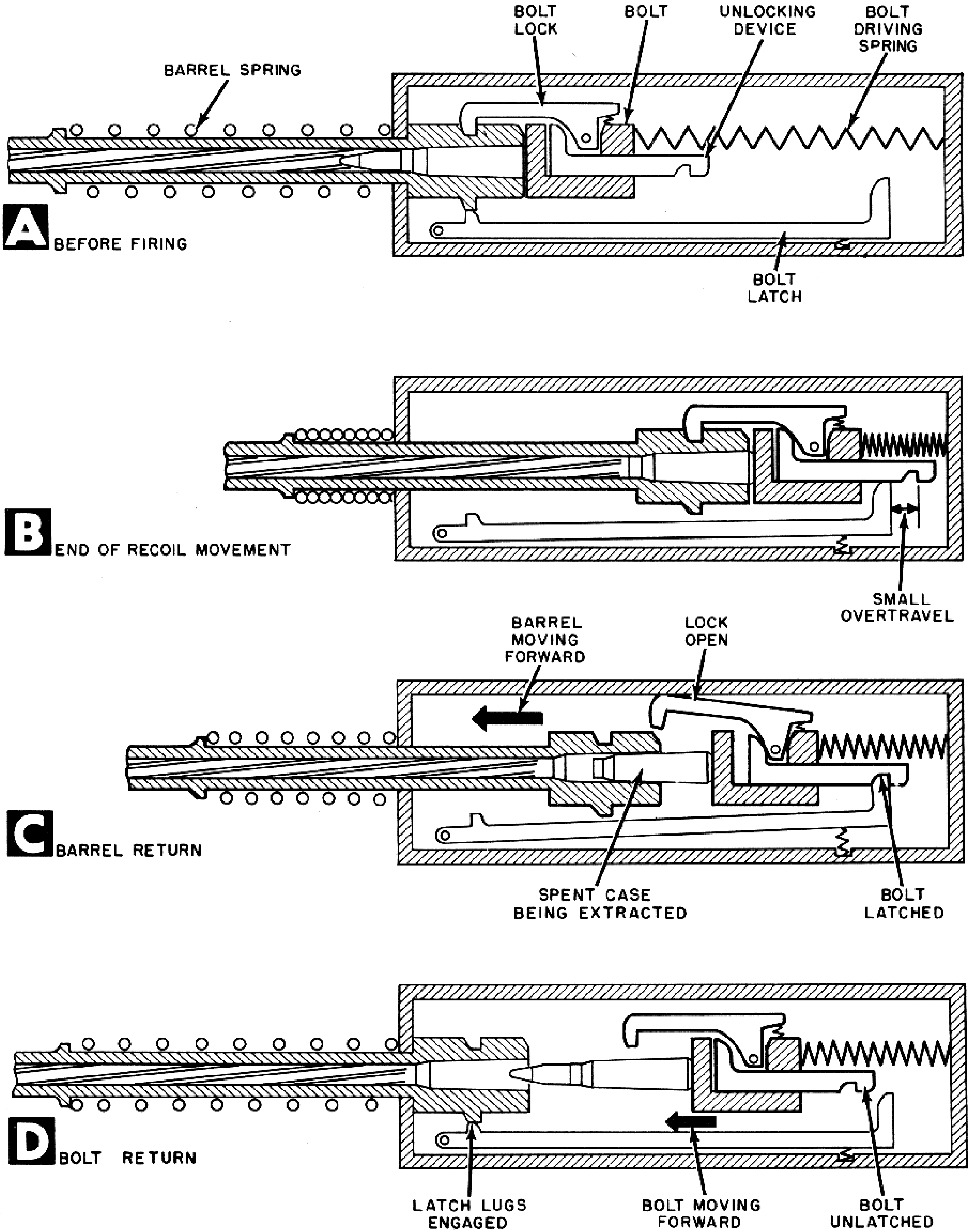

Figure 2–3. Elements of Long Recoil System (Schematic).

small overtravel indicated in the figure is allowed in the design to take care of normal variations in the loading of the cartridges.) Note that up to this point, the bolt is still locked and no automatic operation other than firing has been completed.

After the springs have brought the barrel and bolt to rest, the force of the compressed springs starts moving these parts forward. However, the bolt unlocking device is almost immediately caught and held by the bolt latch (fig. 2–3C) and the forward pull of the barrel causes the bolt lock to open. Therefore, the barrel continues to move forward, causing extraction and ejection of the case. Feeding of a fresh round can not occur until the barrel is at or nearly at the fully forward position, because only then is the bolt open a sufficient amount to permit feeding. Just before the barrel reaches the fully forward position, all of the potential energy stored in the barrel spring during recoil has been transformed back into kinetic energy (except for losses such as are occasioned in unlocking, extraction, ejection, or overcoming friction). Therefore the barrel is moving with considerable velocity and its kinetic energy must be absorbed either by impact or by a buffer.

When the barrel reaches the fully forward position, it actuates the bolt latch to release the bolt (fig. 2–3D). The bolt driving spring then pushes the bolt forward to feed and load a new round, lock the breech, and actuate the firing mechanism to start a new cycle of operation. Just as the bolt locks to the barrel, all of the potential energy stored in the bolt driving spring during recoil has been converted back to kinetic energy (except for the losses due to feeding, loading, locking, and actuating the firing mechanism). This kinetic energy is absorbed by impact as the bolt is brought to rest.

Analysis of Long Recoil

In the preceding descriptions of recoil operation and of the long recoil system, it was pointed out that, since the bolt remains locked until the chamber pressure is zero, there are no special difficulties arising from cartridge case movement under pressure and that the principal problem confronting the designer is how to make efficient use of the available recoil energy. The manner in which the recoil energy is utilized in a long recoil gun is largely dependent upon the power of the cartridge considered in relation to the attainment of a practical rate of fire.

The long recoil system has several important advantages which relate to the problems involved in handling recoil forces and which make it especially suitable for large-caliber guns employing high-powered ammunition. In such guns, the large bore cross-section area coupled with high chamber pressure produces extremely great recoil forces and these forces tend to result in violent action and excessive recoil energy. In a long recoil gun, the rearward thrust of the recoil forces is expended in producing motion of the combined mass of the barrel and bolt and since this mass is quite heavy, the recoil energy will be correspondingly relatively low. Second, since the recoil energy can be absorbed more or less gradually over a relatively long movement in recoil, the forces involved in absorbing the energy can be kept within reasonable limits, thus giving fairly low trunnion reactions as well as reduced stresses in the parts of the gun mechanism.

Although the long recoil system is well adapted to handling large-caliber high-powered ammunition, it has a disadvantage in regard to rate of fire. The basic difficulty with the long recoil system is that the sequences necessary in the automatic cycle of operation do not permit efficient utilization of time. To demonstrate this point, the entire time necessary for the recoil movement is essentially wasted because the bolt must remain locked this entire period, thus delaying the accomplishment of unlocking, extraction, ejection, and the other automatic functions. Furthermore, after unlocking occurs, a substantial portion of the time required for barrel return is expended merely in extracting the spent case. Ejection and feeding must be delayed until the return of the barrel has been practically completed and only then can the bolt start its return movement. Because all of these delays are inherent in the long recoil system, guns based on the long recoil system tend to have a rather low rate of fire.

When considering the expression "rate of fire", it is important to realize that the terms "low" or "high" are only relative and depend entirely on the caliber of the gun. What may be thought of as a very low rate for a 20-mm gun might be a terrifically high rate for a gun of much greater caliber. In a larger sense, the meanings of the terms "low" or "high" as applied to rate of fire are dictated by the type of target for which the gun is intended. For high speed air-to-air combat in which the gun can be brought to bear on target for usually only a split second, a rate of fire of 1000 rounds per minute might be considered none too high. In such combat, the target may be fairly light so that effective hits can be scored with ammunition of relatively small caliber. However, for targets such as buildings, ships, and heavily armored vehicles, it is usually desirable to use high-powered ammunition of large caliber and there probably will be ample time for firing. Under such conditions, a rate of fire of over 1000 rounds per minute is not necessary and it may be preferable to deliver a few devastating blows to the target rather than a large number of lighter hits.

Because of its advantages in regard to handling high recoil forces, the long recoil system is applied extensively for large-caliber weapons and, considering the caliber of these weapons, the rates of fire attained are fairly high. The disadvantage of the long recoil system in regard to rate of fire becomes evident only for smaller caliber guns. In such guns, the distances through which the recoiling parts must move are more or less predetermined by the total length of the cartridge used. Therefore, the only way in which the tendency toward a low cyclic rate can be minimized is to design the gun so that the recoil movement and the return movements of the barrel and bolt occur at the highest velocity attainable on a practical basis. Thus, in an analysis of long recoil as applied to smaller caliber guns, primary attention must be given to those factors which affect the barrel and bolt velocities.

Assuming the use of a particular type of ammunition, the main factor affecting the velocities of the recoiling parts is the weight of these parts. With a given ammunition, the total forward momentum imparted to the projectile and powder gases is some definite amount and the resulting reaction will produce an equal and opposite momentum in the recoiling parts. In other words, the momentum imparted to the recoiling parts is some definite amount which is determined by the cartridge used. The recoil velocity which corresponds to this momentum will be inversely proportional to the weight of the recoiling parts and therefore the maximum recoil velocity will depend on the weight of the recoiling parts. This necessitates that, to obtain a high recoil velocity, the recoiling parts should be made as light as possible.

Unfortunately, there are definite limitations to how small the recoiling parts can be. In order to perform their functions and to withstand the forces to which they are subjected, the barrel, bolt, and other recoiling parts must be ruggedly constructed and will necessarily be fairly massive. In fact, all is based on the propellant charge and the more powerful the ammunition, the heavier these parts will be. Since there is a limit to how light the operating components can be, the maximum attainable recoil velocity is similarly limited.

The extent of this limitation can be illustrated by considering a 20-mm gun. In a gun of this caliber with a maximum chamber pressure of 45,000 pounds per square inch, the barrel and barrel extension assembly alone could hardly weigh much less than 35 pounds, no matter how economically it is designed from the standpoint of weight. Allowing a conservative 6 or 8 pounds for the bolt, locking device and firing mechanism and another 6 or 8 pounds for the effect of the spring masses gives a total minimum weight close to 50 pounds. The recoil momentum produced by the assumed cartridge will be approximately 35 (lb. sec.) and dividing this figure by the mass of the 50-pound recoiling parts gives a maximum free recoil velocity of about 22.5 feet per second. Now it must be realized that this velocity represents (to a fair approximation) the highest value attainable in the assumed weapon because an attempt to increase this velocity by lightening the parts would make the parts too frail.

Thus it appears that the designer of a 20-mm gun operated purely by long recoil is "stuck with" a maximum initial recoil velocity of somewhere near 22.5 feet per second. It will be recalled from the description of the long recoil cycle of operation that the barrel must recoil and counter-recoil the full distance before the bolt starts its return movement. For a 20-mm gun, the recoil distance must be from eight inches to nearly one foot to permit feeding and therefore the barrel must travel a total distance of almost two feet per cycle. Even if it is assumed (although this is impossible) that this entire motion is accomplished at the maximum velocity of 22.5 feet per second and that the bolt return time is ignored completely, this will mean that the time required for each cycle will be $2/22.5 = .089$ second which gives a rate of fire of 675 rounds per minute. Actually the barrel must be stopped and its motion must be reversed at the end of recoil and its average velocity will necessarily be lower than the maximum free recoil velocity. Furthermore, the bolt return time will have a significant effect on the rate of fire under practical conditions. Therefore, the maximum attainable rate of fire will be considerably lower than 675 rounds per minute and the best that can be expected is in the neighborhood of 300 to 500 rounds per minute. In modern terms, this is considered a prohibitively low cyclic rate for any 20-mm machine gun.

From what has been said, it can be seen that to achieve even the relatively low rate of 500 rounds per minute with long recoil operation, the designer must carefully utilize every possible means at his command to take full advantage of the following points:

1. To obtain a high initial recoil velocity, the recoiling parts must be made as light as possible consistent with the practical requirements for strength, rigidity, and durability.
2. The recoil distance should be no greater than the minimum necessary to provide an adequate opening for feeding, as governed by the overall length of the incoming round.
3. The gun mechanism should be arranged to minimize delays by taking advantage of every possible instant of time (rapid unlocking, eject at instant extraction is completed, etc.).
4. In smaller caliber guns, instead of using the barrel spring to absorb most of the recoil energy, this spring could be made as light as possible and be depended upon only to hold the barrel in battery. This would produce a condition of low retardation, thus permitting the barrel and bolt to recoil the entire distance with little decrease in velocity. The reversal of their motion at the end of recoil could then be accomplished by causing the recoiling parts to rebound from an extremely stiff buffer spring. Although this arrangement gives a high average velocity of recoil, it should be noted that the reversing action of the buffer spring will be rather violent, and accompanied by high impact forces. In addition, the impact loss in the buffer may be considerable with the result that the slowness of the long counter-recoil movement of the barrel would reduce or eliminate entirely any advantage gained during recoil. Since the advantage of employing this method is doubtful in a long-recoil gun, the use of a conventional barrel spring will be assumed from this point forward.
5. The barrel spring and bolt spring should be proportioned so that the total time required for returning the barrel and bolt will be minimized. (The calculations necessary to accomplish this are described in the mathematical analysis of long recoil.)
6. It might be mentioned here that some improvement in the rate of fire can be accomplished by the use of a so-called "recoil intensifier" or "muzzle booster". This device utilizes the residual gas pressure by trapping the muzzle blast in such a way as to increase the rearward thrust on the muzzle face of the barrel and thus increases the recoil velocity.

All of the preceding points are concerned with the problem of obtaining the optimum rate of fire from the long recoil system as applied to a smaller caliber gun, but as has been remarked previously, even with these refinements, the cyclic rate will still be relatively low. This limitation, coupled with the design disadvantages arising from the long travel of the heavy barrel and from the inherent complexity of the mechanism, probably accounts for the fact that no successful machine gun using the long recoil system has appeared among modern weapons of 20-mm or smaller caliber.

In the large caliber guns to which the long recoil system has been applied successfully, the high recoil energy involved has made it necessary to ignore many of the points described in the preceding paragraphs. In these guns there is so much excess recoil energy that the problem is one of minimizing and disposing of energy rather than one of taking advantage of every possible means to increase the velocity of recoil and rate of fire. Therefore the approach is exactly opposite to that described for smaller caliber guns. The recoiling parts are deliberately made heavy to minimize the energy imparted to them, and recoil brakes and buffers are utilized to remove energy from the system. The recoil stroke is made as long as practical considerations will permit and muzzle brakes rather than muzzle boosters are sometimes employed. All things considered, the long recoil system is best adapted to handling high recoil forces and is not the best system for use in smaller caliber weapons in which high cyclic rates are desired. If the number of rounds delivered per minute is the primary consideration

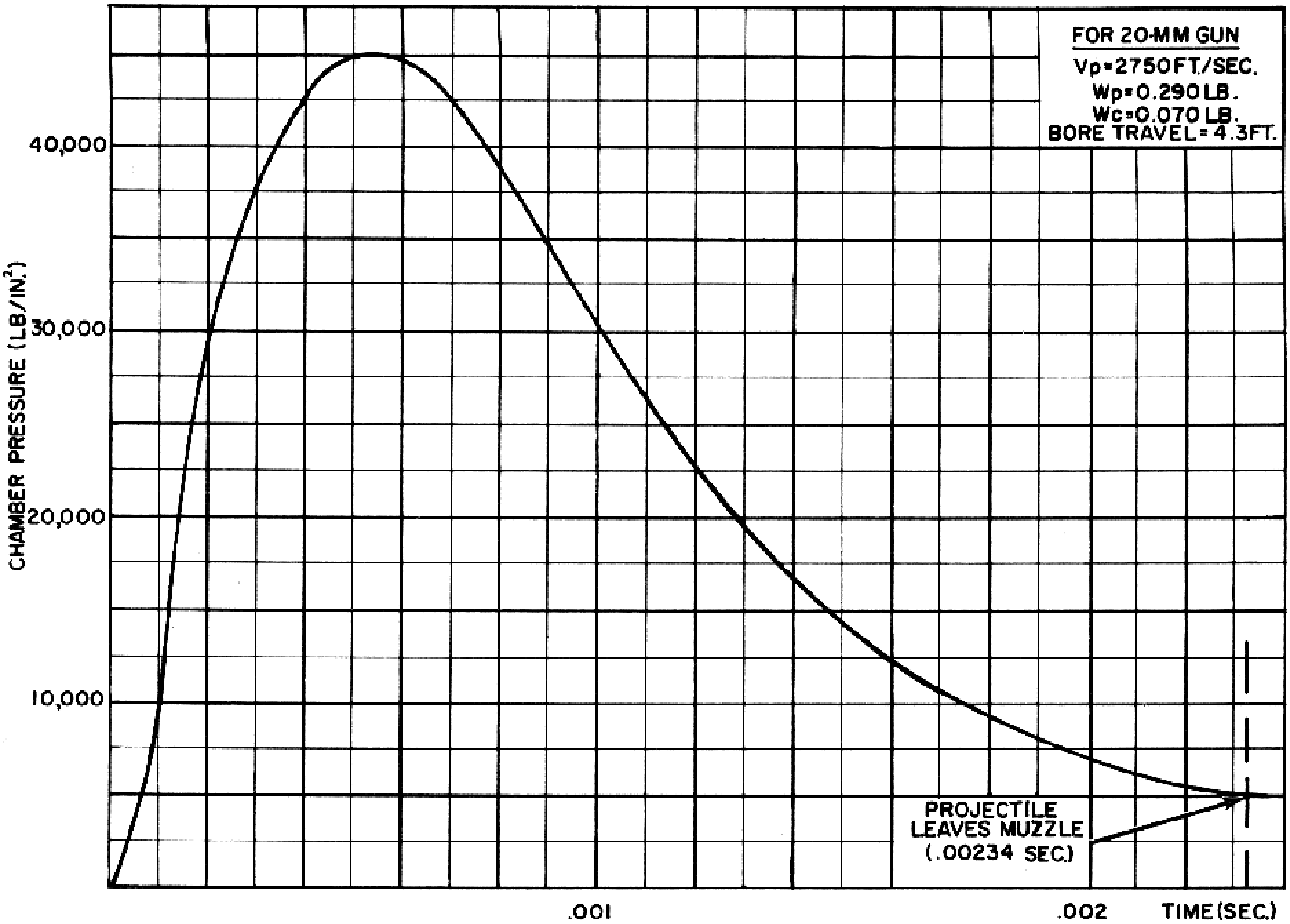

Figure 2–4. Graph of Chamber Pressure Versus Time (20 mm. Gun).

and the recoil forces are not excessive, it is safe to say that some other system than long recoil should be used.

In the following mathematical analysis, the gun used to illustrate the computations will be a 20-mm gun in spite of the fact that long-recoil may not be the ideal system for a gun of this caliber. This is done in order to permit comparison of the results of the analysis with the results obtained from the analyses of the other operating systems described in this publication which also used 20-mm data for purpose of illustration.

Mathematical Analysis of Long Recoil

The following paragraphs describe a systematic procedure for performing the computations necessary in a basic analysis of a gun operated purely by long recoil. This procedure follows the same general lines used for the analysis of the other systems described in this publication with the modifications necessary for considering the specific problems arising in the design of long recoil machine guns. As in the other analyses, no attempt will be made to discuss the straightforward machine design methods used for arriving at the particular physical form of the mechanisms or to make detailed computations for the effects of friction or the relatively minor forces incident to operating the auxiliary mechanisms such as the bolt lock, feeder, firing device, or ejector.

The following analysis is based on the assumption that a particular cartridge with known characteristics is to be used and that the desired muzzle velocity and barrel length have been predetermined. It is also assumed that all necessary interior ballistics data are known and that graphs showing the time variation of projectile velocity, chamber pressure,

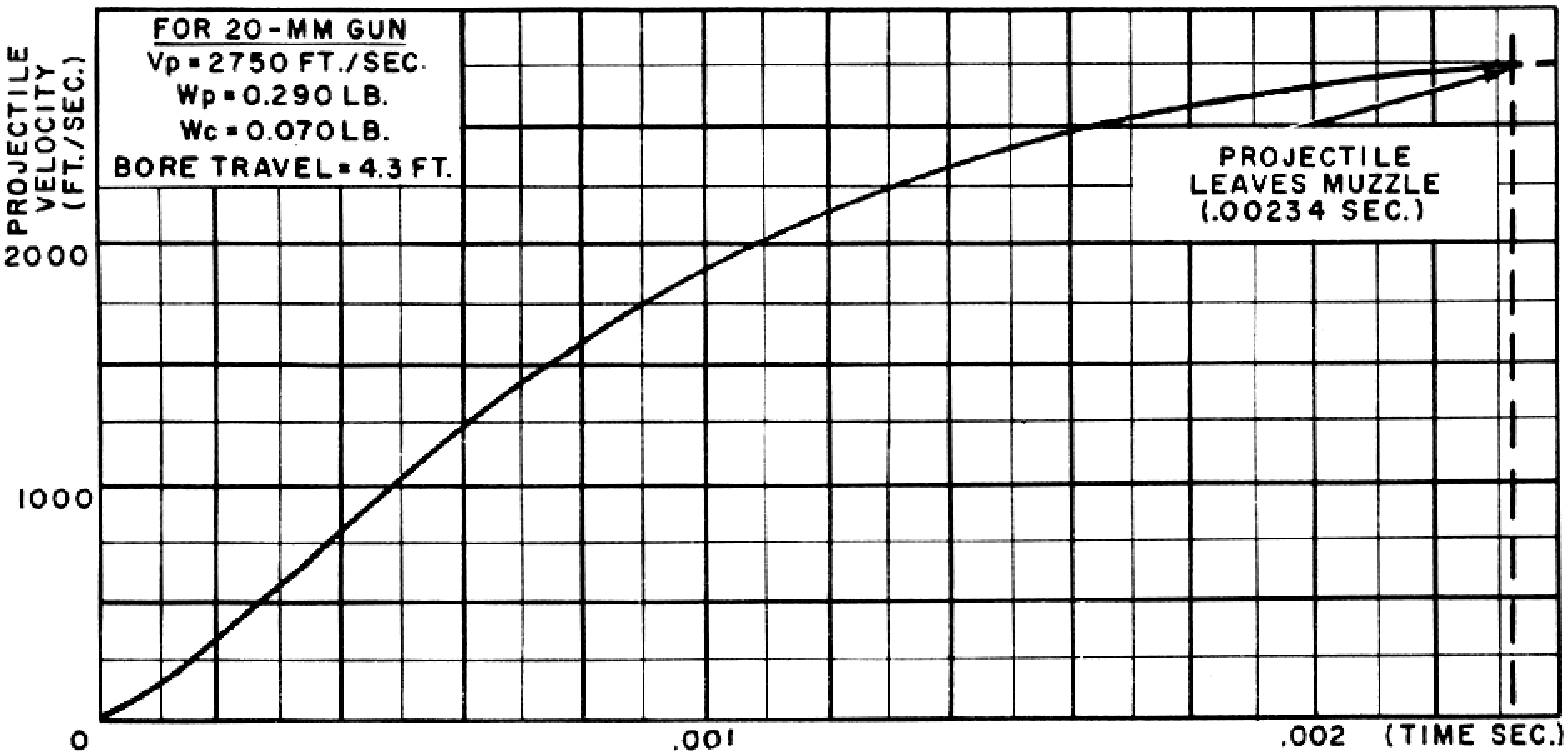

Figure 2-5. Graph of Projectile Velocity Versus Time (20 mm Gun).

and bore travel are available (figs. 2-4, 2-5, and 2-6).

NOTE: For some design problems, all or part of this information may not be available. Analytical methods by which the required data and graphs can be approximated for use in preliminary studies may be determined by conventional interior ballistics computations.

As has been explained, the primary factor affecting the performance of a long-recoil operated gun is the weight of the recoiling parts and in order to obtain a reasonable rate of fire, this weight must be kept to the bare minimum consistent with the requirements for strength, rigidity, and durability. The weight of these parts will be affected not only by strength considerations but also by the particular configuration of the mechanism selected by the designer. (For example, if the designer wishes to have the bolt slide in a long barrel extension, the recoiling parts might be heavier than they would be if the bolt moved on guide rails which were part of the receiver.) Accordingly, in order to determine the weight of the recoiling parts, the barrel must be designed first and the remainder of the mechanism must be planned at least to the extent which will make it possible to obtain a fair preliminary estimate of what weights will be involved. In the process of planning the mechanism it will also be necessary to determine what distances the parts must travel.

Of course, the final dimensions and weights of some of the recoiling parts can not be defined until complete consideration is given to the forces which act on these parts as the result of the accelerations and shocks to which they are subjected in operation and which yet remain to be determined. However, the estimated weight obtained from a carefully made preliminary design and layout should be accurate enough to serve as the starting point for the calculations necessary to determine the operating forces. It is these calculations which are the main concern of the following analysis.

As the analysis progresses, its application will be illustrated by means of sample calculations. Although these calculations and the related graphs are for a specific 20-mm cartridge and barrel and are based on an assumed weight of recoiling parts, the methods are generally applicable to long-recoil guns of any caliber. The calculations cover the following important points:

1. Determination of the conditions of free recoil.
2. Determination of the data necessary for designing barrel spring and bolt driving spring which will permit the recoil distance required for feeding.
3. Computation of the rate of fire.
4. Development of graphs showing how the velocity and travel of the recoiling parts vary with time.

Symbols Used in Analysis

- A Area of bore cross-section—in.^{2}
- B Ratio between average forces of barrel spring and bolt spring.
- C Arbitrary constant of integration (also ratio between masses of barrel and bolt).
- D Total recoil travel of bolt—ft.
- d Recoil travel of bolt for time t—ft.
- d Distance recoiled in first 0.010 second—ft.
- E_r Initial bolt energy—ft. lb.
- F_{av} Average combined force of barrel and bolt spring over distance D—lb.
- F_{av_1} Average force of barrel spring over distance D—lb.
- F_{av_2} Average force of bolt spring over distance D—lb.
- F_o Combined initial compression of barrel spring and bolt spring—lb.
- F_{o_1} Initial compression of barrel spring—lb.
- F_{o_2} Initial compression of bolt spring—lb.
- g Acceleration of gravity—32.2 ft./sec.^{2}
- K Combined spring rate of barrel and bolt springs—lb./ft.
- K_1 Spring rate of barrel spring—lb./ft.
- K_2 Spring rate of bolt spring—lb./ft.
- M_c Mass of powder charge—lb. sec.^{2}/ft.
- M_p Mass of projectile—lb. sec.^{2}/ft.
- M_r Total mass of recoiling parts—lb. sec.^{2}/ft.
- M_1 Mass of barrel—lb. sec.^{2}/ft.
- M_2 Mass of bolt—lb. sec.^{2}/ft.
- P Muzzle pressure—lb./in.^{2}
- T Time to recoil—sec.
- T′ Total cycle time—sec.
- T_1 Time for counter-recoil of barrel—sec.
- T_2 Time for return of bolt—sec.
- t Time—sec.
- t_r Approximate total return time for barrel and bolt—sec.
- T_{res} Time of duration of residual pressure—sec.
- V_p Muzzle velocity of projectile—ft./sec.
- v_p Velocity of projectile in bore at time t—ft./sec.
- v_r Velocity of retarded recoil at time t—ft./sec.
- V_{r_f} Maximum velocity of free recoil—ft./sec.
- v_{r_f} Velocity of free recoil at time t—ft./sec.
- W_c Weight of powder charge—lb.
- W_p Weight of projectile—lb.
- W_r Weight of recoiling parts—lb.

5. Computation of the power absorbed by the recoiling parts.

In the course of describing these calculations, the following fundamental formulas will be developed and explained:

a. Momentum and velocity relation for time projectile is in bore.
b. Formula for determining momentum and velocity of free recoil.
c. Expression for duration of residual pressure.
d. Formula for determining initial energy of the recoiling parts.
e. Formulas for determining spring retardations.
f. Energy equation for recoiling parts and springs.
g. Formula for determining time to recoil.
h. Expression for computing rate of fire.

1. *Condition of free recoil*

Under the heading "Principles of Recoil" it was pointed out that, if a gun is mounted so that it can move freely without friction or any other restraint, the impulse of the recoil force will impart to the gun a rearward momentum equal to the total forward momentum of the projectile and powder gases. For the time the projectile is in the bore, this momentum relationship is expressed by the equation:

(2–1) $$M_r v_{r_f} = M_p v_p + M_c v_c$$

Since the powder gases will be thoroughly mixed by the turbulence created in the explosion it is reasonable to assume that the center of mass of the gases moves forward at one-half the velocity of the projectile. Actually, this is not quite accurate because the presence of the enlargement at the chamber and the fact that the rifling does not extend the full length of the space occupied by the gases creates a condition in which the volume of the space is not uniformly distributed along its length. Nevertheless, the assumption is close enough for present purposes. Therefore equation 2–1 may be rewritten as:

(2–2) $$M_r v_{r_f} = M_p v_p + M_c \frac{v_p}{2} = \left(M_p + \frac{M_c}{2}\right) v_p$$

NOTE: It should be pointed out here that the momentum equality expressed by equation 2–2 is not affected by the internal frictional forces opposing the motion of the projectile and powder gases or by the forces incident to engraving the rifling band and to imparting the rotational velocity of the projectile. Although all of these forces retard the forward motion

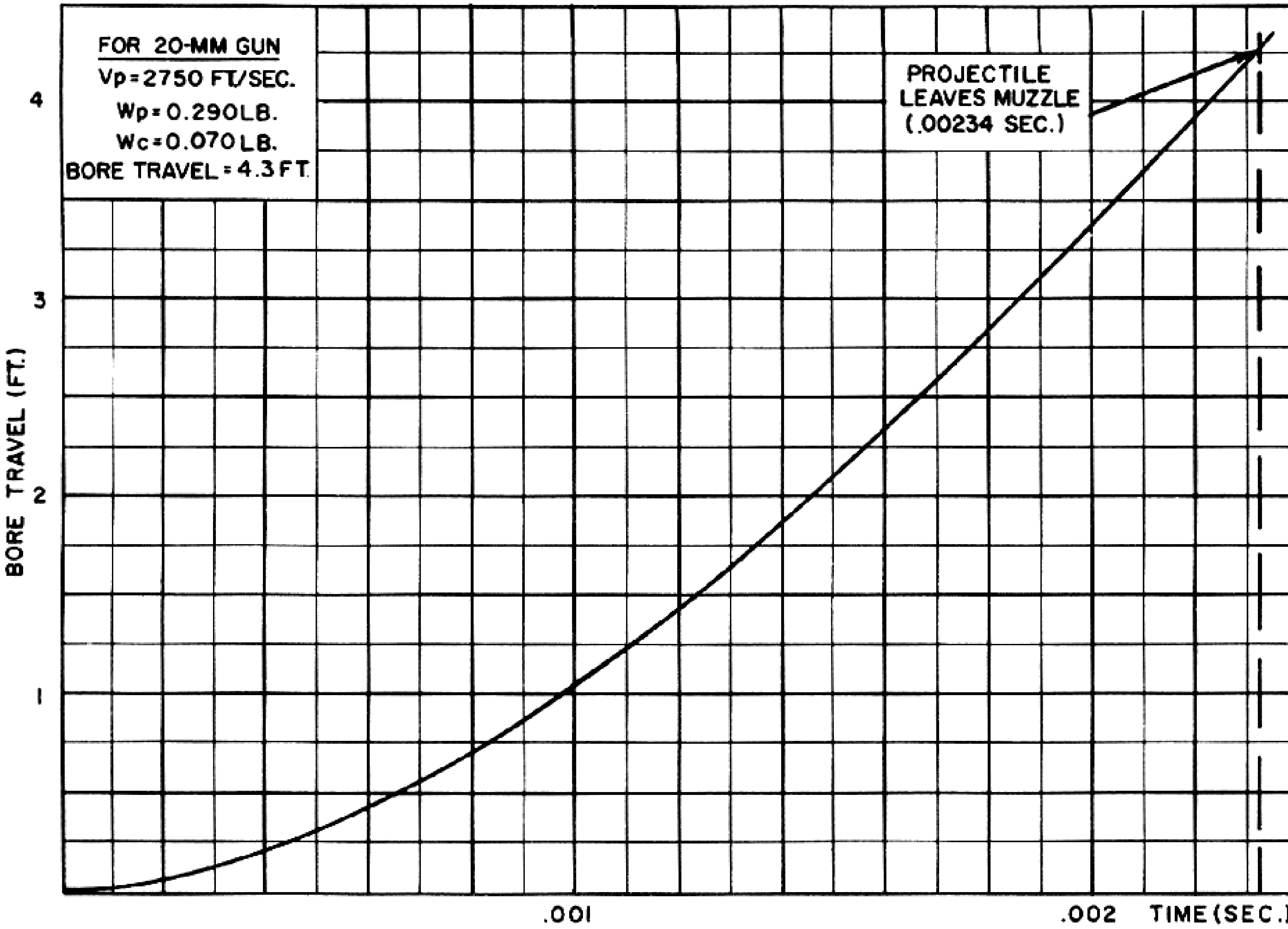

Figure 2–6. Graph of Projectile Bore Travel Versus Time (20 mm. Gun).

of the projectile and powder gases, they produce equal and opposite reactions on the barrel which result in a corresponding retardation of the rearward movement of the gun. In other words, the internal resistances merely decrease the effective impulse producing motion but they do not cause any inequality in the forward and rearward momentums.

Solving equation 2–2 for v_{r_f} gives the velocity of free recoil for the time the projectile is in the bore as:

(2–3)
$$v_{r_f}=\frac{M_p+\frac{M_c}{2}}{M_r}v_p=\frac{W_p+\frac{W_c}{2}}{W_r}v_p$$

Equation 2–3 can be used to plot a curve showing the free recoil velocity versus time for the period before the projectile leaves the muzzle. The weights of the projectile and powder charge are both known and it is assumed that the weight of the recoiling parts have been estimated in accordance with a preliminary design plan. Also, the velocity of the projectile at any time is known from the available ballistic data (fig. 2–5). Therefore, the ordinate of the free recoil velocity curve at any time, t, can be found by multiplying the corresponding ordinate of the projectile velocity curve by the factor:

$$\frac{W_p+\frac{W_c}{2}}{W_r}$$

Assuming that in the 20-mm gun to be used as an example the estimated weight of the recoiling parts is 50 pounds and the weights of the projectile and powder charge are as shown in fig. 2–5, the value of the multiplying factor is:

$$\frac{W_p+\frac{W_c}{2}}{W_r}=\frac{.29+\frac{.070}{2}}{50}=.00650$$

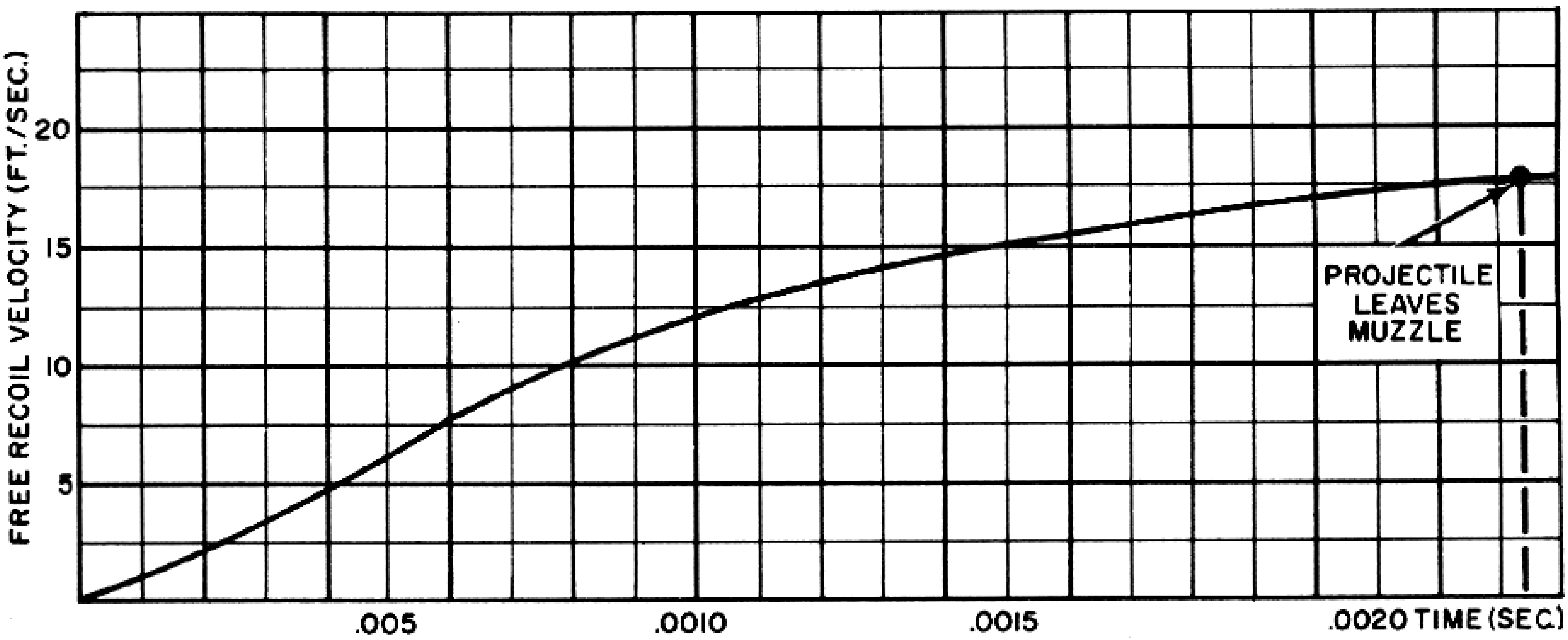

Figure 2–7. Free Recoil Velocity While Projectile Is in Bore.

Therefore, before the projectile leaves the muzzle, the free velocity of the recoiling parts is:

$$v_{r_f} = .00650\ v_p \left(\frac{\text{ft.}}{\text{sec.}}\right)$$

The curve obtained by using this relation is shown in fig. 2–7 and is also shown in fig. 2–8 as the portion between t=0 and t=.00234 second. (In fig. 2–8, the time axis is compressed in order to show how the velocity varies after the projectile leaves the muzzle.)

The manner in which the free recoil velocity varies after the projectile leaves the muzzle can not be determined from equation 2–3 because the projectile is no longer part of the system. Since the effect of the residual pressure can not be expected in simple terms, a special method is used to extend the curve obtained from equation 2–3. This method is based on the fact that the results of experimental firings of various guns show that the maximum velocity of free recoil may be closely approximated as:

(2–4) $$V_{r_f} = \frac{W_p V_p + 4700\ W_c}{W_r}$$

This relationship is equivalent to saying that the maximum momentum imparted to the recoiling parts is equal to the sum of the muzzle momentum of the projectile and the momentum of the powder gases, assuming that the powder gases leave the gun at an average velocity of 4700 feet per second. For the gun used as an example:

$$V_{r_f} = \frac{.29 \times 2750 + 4700 \times .070}{50} = 22.5 \left(\frac{\text{ft.}}{\text{sec.}}\right)$$

A line representing this value of the maximum velocity of free recoil is drawn on the velocity graph (fig. 2–8) and the curve previously drawn from equation 2–3 is extrapolated until it becomes tangent to the line. The point at which the curve becomes tangent represents the time at which the residual pressure becomes zero and therefore imparts no further velocity to the recoiling parts. Although an error in locating the exact point of tangency will not have any serious effect on the accuracy of the results, it may be of some assistance in plotting to determine this point by using Vallier's formula for approximating the duration of the residual pressure:

(2–5) $$T_{res} = \frac{M_c}{AP} (9400 - V_p)$$

For the sample cartridge and barrel:

$$T_{res} = \frac{.070}{32.2 \times \frac{\pi}{4} (.790)^2 \times 5000} (9400 - 2750)$$

$$= .00592 \text{ (sec.)}$$

To obtain the total time of action of the powder gases, this value is added to the time at which the projectile leaves the muzzle:

$$T_{res} = .00234 + .00592 = .00826 \text{ (sec.)}$$

Extending the original curve until it is tangent at this point gives the complete free recoil velocity

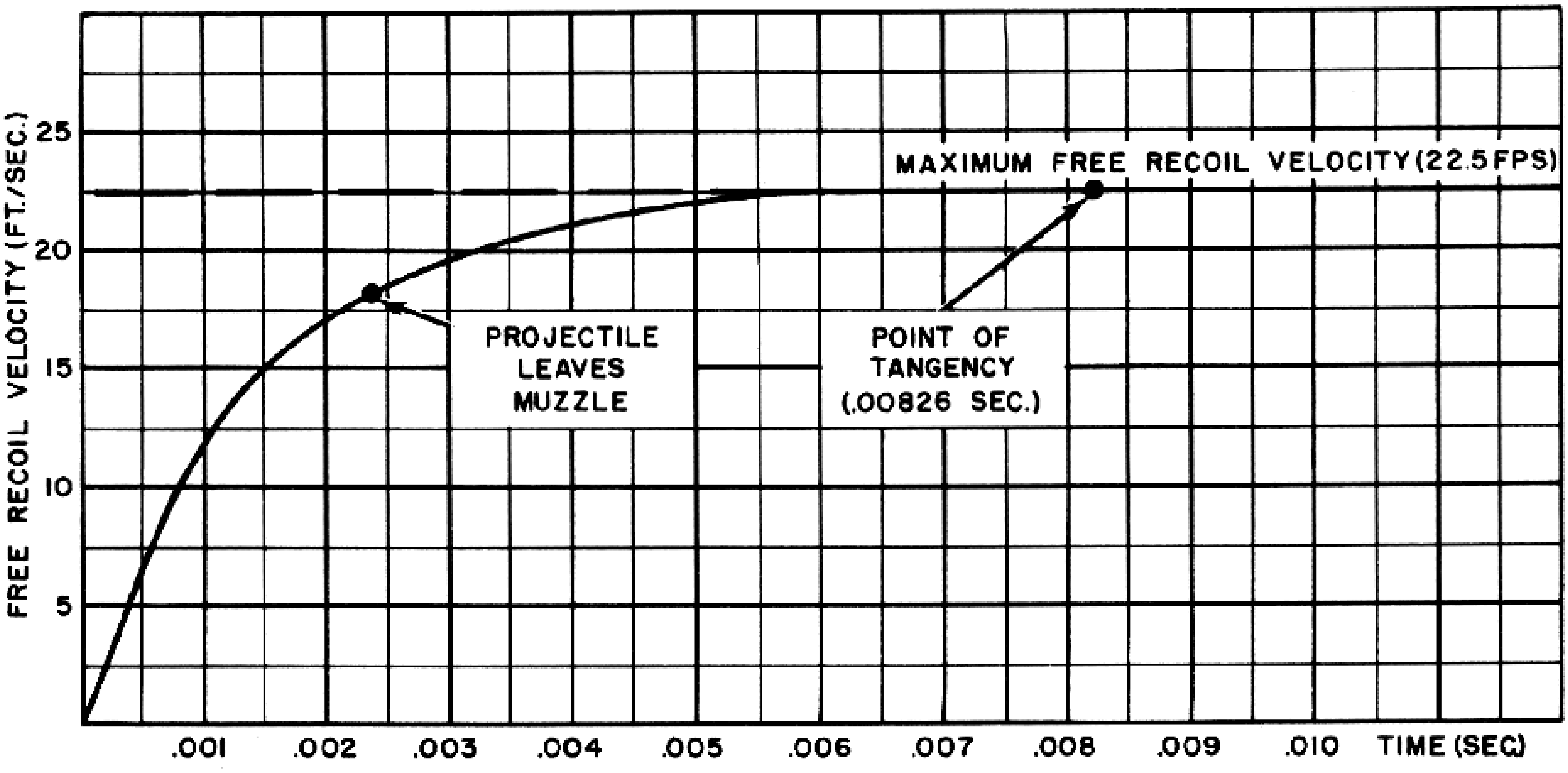

Figure 2–8. Free Recoil Velocity for First 0.010 Second.

curve shown in fig. 2–8. This curve will be used as the basis for the remainder of the calculations in this analysis.

2. *Determination of spring design data*

The calculations made for obtaining the free recoil velocity curve give the maximum velocity of free recoil as 22.5 feet per second. Since the total acceleration of the recoiling parts occurs in less than 0.010 second and since the retardation offered during this interval by the barrel spring and bolt driving spring will be very small, it may be assumed for purposes of considering the effect of the springs that an initial recoil velocity equal to the maximum velocity of free recoil is imparted instantaneously to the recoiling mass. On the basis of this assumption, the initial kinetic energy of the recoiling parts is given by the expression:

$$E_r = \frac{1}{2} M_r V_{r_f}^2 = \frac{W_r V_{r_f}^2}{2g} \text{ (ft. lb.)}$$

Evaluating this expression for the conditions of the example gives the initial bolt energy as:

$$E_r = \frac{50 \times 22.5^2}{2 \times 32.2} = 394 \text{ (ft. lb.)}$$

Since it has been assumed that this kinetic energy is instantaneously transferred to the recoiling parts, the springs must be proportioned to absorb this energy over the entire distance through which the barrel and bolt move in recoil. The energy absorbed by the springs is equal to the distance through which they are compressed times the average force required to produce this deflection. That is:

$$\text{(2–7)} \qquad E_r = F_{av} D \text{ or } F_{av} = \frac{E_r}{D}$$

If it is assumed that the bolt in the example must open 10.5 inches to permit feeding of a 20-mm cartridge (including a slight overtravel allowed to account for minor variations in the loading of the cartridges), the total recoil distance is 10.5 inches (0.875 feet). Therefore the average combined force of the barrel spring and bolt driving spring must be:

$$F_{av} = \frac{394}{.875} = 450 \text{ (lb.)}$$

It should be noted here that the friction between the recoiling parts and the slide will produce an essentially constant retarding force. If it is expected that the force required to overcome friction will be considerable, this force should be determined and subtracted from the average spring force computed by using equation 2–7. Ordinarily, however, the friction force should be small when compared to the average spring force of 450 pounds and for purposes of the present analysis, the friction force will be neglected.

Having the average combined spring force, it remains to choose spring characteristics such that this average force will result from compressing both barrel return and bolt springs through the required recoil distance. The first problem that presents itself in this connection is how the spring resistance should be proportioned between the springs. One obvious choice would be to make the spring resistances proportional to the weights of the barrel and bolt respectively but if it is important to obtain the maximum possible rate of fire, the particular spring combination which would produce this condition should be determined before the selection is made.

The effect of the manner in which the springs are proportioned to each other will become apparent during the counter-recoil strokes of the barrel and bolt. During recoil both springs act together but during counter-recoil the barrel spring returns the barrel to battery and then the bolt driving spring returns the bolt. The strength of the springs will determine the time in which these parts are returned and by proper choice of the springs, the total return time can be held to a minimum. The following calculations show how the ratio B between the average forces exerted by the barrel spring and bolt driving spring is determined so that the total return time will be minimum.

At the end of the counter-recoil movement, the kinetic energy in either the barrel or bolt will be equal to the average force exerted by its spring times the counter-recoil distance.

$$E=\frac{1}{2}MV^2=F_{av}D$$

Solving for the terminal velocity V gives:

$$V=\sqrt{\frac{2F_{av}D}{M}}$$

The time required for counter-recoil will be approximately inversely proportional to this velocity:

$$t_r\alpha\sqrt{\frac{M}{2F_{av}D}}$$

Therefore, the total return time for the barrel and bolt may be expressed as

$$t_r\alpha\sqrt{\frac{M_1}{2F_{av_1}D}}+\sqrt{\frac{M_2}{2F_{av_2}D}}$$

(Note that for simplicity, this relation does not consider the effects of the overtravel previously mentioned.)

Now:

$$M_1=CM_2$$

$$F_{av_1}+F_{av_2}=F_{av} \text{ and,}$$

$$F_{av_1}=B\,F_{av_2}$$

Solving the last two equations simultaneously for F_{av_1} and F_{av_2} gives:

$$F_{av_1}=\frac{F_{av}B}{B+1} \text{ and,}$$

$$F_{av_2}=\frac{F_{av}}{B+1}$$

In the equation for the total return time, substituting CM_2 for M_1 and the above values for F_{av_1} and F_{av_2} yields:

$$t_r\alpha\sqrt{\frac{CM_2}{2\frac{F_{av}B}{B+1}D}}+\sqrt{\frac{M_2}{2\frac{F_{av}}{B+1}D}}$$

Simplifying:

$$t_r\alpha\left[\sqrt{\frac{C(B+1)}{B}}+\sqrt{B+1}\right]\sqrt{\frac{M_2}{2F_{av}D}}$$

The value of t_r will be minimum when the factor enclosed in brackets is minimum; that is when

$$\frac{d}{dB}\left[\sqrt{\frac{C(B+1)}{B}}+\sqrt{B+1}\right]=0$$

$$\frac{d}{dB}\left[\sqrt{B+1}\left(\sqrt{\frac{C}{B}}+1\right)\right]=0$$

Differentiating:

$$\sqrt{B+1}\left(\frac{-\frac{C}{B^2}}{2\sqrt{\frac{C}{B}}}\right)+\left(\sqrt{\frac{C}{B}}+1\right)\frac{1}{2\sqrt{B+1}}=0$$

Solving for B:

$$\frac{\sqrt{B+1}}{B}\sqrt{\frac{C}{B}}=\left(\sqrt{\frac{C}{B}}+1\right)\frac{1}{\sqrt{B+1}}$$

$$\frac{B+1}{B}\sqrt{\frac{C}{B}}=\sqrt{\frac{C}{B}}+1$$

$$\left(\frac{B+1}{B}-1\right)\sqrt{\frac{C}{B}}=1$$

$$\frac{1}{B}\sqrt{\frac{C}{B}}=1$$

$$B=\sqrt[3]{C}$$

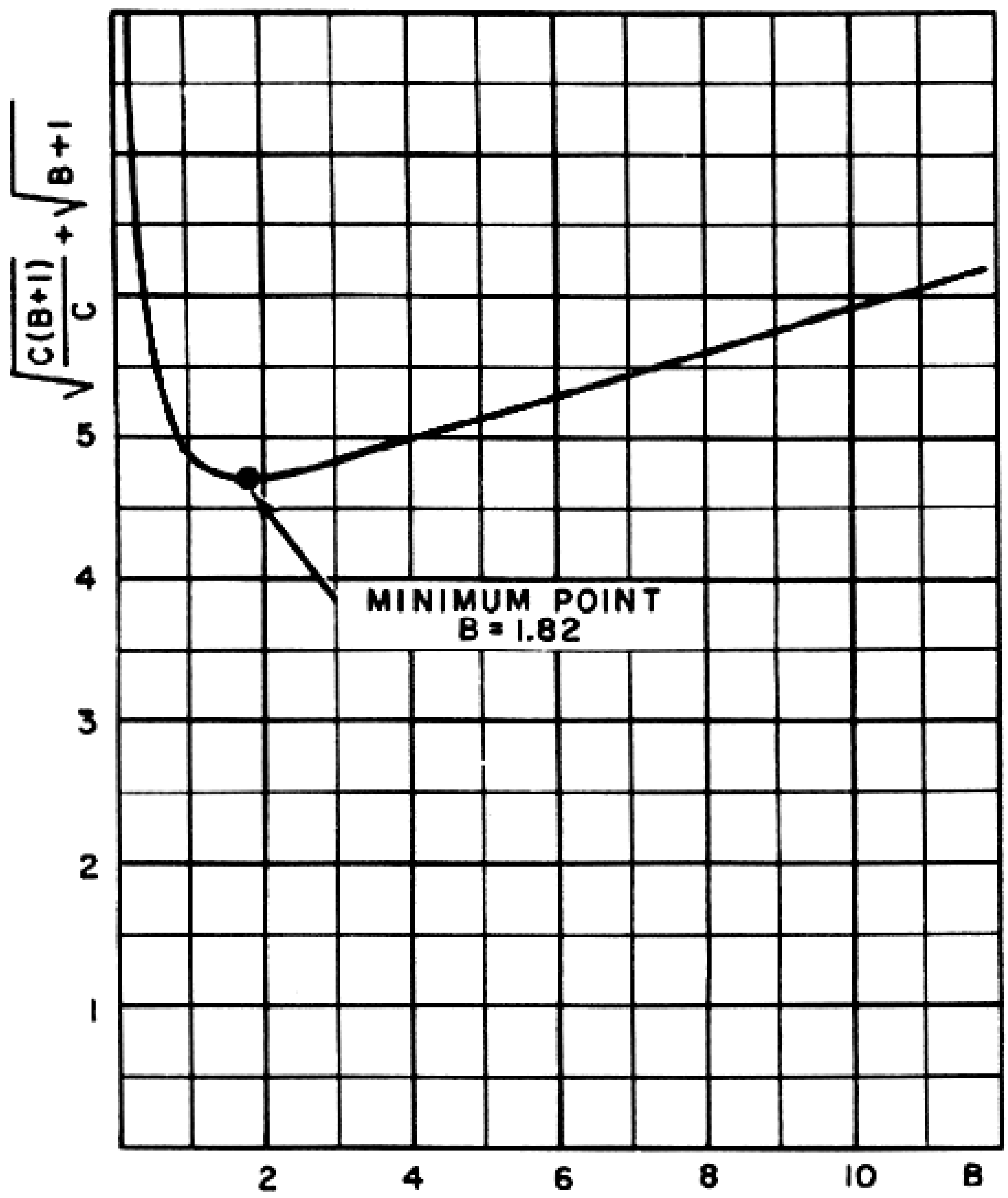

Figure 2–9. Graph Showing Values of Factor $\sqrt{\frac{C(B+1)}{C}}+\sqrt{B+1}$ Versus B When C=6.

Thus, it appears that the total counter-recoil time will be minimum if the barrel spring and bolt driving spring are proportioned to each other so that the ratio between their average forces is equal to the cube root of the ratio between the barrel weight and bolt weight. It will be assumed for purposes of the example that the barrel is six times heavier than the bolt, that is, C=6.

Fig. 2–9 shows the value of the factor

$$\left[\sqrt{B+1}\left(\sqrt{\frac{C}{B}}+1\right)\right]$$

for various values of B when C=6. Note that the curve reaches its minimum point at B=1.82 which is the cube root of 6. If this ratio between the spring forces were used in the example, the total required average force of 450 pounds breaks down so that the bolt spring would have an average force of 160 pounds and the average force of the barrel spring would be 290 pounds. It should be realized that the use of a bolt spring with an average force as high as 160 pounds would cause difficulty in charging the gun manually unless some mechanical aid is provided. For this reason, it may be desirable to increase the ratio B, thus sacrificing some speed of operation for ease in charging. However, if the gun is to be charged pneumatically or by some other means, the computed values are not unreasonable and will therefore be employed for the remainder of the analysis.

The next problem relating to the design of the springs is to choose values for the initial compression F_o and the spring constant K such that the required average force will be obtained when the springs are compressed through the desired recoil distance (10.5 inches in the example). As has been mentioned before, the practical problems involved in designing springs for machine guns require very careful analysis to take into consideration such factors as spring losses, forced vibrations set up along the length of the spring, shock loads, and other complications. If this is not done, serious operational difficulties or even failure of the spring may result. For this reason, the design of springs which are to be subjected to large and rapidly varying forces is a highly specialized art in the field of machine design and often a satisfactory spring for a machine gun can be found only by experimental means. Since it is beyond the scope of the present analysis to attempt a practical spring design at this point, an arbitrary selection of the spring characteristics will be made.

In making the selection of F_o and K for the springs of the gun used as an example, the value of F_o will be kept relatively small in order to gain an advantage in regard to rate of fire. (Cf. paragraph 5 in the mathematical analysis of the plain blowback system.) For the barrel spring, an initial compression of 115 pounds is reasonable and this choice requires that the maximum force be 465 pounds to produce the required average force of 290 pounds. Since the difference between the maximum force and initial compression is 350 pounds and the recoil distance is 10.5 inches (0.875 feet), the spring rate will be 400 pounds per foot or 33.3 pounds per inch. For the bolt spring, if F_o is selected as 55 pounds, the average force of 160 pounds will be obtained if the maximum force is 265 pounds. The difference between the maximum force is then 210 pounds. Since the recoil distance is 0.875 feet, the spring rate is 240 pounds per foot or 20 pounds per inch.

The foregoing determinations complete the basic preliminary design of the gun and the remaining task is to investigate what performance this design may be expected to give.

3. *Derivation of recoil equations*

Having the estimated weights of the recoiling parts and having the characteristics of the barrel spring and bolt spring, the performance of the gun can be determined by considering the energy relations which exist during recoil. These relations are expressed by a number of important equations which will be derived on the basis of the fact that as the recoiling parts move to the rear, the springs absorb and store the kinetic energy imparted by the propellant explosion. If it is assumed that the recoil energy is imparted instantaneously and that the losses due to friction and other causes are negligible, the energy remaining in the recoiling parts at any time during recoil is expressed by the equation:

(2-8)

$$\frac{M_r v_r^2}{2}=E_r-\int_0^d (F_o+Kd)\,dd=E_r-\left(F_o d+\frac{Kd^2}{2}\right)$$

NOTE: In this equation, F_o represents the combined initial compressions of the barrel spring (F_{01}) and of the bolt spring (F_{02}). Similarly K represents the combined spring rate of the barrel spring K_1 and of the bolt spring, K_2.

This equation may be used for deriving the equation expressing the relation between time and the motion of the recoiling parts as follows: Solving for v_r gives:

$$v_r=\sqrt{-\frac{K}{M_r}d^2-\frac{2F_o}{M_r}d+\frac{2E_r}{M_r}}=\frac{dd}{dt}$$

$$dt=\frac{dd}{\sqrt{-\frac{K}{M_r}d^2-\frac{2F_o}{M_r}d+\frac{2E_r}{M_r}}}$$

From a table of integrals, this expression is of the form:

$$\int\frac{dd}{\sqrt{ad^2+bd+c}}=\frac{1}{\sqrt{-a}}\sin^{-1}\frac{-2\,ad-b}{\sqrt{b^2-4\,ac}}+C$$

where:

$$a=-\frac{K}{M_r}\ (a<0)$$

$$b=-\frac{2F_o}{M_r}$$

$$c=+\frac{2E_r}{M_r}$$

Therefore:

$$t=\sqrt{\frac{M_r}{K}}\left[\sin^{-1}\frac{\frac{2K}{M_r}d+\frac{2F_o}{M_r}}{\sqrt{\frac{4F_o^2}{M_r^2}+\frac{8KE_r}{M_r^2}}}\right]+C$$

$$=\sqrt{\frac{M_r}{K}}\left[\sin^{-1}\frac{Kd+F_o}{F_o^2+2KE_r}\right]+C$$

But at the end of the recoil movement, the energy stored in the driving spring is equal to the initial bolt energy. That is:

$$E_r=F_oD+\frac{KD^2}{2}$$

Therefore:

$$F_o^2+2KE_r=F_o^2+2K\left(F_oD+\frac{KD^2}{2}\right)$$

$$=F_o^2+2KF_oD+K^2D^2$$

$$=(F_o+KD)^2$$

Substituting this value in the equation for t gives:

$$t=\sqrt{\frac{M_r}{K}}\sin^{-1}\frac{Kd+F_o}{KD+F_o}+C$$

To evaluate C: when t=0, d=0 and therefore

$$C=-\sqrt{\frac{M_r}{K}}\sin^{-1}\frac{F_o}{KD+F_o}$$

Substituting this expression for C gives the equation for the time, t, required to recoil any distance, d.

(2-9) $$t=\sqrt{\frac{M_r}{K}}\left[\sin^{-1}\frac{Kd+F_o}{KD+F_o}-\sin^{-1}\frac{F_o}{KD+F_o}\right]$$

Solving this equation for d gives the inverse relation expressing the distance recoiled in any time, t.

(2-10) $$d=\frac{KD+F_o}{K}\sin\left[\sqrt{\frac{K}{M_r}}\,t+\sin^{-1}\frac{F_o}{KD+F_o}\right]-\frac{F_o}{K}$$

Equation 2–9 may also be used to obtain the total time, T, required for the recoiling parts to move through the entire recoil distance, D. Substituting D for d gives:

(2–11) $$T=\sqrt{\frac{M_r}{K}}\left[\sin^{-1}1-\sin^{-1}\frac{F_o}{KD+F_o}\right]$$

$$T=\sqrt{\frac{M_r}{K}}\left[\frac{\pi}{2}-\sin^{-1}\frac{F_o}{KD+F_o}\right]$$

$$=\sqrt{\frac{M_r}{K}}\left(\cos^{-1}\frac{F_o}{KD+F_o}\right)$$

or:

$$T=\sqrt{\frac{M_{r_1}+M_{r_2}}{K_1+K_2}}\left[\cos^{-1}\frac{F_{o_1}+F_{o_2}}{(K_1+K_2)D+F_{o_1}+F_{o_2}}\right]$$

If it is assumed that the losses are negligible, the times required for the barrel and bolt to return to the firing position may be determined by the use of equation 2–11 providing that the proper values are substituted for M_r, K, F_o, and D. Making these substitutions and adding the times gives the time for a complete cycle as:

(2–12)

$$T'=\sqrt{\frac{M_{r_1}+M_{r_2}}{K_1+K_2}}\left[\cos^{-1}\frac{F_{o_1}+F_{o_2}}{(K_1+K_2)D+F_{o_1}+F_{o_2}}\right]+\sqrt{\frac{M_{r_1}}{K_1}}\left[\cos^{-1}\frac{F_{o_1}}{K_1D+F_{o_1}}\right]+\sqrt{\frac{M_{r_2}}{K_2}}\left[\cos^{-1}\frac{F_{o_2}}{K_2D-F_{o_2}}\right]$$

Note that in the last two terms of equation 2–12, no consideration is given to the overtravel which was allowed in the design. (See fig. 2–3.) The resulting error is so slight that there is no need to complicate the equation further by taking it into account.

Since T′ is the total time required for one complete cycle of operation, the rate of fire in rounds per minute will be:

(2–13) $$N=\frac{60}{T'}$$

For the conditions of the example, N is evaluated as follows:

The total weight of the recoiling parts is 50 pounds. The effective weight of the barrel and its related parts will be taken as 40 pounds and the effective weight of the bolt and its related parts will be taken as 10 pounds. Therefore:

$$T'=\sqrt{\frac{40+10}{32.2(400+240)}}\left(\cos^{-1}\frac{115+55}{(400+240).875+114+55}\right)+\sqrt{\frac{40}{32.2\times400}}\left(\cos^{-1}\frac{115}{400\times.875+115}\right)+\sqrt{\frac{10}{32.2\times240}}\left(\cos^{-1}\frac{55}{240\times.875+55}\right)$$

$$=.0660+.0737+.0487$$

$$=0.1884\ \text{(second)}$$

The rate of fire is then:

$$N=\frac{60}{.1884}=319\ \text{(rounds per minute)}$$

(This rate of fire is based on the use of springs which absorb all of the recoil energy. As pointed out previously, some improvement in the rate might be gained by using lighter springs and permitting the parts to rebound from buffers at the end of recoil but since such a gain would not be very great, no consideration will be given to this method here.)

With the rate of fire and recoil energy known, the horsepower absorbed by the recoiling parts can be computed by means of the formula:

(2–14) $$HP=\frac{E_rN}{33{,}000}$$

The horsepower absorbed by the recoiling parts in the gun of the example will be:

$$HP=\frac{394\times319}{33{,}000}=3.81$$

4. *Development of theoretical time-travel and time-velocity curves.*

In the design of the various details of the breech mechanism and of the other gun mechanisms such as the feeder and firing device, it is necessary to have information relating to the motion of the recoiling parts during the progress of the cycle of operation. This information can be presented in convenient form by means of theoretical curves which show the relation between time, the travel of the recoiling parts, and the velocity of the recoiling parts. Such curves may be drawn by using the formulas developed under the preceding heading, but it should be realized that all of these formulas are based on the assumption that the initial energy was transferred instantaneously to the recoiling parts. Therefore, curves plotted in this way would not take account of the detailed effects resulting from the conditions which exist during the time of action of the powder gas pressures. This time is so short that it will be relatively negligible when the overall cycle of operation is considered, particularly if the rate of fire is low. However, for higher rates of fire, the time of action of the powder gas pressure may represent a small but significant portion of the time required for recoil and accordingly should be given due consideration in plotting bolt motion curves. In addition, because of the high accelerations which occur during the propellant explosion, it is highly desirable to determine in detail what motion characteristics may be expected in the initial portion of the recoil stroke.

The effects of the powder gas pressure can not be expressed by simple equations and therefore a special method is employed to account for these effects in plotting the bolt motion curves. The method consists essentially of first plotting a curve of free recoil velocity and then subtracting from each ordinate of this curve the velocity loss resulting from the retarding effects of the springs.

The curves showing the velocity of free recoil versus time were developed previously and are shown in figs. 2–7 and 2–8. These curves will be used to illustrate the following description of the method.

To determine the retarding effects of the spring, use is made of the law expressed by the equation:

(2–15) $$F dt = M dv$$

This law states that the change in the momentum of a mass is equal to the applied impulse (the product of the force and the time for which it is applied). Solving for dv gives:

$$dv = \frac{F dt}{M}$$

To obtain the variation of the change in velocity with respect to time, this expression is integrated.

(2–16) $$v = \int_0^t \frac{F dt}{M} = \frac{1}{M}\int_0^t F dt$$

In accordance with equation 2–16, the retarding effect of a force on a given mass can be determined as follows:

1. Plot a curve showing the variation of the force with respect to time.
2. Measure the area under the curve between $t=0$ and some time t_1.
3. Divide the measured area by the mass. This gives the ordinate of the retardation curve for the time t_1.
4. Repeat steps 2 and 3 for other values of t and plot the retardation curve.

Applying this procedure using the mass of the recoiling parts and the combined resistance of the barrel spring and bolt spring produces a curve showing the loss in recoil velocity resulting from the action of the springs. Since the free recoil velocity curve shows the gain in velocity resulting from the thrust of the powder gases, the difference between the curves will be the net recoil velocity, or in other words the velocity of retarded recoil.

The foregoing method would be very simple if the retarding force were constant or if the variation of this force with respect to time were known. However, when the force varies with recoil travel as it does with the springs assumed for purposes of analysis, a difficulty is encountered. In order to plot a graph showing the variation of the retarding force with respect to time, it is necessary to have a curve showing the variation of the recoil travel with respect to time, and the latter curve is one of those which yet remain to be determined.

To overcome this difficulty, the problem is considered in two stages. For the first 0.010 second while the powder gas pressures are acting, the loss in velocity resulting from the retarding effect of the springs will be relatively small and will be almost entirely due to the constant effect of the initial compression. The varying force due to the spring constant during this interval of time will almost certainly be negligible but, if necessary, it can be approximated very closely. In this way, accurate results can be obtained for the first 0.010 second and for the remainder of the cycle of operation, while the powder gas pressures are not acting, the recoil travel can be determined analytically without any trouble.

The procedure for plotting the velocity and travel curves during the first 0.010 second is as follows:

1. Plot curve of free recoil velocity versus time (fig. 2–7).

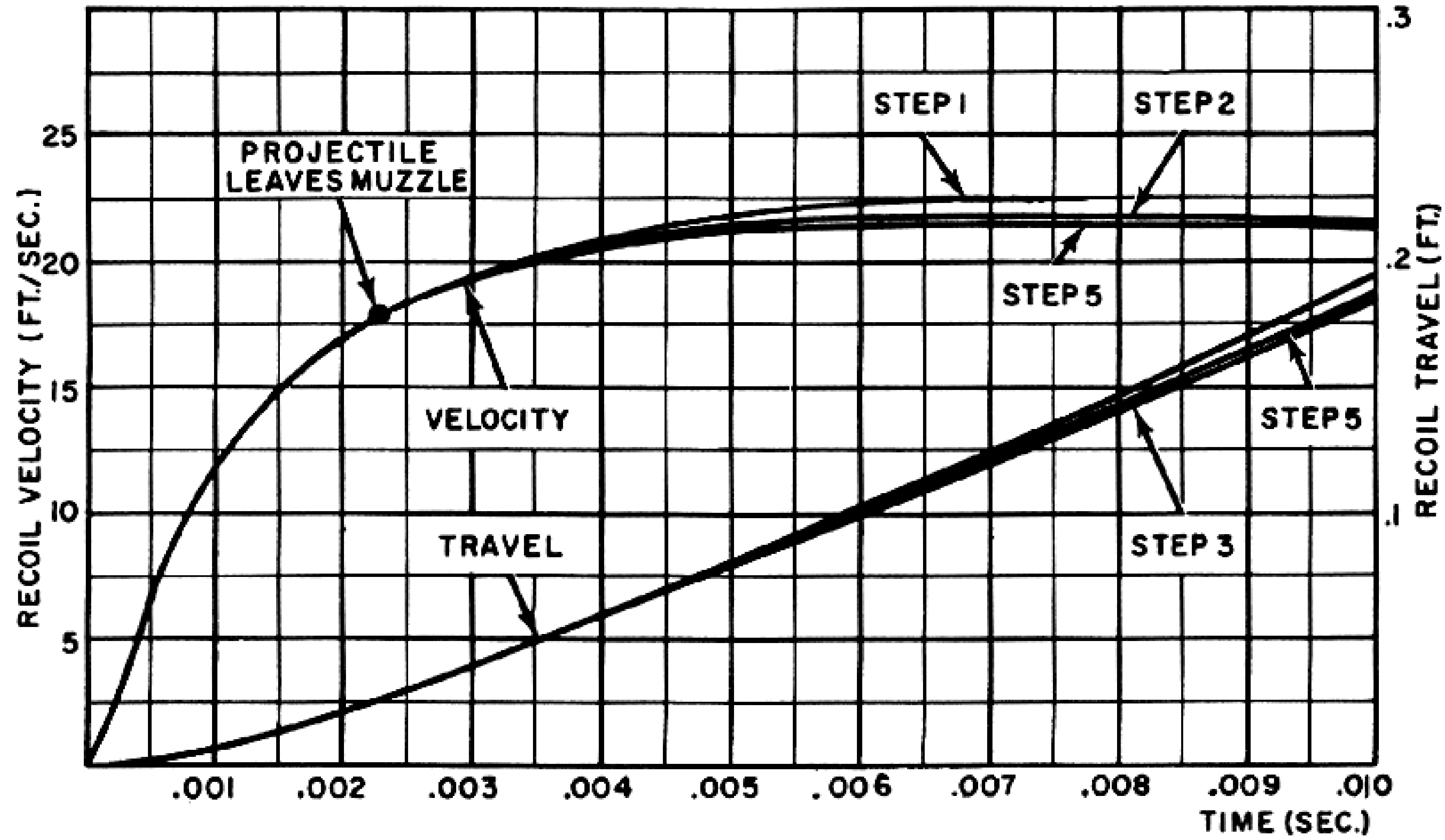

Figure 2–10. Development of Time-Travel Curves for First 0.010 Second.

2. The loss in velocity due to the initial compression of the springs is equal to:

$$\frac{(F_{o_1}+F_{o_2})\ t}{M_r}$$

Determine the velocity loss for various values of t, substract each from the corresponding ordinate of the free recoil velocity curve and draw a curve through the resulting points. If the effect of the spring constant proves to be negligible, this curve is the retarded velocity curve.

3. Integrate under the curve drawn in step 2 to obtain the displacement curve.
4. Assume that the curve drawn in step 3 represents the actual time-travel curve and use this curve to determine the retardation due to the spring constant. (Use the combined spring constant for the barrel spring and bolt spring, K_1+K_2.) Ordinarily, it will be found that this retardation is so small that it will not have any effect worthy of consideration.
5. In the event that the retardation determined in step 4 is sufficient to affect the velocity, use it to modify the curve drawn in step 2 and then integrate under the new curve to obtain a corrected displacement curve.
6. Steps 4 and 5 can be repeated as often as is necessary until no significant change occurs in the displacement curve. Actually, this process of successive approximation should never be necessary and satisfactory results should be achieved in the first three steps or at least in the first five steps.

Fig. 2–10 shows the curves obtained for the gun of the example. The total loss in velocity due to the combined effect of the initial compressions of the springs during the first 0.010 second is:

$$V=\frac{(F_{o_1}+F_{o_2})\ t}{M_r}=\frac{(115+55).01\times 32.2}{50}$$

$$=1.09\left(\frac{\text{ft.}}{\text{sec.}}\right)$$

The loss due to the combined effect of the spring constants as determined by the method of step 4 is only about 0.345 foot per second. The final curves shown in fig. 2–10 are the result of performing step 5. Since the velocity loss due to the effect of the spring constant is so small, step 6 need not be taken.

The remainder of the displacement curve for the recoil stroke can now be determined analytically by using equation 2–10:

$$d=\frac{KD+F_o}{K}\sin\left[\sqrt{\frac{K}{M_r}}\ t+\sin^{-1}\frac{F_o}{KD+F_o}\right]-\frac{F_o}{K}$$

However, since some recoil travel (d′) occurred during the first 0.010 second, the values of F_o, D, and t must be modified to take this motion into account and d′ must be added to the resulting values obtained for d. Also note that the values for K, F_o, D, and M_r must be selected to suit the particular portion of the operating cycle under consideration. During recoil, both springs act on the total mass of the recoiling parts but in counter-recoil the barrel is returned to battery first while the bolt remains latched and then the bolt is returned. Thus it is necessary to consider the motions in three phases: recoil motion, barrel counter-recoil, and bolt return.

To account for the recoil movement during the time of action of the powder gases, the following changed values are used in equation 2–10:

$$F_o' = F_o + Kd' \text{ or } F_o' = F_{o_1} + F_{o_2} + (K_1 + K_2)d'$$

$$D' = D - d'$$

$$t' = t - .010$$

Also since the barrel and bolt and their springs act as a unit during the recoil stroke, the following substitutions are also made in equation 2–10:

$$F_o = F_{o_1} + F_{o_2}$$

$$K = K_1 + K_2$$

$$M_r = M_{r_1} + M_{r_2}$$

Making these substitutions gives the modified form of equation 2–10 as it applies to the recoil stroke as:

$$d = \frac{(K_1+K_2)(D-d') + F_{o_1} + F_{o_2} + (K_1+K_2)d'}{K_1+K_2} \sin\left[\sqrt{\frac{K_1+K^2}{M_{r_1}+M_{r_2}}}(t-.010) + \sin^{-1}\frac{F_{o_1}+F_{o_2}+(K_1+K_2)d'}{(K_1+K_2)(D-d')+F_{o_1}+F_{o_2}+(K_1+K_2)d'}\right] - \frac{F_{o_1}+F_{o_2}-(K_1+K_2)d'}{K_1+K_2} + d'$$

Simplifying:

$$d = \frac{(K_1+K_2)D + F_{o_1} + F_{o_2}}{K_1+K_2} \sin\left[\sqrt{\frac{K_1+K_2}{M_{r_1}+M_{r_2}}}(t-.010) + \sin^{-1}\frac{F_{o_1}+F_{o_2}+(K_1+K_2)d'}{(K_1+K_2)D+F_{o_1}+F_{o_2}}\right] - \frac{F_{o_1}+F_{o_2}+(K_1+K_2)d'}{K_1+K_2} + d'$$

This equation is employed to plot the displacement curve from the time t=0.010 until the bolt is latched at the rear. Since the design used as example allows for only a very slight overtravel, this overtravel will be neglected and it will be considered that the bolt is latched when the counter-recoil movement is equal to D (0.875 foot).

After the bolt is latched and the bolt lock is opened, the barrel continues its forward movement in counter-recoil and is now driven by the barrel spring alone. The movement of the barrel during this time can be determined by using equation 2–10 in a special way. Since the barrel spring only is acting, the value K_1 is substituted for K, F_{o_1} is substituted for F_o, and M_{r_1} is substituted for M_r. In the equation, the time used for determining the barrel counter-recoil curve must be equal to $t+(T_1-T)$; where T is the time to recoil expressed by equation 11, and T_1 is the time required for the barrel alone to complete its counter-recoil movement. This substitution is necessary because the period of the sine curve expressing the barrel counter-recoil movement is different from that of the curve expressing the recoil movement of the combined mass of the barrel and bolt. Making the necessary substitutions gives the modified form of equation 2–10 as it applies to the barrel counter-recoil movement as:

$$d = \frac{K_1D + F_{o_1}}{K_1} \sin\left[\sqrt{\frac{K_1}{M_{r_1}}}(t+T_1-T) + \sin^{-1}\frac{F_{o_1}}{K_1D+F_{o_1}}\right] - \frac{F_{o_1}}{K_1}$$

This equation is applicable from the time t=T to the time $t=T+T_1$ at which time the curve reaches the zero axis.

For purposes of analysis, it will be assumed that the bolt is unlatched just as the barrel reaches the battery position at the time $t=T+T_1$. The movement of the bolt after its release can be determined by using equation 2–10 in the same general way as for the barrel. In this case, since the bolt is driven by the bolt spring alone, the value K_2 is substituted for K, F_{o_2} is substituted for F_o, and M_{r_2} is substi-

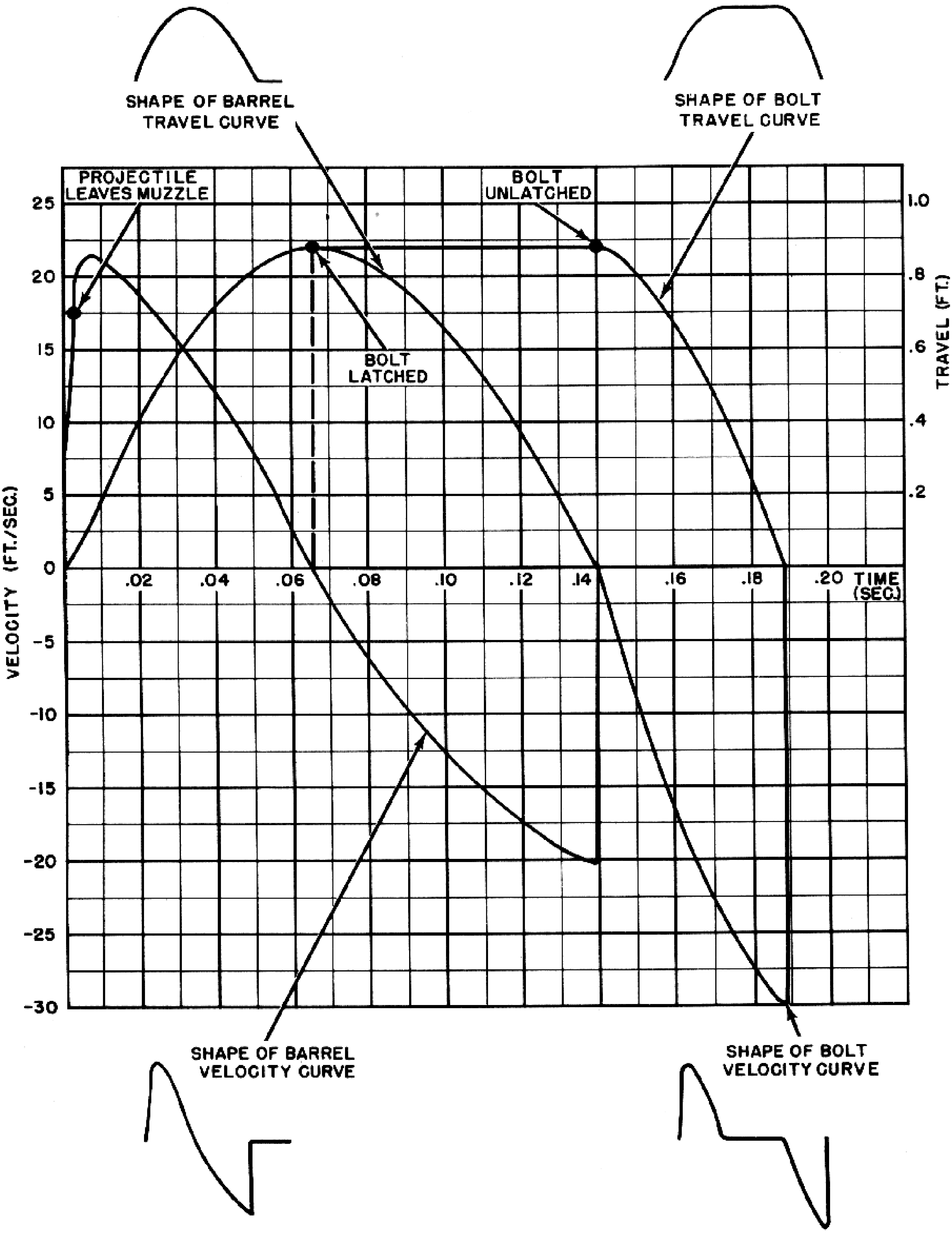

Figure 2–11. Time-Travel and Time-Velocity Curves (Complete Cycle).

tuted for M_r. The time used in the equation must be equal to $t+T_2-(T+T_1)$; where T_2 is the time required for the bolt alone to complete its return movement. This substitution is necessary for the same reason as explained in the preceding paragraph. Making the indicated substitutions gives the modified form of equation 2–10 as it applies to the bolt return movement as:

$$d=\frac{K_2+F_{o_2}}{K_2}\sin\left[\sqrt{\frac{K_2}{M_{r_2}}}(t+T_2-T-T_1)+\sin^{-1}\frac{F_{o_2}}{K_2D+F_{o_2}}\right]-\frac{F_{o_2}}{K_2}$$

This equation is applicable from the time $t=T+T_1$ to the time $t=T+T_1+T_2$, at which time the curve reaches the zero axis.

The three equations described in the preceding paragraph are used to complete the curves showing the recoil and counter-recoil movements of the barrel and bolt. The resulting curves can be used to determine curves showing the variation with time of the forces exerted by the springs during the various parts of the cycle of operation. To obtain the spring force curves for the recoil stroke, the ordinates of the corresponding portion of the displacement curve are multiplied by the factor K_1+K_2 and are increased by $F_{o_1}+F_{o_2}$. For the barrel counter-recoil movement, the spring force curve is determined by multiplying each ordinate of the corresponding portion of the displacement curve by K_1 and increasing the result by F_{o_1}. The spring force curve for the bolt return stroke is determined in the same way using K_2 and F_{o_2}. Integrating under the first portion of the curve and dividing by $M_{r_1}+M_{r_2}$ in accordance with equation 2–16 gives a graph showing the loss in recoil velocity resulting from the combined force of the barrel and bolt springs. Subtracting this curve from the free bolt velocity curve produces the graph showing the retarded recoil velocity. The curve showing the

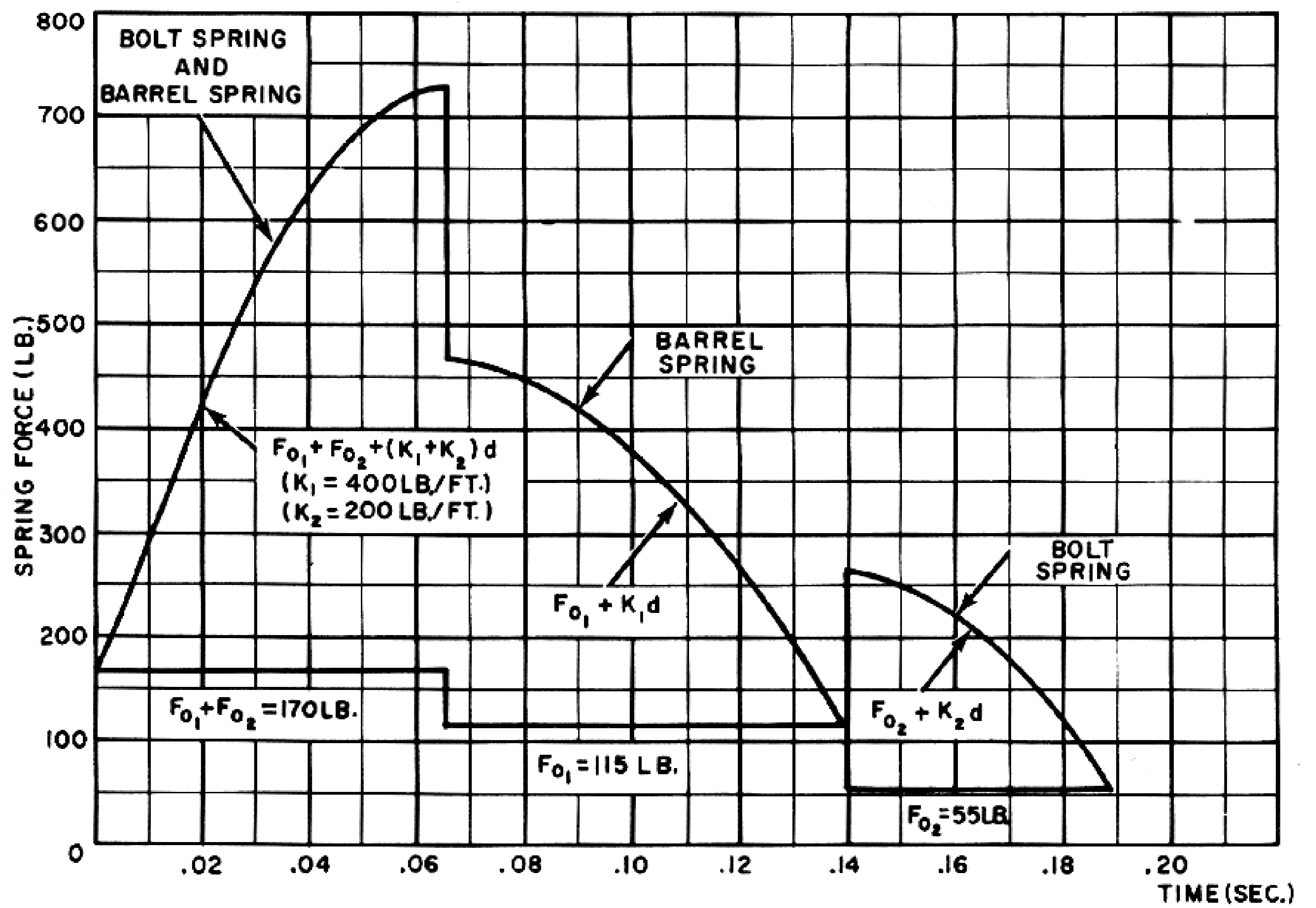

Figure 2–12. Variation of Spring Forces With Time.

counter-recoil velocity of the barrel is obtained by integrating under the second portion of the spring force curve and dividing by M_{r_1}. (The resulting ordinates are plotted as negative values because the barrel is now moving forward.) A similar method is used to plot the curve showing the velocity at which the bolt returns. The third part of the spring force curve is used and the integrals are divided by M_{r_2}.

Fig. 2–11 shows the displacement and velocity curves obtained by the method described in the preceding paragraphs, using the data for the gun of the example. After the necessary substitutions are made, the final forms of the three equations used after the first 0.010 second are:

(t from 0.010 to T)

$$d=1.14 \sin[20.3t+.204]-.265$$

(t from T to $T+T_1$)

$$d=1.162 \sin[17.93t+.393]-.287$$

(t from $T+T_1$ to $T+T_1+T_2$)

$$d=1.103 \sin[27.8t-2.31]-.229$$

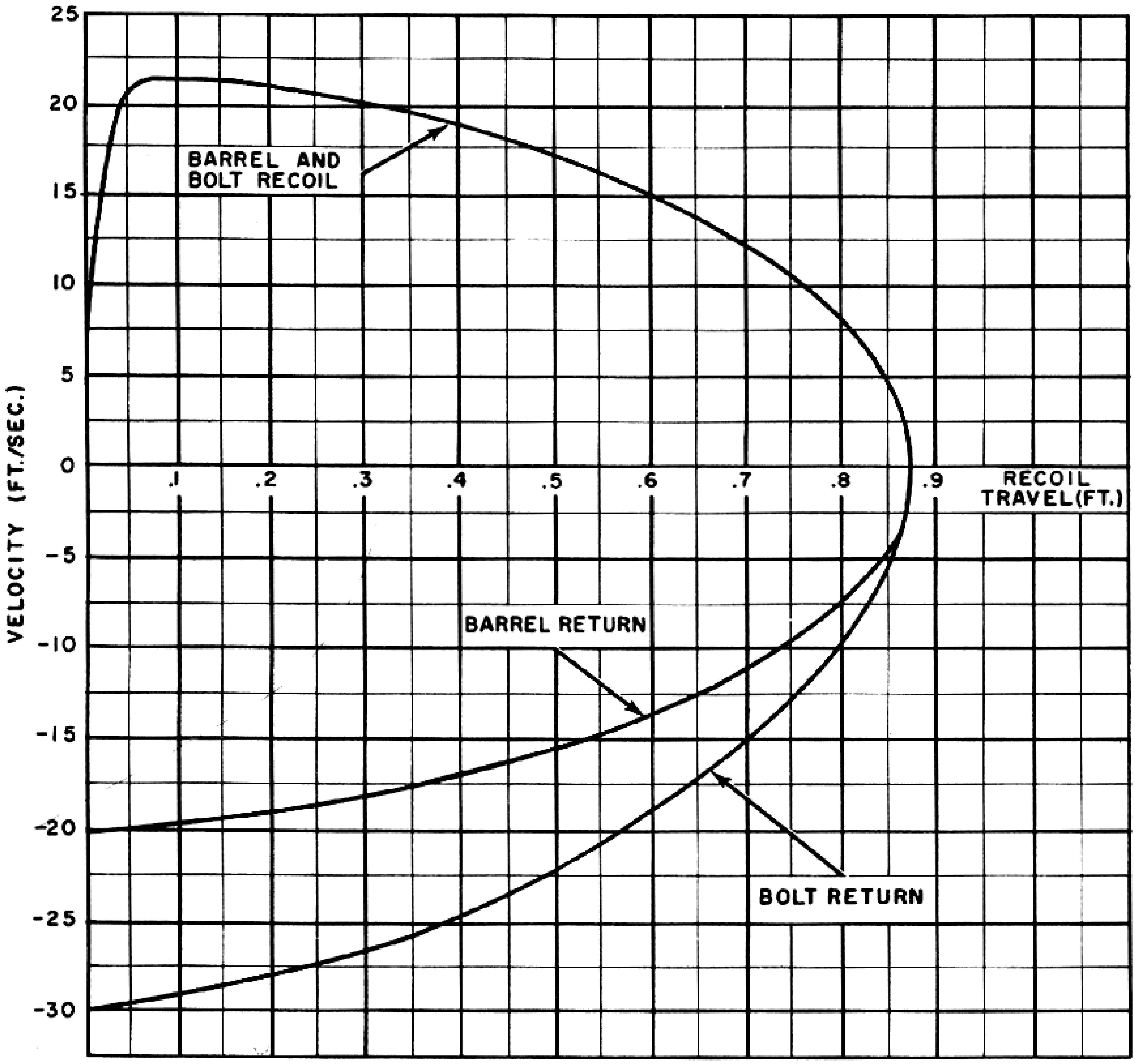

Figure 2–13. Velocity-Displacement Curve.

The spring force curve obtained from the displacement curve of fig. 2–11 is shown in fig. 2–12.

In an actual design problem, it may be desirable to consider the effects produced on the displacement and velocity curves by forces resulting from friction and from operation of the gun mechanism. These forces are treated by methods similar to those employed for the spring forces. For example, the friction force resisting the recoil movement will be essentially constant and therefore can be taken into account by increasing F_0 in equation 2–10. If the force under consideration is a constant or varying load which exists for only a small portion of the operating cycle (such as the force required to strip a cartridge out of the feeder), it can be treated in a similar manner, providing the problem is considered in stages by methods like those described in the preceding paragraphs.

Another useful type of curve for design and analysis purposes may be obtained by plotting the velocities involved in each portion of the cycle against the corresponding values for the displacement. These curves can be drawn easily because the displacement and velocity curves shown in fig. 2–11 can be used to obtain the velocity corresponding to any displacement. Fig. 2–13 shows the velocity versus displacement curves for the barrel and bolt of the gun of the example.

SHORT RECOIL SYSTEM

In the short recoil system of operation, the barrel and bolt remain locked and recoil together for a short distance until the powder gas pressure has dropped to a safe limit. The recoil movement is then utilized to unlock the bolt and after unlocking, the barrel is stopped while the bolt continues to move to the rear until the opening between the barrel and bolt is sufficient to permit feeding. It would be possible for the bolt to complete this movement merely by virtue of the momentum it possesses at the instant of unlocking, but in all short-recoil weapons, in order to speed up operation, the bolt is given additional momentum by means of an accelerating device which transfers energy to the bolt from the barrel during the short time that the barrel is still moving to the rear after unlocking. Also, unlocking usually occurs before the residual pressure reaches zero and therefore the bolt receives an additional impulse from blowback action.

The essential elements of a gun which operates by the short recoil system are shown schematically in fig. 2–14A. These elements consist of the bolt, an arrangement for locking the bolt to the barrel and for unlocking it, an accelerating device, a barrel stop, a backplate buffer, and springs for returning the barrel and bolt after recoil. In the mechanism illustrated, the barrel is latched in the position at which it is stopped after unlocking. The returning bolt unlatches the barrel before the bolt locks to the barrel extension and then the barrel and bolt return to battery together. In other weapons, the barrel may be returned to battery independently before the bolt returns. The other portions of fig. 2–14 show different stages during the cycle of operation.

Cycle of Operation

The operating cycle of a typical short recoil gun occurs as follows:

The cycle starts with a cartridge in the chamber and with the bolt locked to the barrel (fig. 2–14A). When the cartridge is fired, the pressure of the powder gases drives the projectile and gases forward through the bore and at the same time drives the barrel and locked bolt to the rear in recoil. During the action of the powder gas pressure, the retardation offered by the combined action of the bolt driving spring and barrel spring is relatively small so that the only really significant factor in limiting the recoil acceleration is the mass of the recoiling parts.

The large forces exerted by the peak pressure of the powder gases exist for a relatively short time. In a typical 20-mm gun with a barrel length of about five feet the projectile leaves the muzzle 0.008 or 0.009 second after ignition of the primer. However, 0.001 or 0.002 second after the projectile leaves the muzzle, the residual pressure has dropped to a safe limit and the bolt may be unlocked in order to take advantage of the blowback action produced by the residual pressure. Therefore, at this instant, the unlocking device is actuated to free the bolt from the barrel (fig. 2–14B).

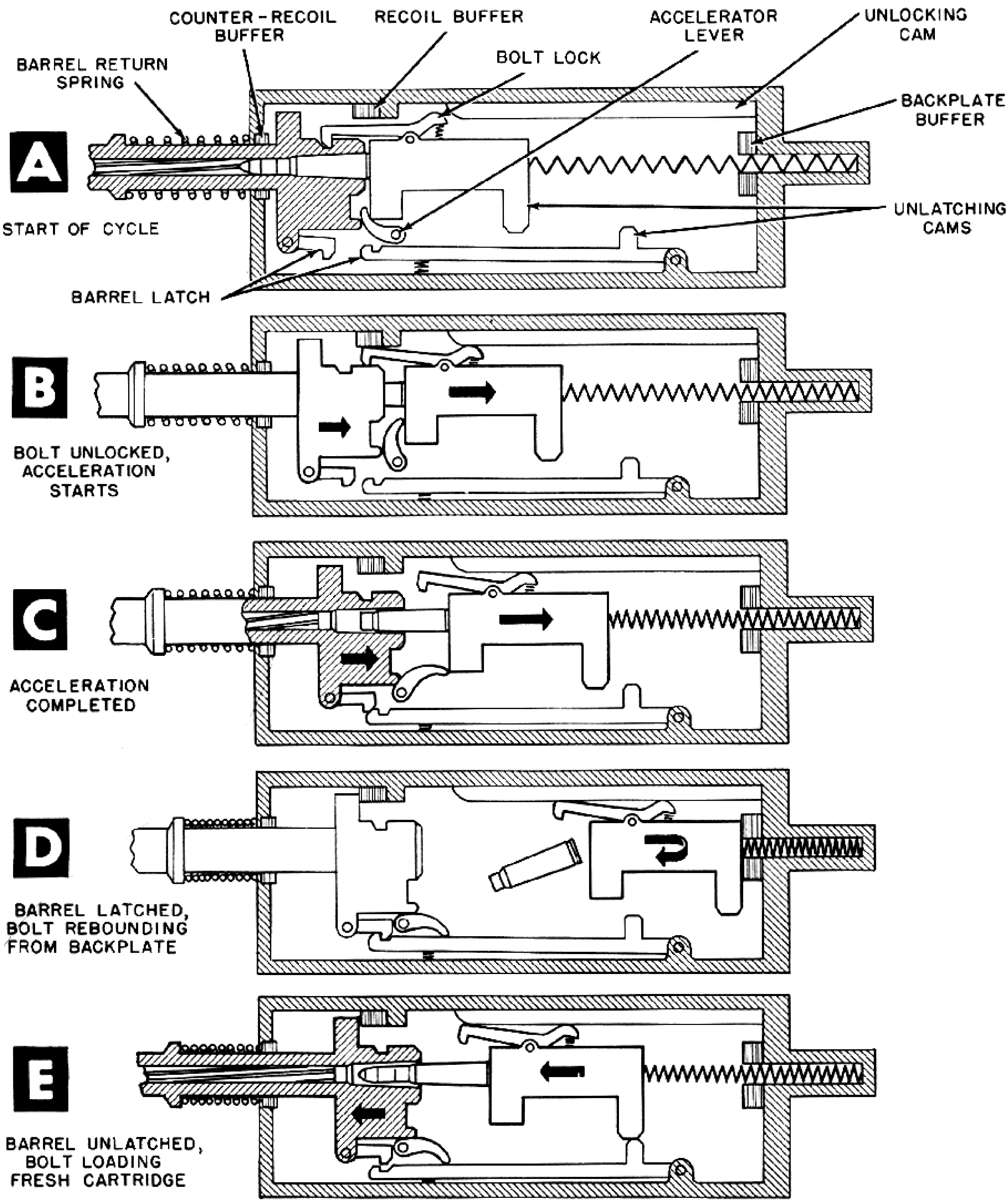

Figure 2–14. Elements of Short-Recoil System (Schematic).

Shortly after unlocking occurs, the barrel (which is still moving to the rear of its own momentum) strikes the accelerating device (fig. 2–14C). This device can take many forms, but in the mechanism illustrated, it is a lever pivoted in the breech casing. Fig. 2–15 shows the action of this lever in detail. In fig. 2–15A, the barrel extension is just in engagement with the lever and in fig. 2–15B the lever has been rotated to where it has started to thrust on the bolt. As the barrel continues moving to the rear, the lever rotates and the point of contact between the barrel extension and the lever moves closer to the lever pivot (fig. 2–15C). This causes the top of the lever to move more rapidly, thus imparting a high acceleration to the bolt.

When the accelerating action is completed, the barrel strikes a buffer stop which absorbs the remaining recoil energy in the barrel and its associated parts. After the barrel has been stopped, it is latched in its rearward position so that it is not immediately driven forward to battery by the compressed barrel return spring.

The combined action of the accelerating device and the blowback produced by the residual pressure imparts a high velocity to the bolt and then the bolt continues to move to the rear of its own momentum until the opening between the barrel and bolt is sufficient to permit feeding. As the bolt moves back, the spent cartridge case is extracted from the chamber and ejected and the bolt driving spring is compressed. This spring is relatively light and its only function is to assist the return motion of the bolt. Therefore, the driving spring does not absorb any great portion of the kinetic energy of the recoiling bolt and the bolt moves through its entire recoil distance at high velocity. The bolt then strikes the backplate buffer and rebounds. The forward velocity of the bolt immediately after leaving the backplate is somewhat less than the velocity at which it strikes the backplate because the impact is not purely elastic and some energy is lost as heat in the exchange.

As the bolt moves forward, its motion is aided by the driving spring. The bolt picks up a fresh cartridge from the feed mechanism and loads this cartridge into the chamber. Just before the bolt locks to the barrel, the barrel is unlatched so that the bolt and barrel move forward into battery while locked together. Shortly before the recoiling parts reach their most forward position, the firing mechanism is actuated and a new cycle begins. Since the cartridge is fired before the counter-recoil motion is completed, the forward velocity of the recoiling parts is first checked by the initial part of the rearward thrust exerted by the exploding propellant charge and the recoiling parts are then driven to the rear. (Timing the firing in this way eliminates the need for a heavy counter-recoil buffer to absorb and dissipate the forward kinetic energy of the recoiling parts.)

Analysis of Short Recoil

The most outstanding feature of the short recoil system of operation is that by proper design, very high cyclic rates can be attained. The bolt is unlocked without unnecessary delay shortly after the projectile has left the muzzle and then the bolt, which is already moving with considerable recoil velocity, is propelled to the rear at even greater velocity by the combined effects of the accelerator and blowback. With this high bolt velocity, the recoil movement of the bolt and its return to battery are accomplished in a very short time.

From the foregoing, it is evident that the bolt velocity in a short recoil gun is determined by three separate factors: (1) the recoil velocity at the time of unlocking, (2) the additional velocity imparted by blowback, and (3) the additional velocity resulting from the action of the accelerating device. In the following paragraphs, each of these factors is analyzed separately.

The recoil velocity of the bolt at the instant of unlocking is the result of the total impulse applied by the powder gases to the combined mass of the barrel and bolt while these parts are locked together. For any particular cartridge, the total forward momentum of the projectile and powder gases will produce an equal and opposite momentum in the recoiling parts. The recoil velocity resulting from this momentum will be inversely proportional to the weight of the recoiling parts; that is, the lighter the recoiling parts are, the higher will be their velocity. Therefore, within reasonable limits, to obtain a high recoil velocity while the barrel and bolt are still

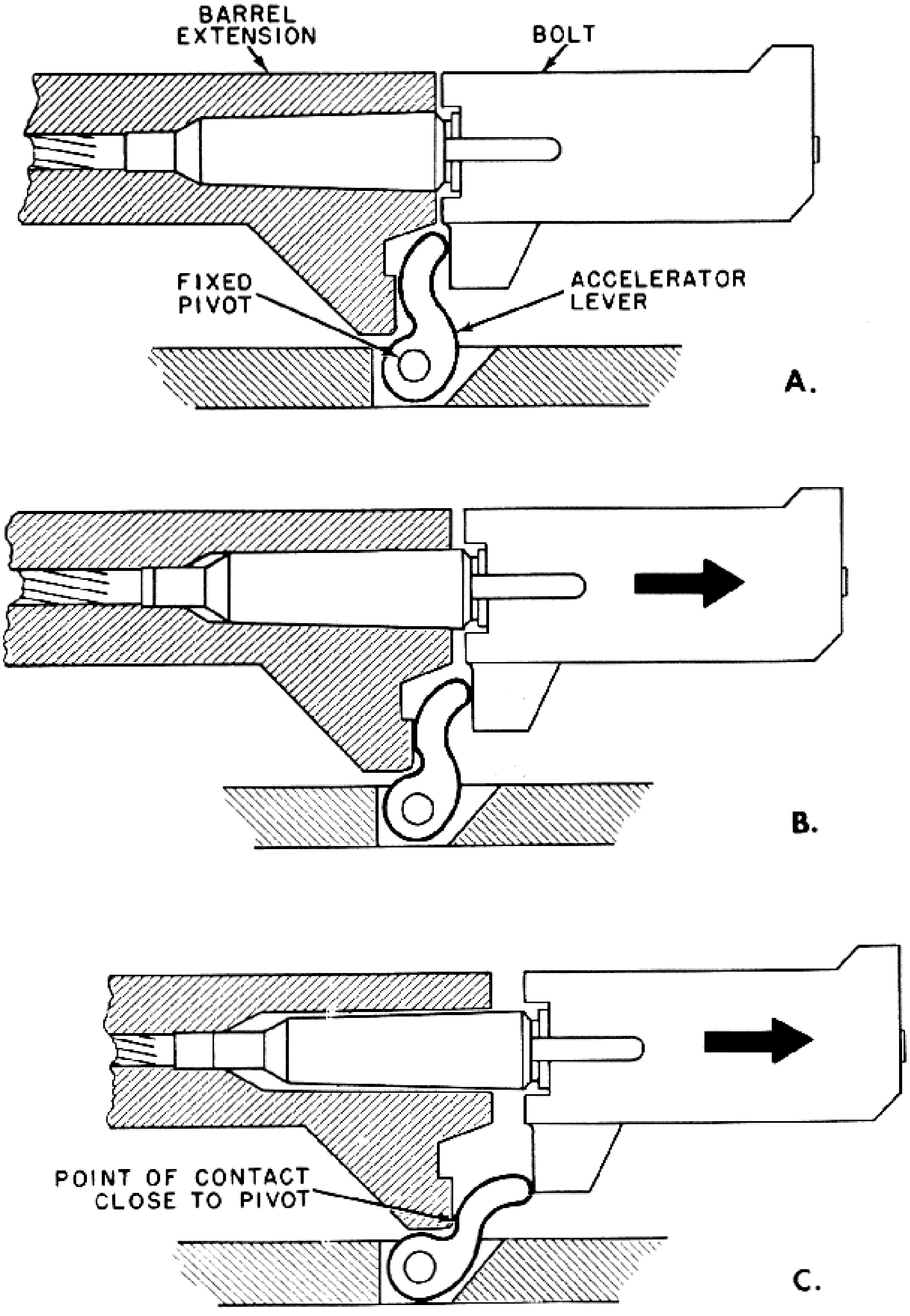

Figure 2-15. Action of Catapult Lever-Type Accelerating Mechanism.

locked together, the total weight of the recoiling parts should be kept to a minimum.

The maximum recoil velocity attainable in a practicable gun is limited because there are limitations on how light the recoiling parts can be. In order to perform their functions and to withstand the forces to which they are subjected, the barrel, bolt, and other recoiling parts must be ruggedly constructed and will necessarily be fairly massive. This is particularly true of the barrel which must be designed for sufficient strength to withstand the peak pressure of the propellant explosion and is also true of the barrel extension, bolt, and bolt locking device, all of which are subjected to the large forces produced by the powder gas pressure.

As has been mentioned previously, the effect of the limitations on the recoil velocity can be illustrated by considering a 20-mm gun. In a gun of this caliber, with a maximum chamber pressure of 45,000 pounds per square inch, the total weight of the recoiling parts including the barrel, bolt, bolt locking device, firing mechanism, springs, and other parts could not be much less than 40 to 50 pounds. The recoil momentum produced by a typical high-powered cartridge of this caliber would be approximately 35 (lb. sec.) and dividing this figure by the mass of the recoiling parts will give a maximum free recoil velocity of from 22 to 28 feet per second. Actually, in a short recoil gun, the bolt will be unlocked before this maximum velocity is attained and the recoil velocity at the instant of unlocking will be closer to 20 feet per second. It should be realized that an attempt to obtain a significantly higher velocity than this in the assumed weapon by lightening the parts would probably make the gun too frail.

The next point to consider is the additional bolt velocity produced by blowback after the bolt is unlocked. This effect in a short recoil gun is very similar to the action in a delayed blowback gun and all of the design factors which apply with delayed blowback are applicable with short recoil. The principal factor affecting the design is the allowable movement of the cartridge case during the action of the residual gas pressure.

Before blowback action is analyzed, it is appropriate to mention an operational feature associated with unlocking which can greatly improve performance during the blowback phase of the cycle. Effective blowback action is largely dependent on the absence of binding or excessive friction between the cartridge case and the walls of the chamber. When lubricated ammunition is used, friction and binding do not present a problem but with unlubricated ammunition, such as is used in short recoil guns, trouble may be encountered with binding. This binding results because the peak chamber pressures and the heat of the explosion expand the cartridge case tightly against the chamber and since unlocking occurs while there is still an appreciable residual pressure, the cartridge case does not have a chance to contract sufficiently to permit it to move freely under blowback. This difficulty can be avoided by employing an operational feature known as "initial extraction." When this feature is incorporated in the unlocking mechanism, the bolt is not unlocked completely at first but is cammed back slightly just sufficiently to cause the taper of the cartridge case to break free of the chamber walls. Immediately thereafter, the bolt is unlocked completely and blowback can occur without binding.

The first consideration relating to the blowback action is that unlocking must not occur too soon. At the instant initial extraction occurs and the bolt is unlocked, the pressure of the powder gases in the chamber will begin to drive the cartridge case and bolt to the rear. The velocity of the bolt motion imparted by this blowback effect will depend on the magnitude of the gas pressures and the mass of the parts subject to the blowback action. Since the bolt of a short recoil gun is of necessity quite light, it is possible in the presence of high gas pressures for the bolt to acquire an extremly high velocity. However, there is a definite limitation on the magnitude of the velocity which can be allowed under practical conditions. If the cartridge case and bolt move too rapidly under high pressure, the rear end of the case will move so far out of the chamber that the thin walls near the base of the cartridge case will not be supported by the chamber and will therefore rupture as the result of the high internal pressure. In other words, the motion of the cartridge case must be limited so that the case does not move too far while the chamber pressure is high enough to cause rupture.

The actual limit on the amount the cartridge case can be permitted to move as it is related to the chamber pressure will of course depend on the specific cartridge case under consideration. A good way to estimate the limit for a given cartridge case is to consider what pressure could be withstood by the case when the case has moved just far enough to the rear so that the thin walls near the base are exposed. (See fig. 2–16.) For an ordinary 20-mm cartridge case this occurs when the case has moved approximately 0.250 inch to the rear. When the case has reached this position, it is reasonable to assume that the internal pressure should not be in excess of 750 pounds per square inch, in order to be sure that the case will not be ruptured. Fig. 2–17, which is a graph showing the residual pressure variation with time for the assumed gun and cartridge, indicates that the pressure does not fall to 750 pounds per square inch until 0.005 second after ignition of the propellant charge.

Since the weight of the bolt in a short recoil gun is kept as low as possible, the only means whereby the movement of the bolt can be limited as desired is by selecting the proper time for unlocking. If the bolt is unlocked too soon, it will receive too great an impulse from the powder gases and its average velocity will be so great that the allowable 0.250-inch movement will be exceeded before the pressure drops to the safe limit of 750 pounds per square inch. If unlocking is delayed too long, the impulse imparted to the bolt will be unnecessarily small and the full benefit of blowback will not be realized. The ideal unlocking time for a given bolt weight is that which will permit the bolt to move the full allowable 0.250 inch and no more by the time that the pressure has dropped to 750 pounds per square inch.

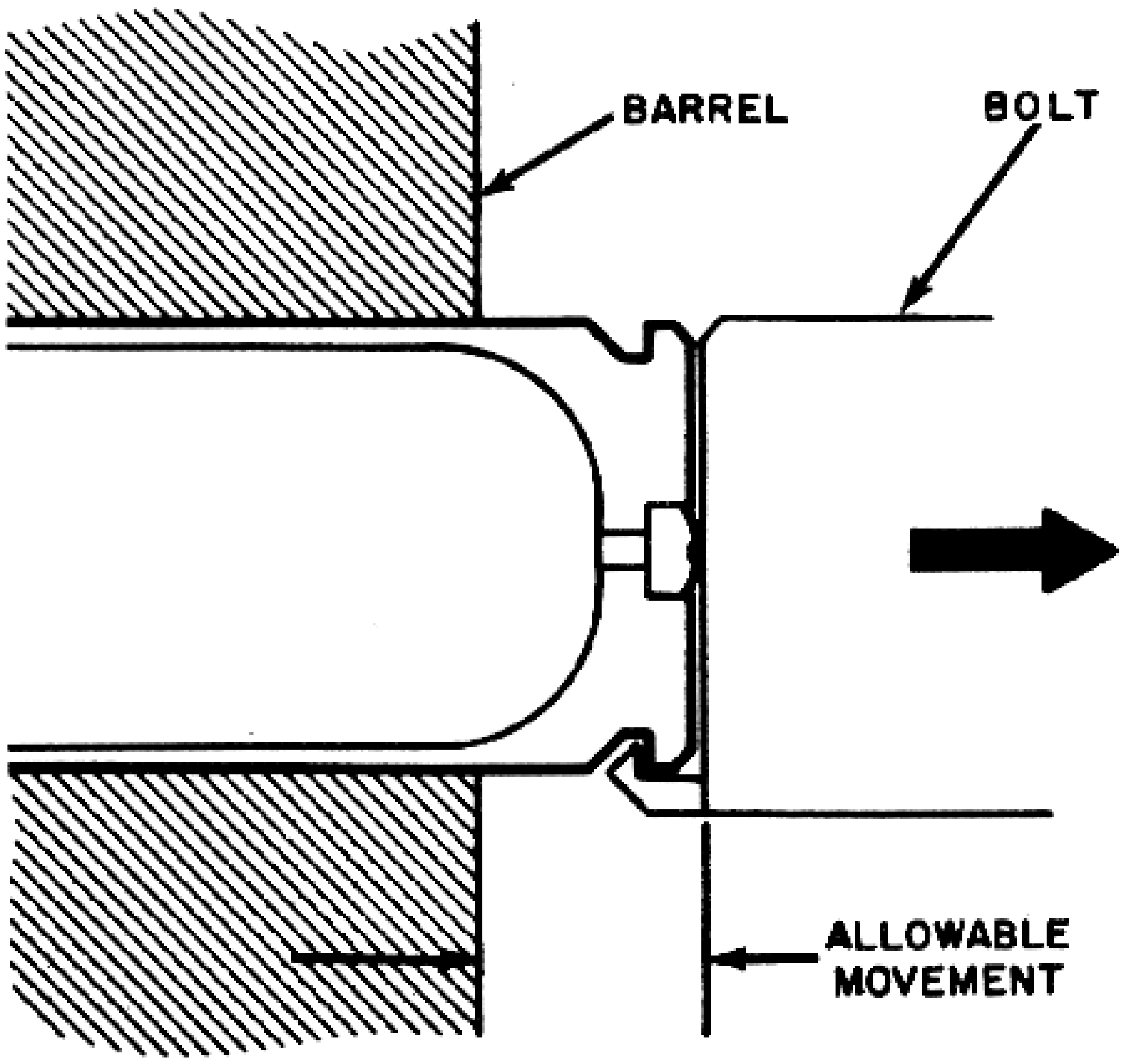

Figure 2–16. Limit of Cartridge Case Movement Rearward Before Residual Pressure Reaches Safe Value.

It is appropriate here to consider the effect of bolt weight as it is related to the blowback action in a short recoil gun. First, the primary purpose in making use of blowback is to obtain an increase in bolt velocity and therefore it is obviously desirable to set up the design so as to make the best possible use of the available blowback action. As has been explained in the preceding paragraphs, it is possible for blowback to produce extremely high bolt velocities but unfortunately it is necessary to limit the bolt motion in order to avoid rupture at the base of the cartridge case. (The limit assumed for the sample conditions is a bolt motion of 0.250 inch up to the time that the residual pressure has dropped to 750 pounds per square inch.) The question now at hand is how to limit the bolt movement as required and yet obtain a high velocity. The answer to this question lies in the selection of bolt weight and unlocking time.

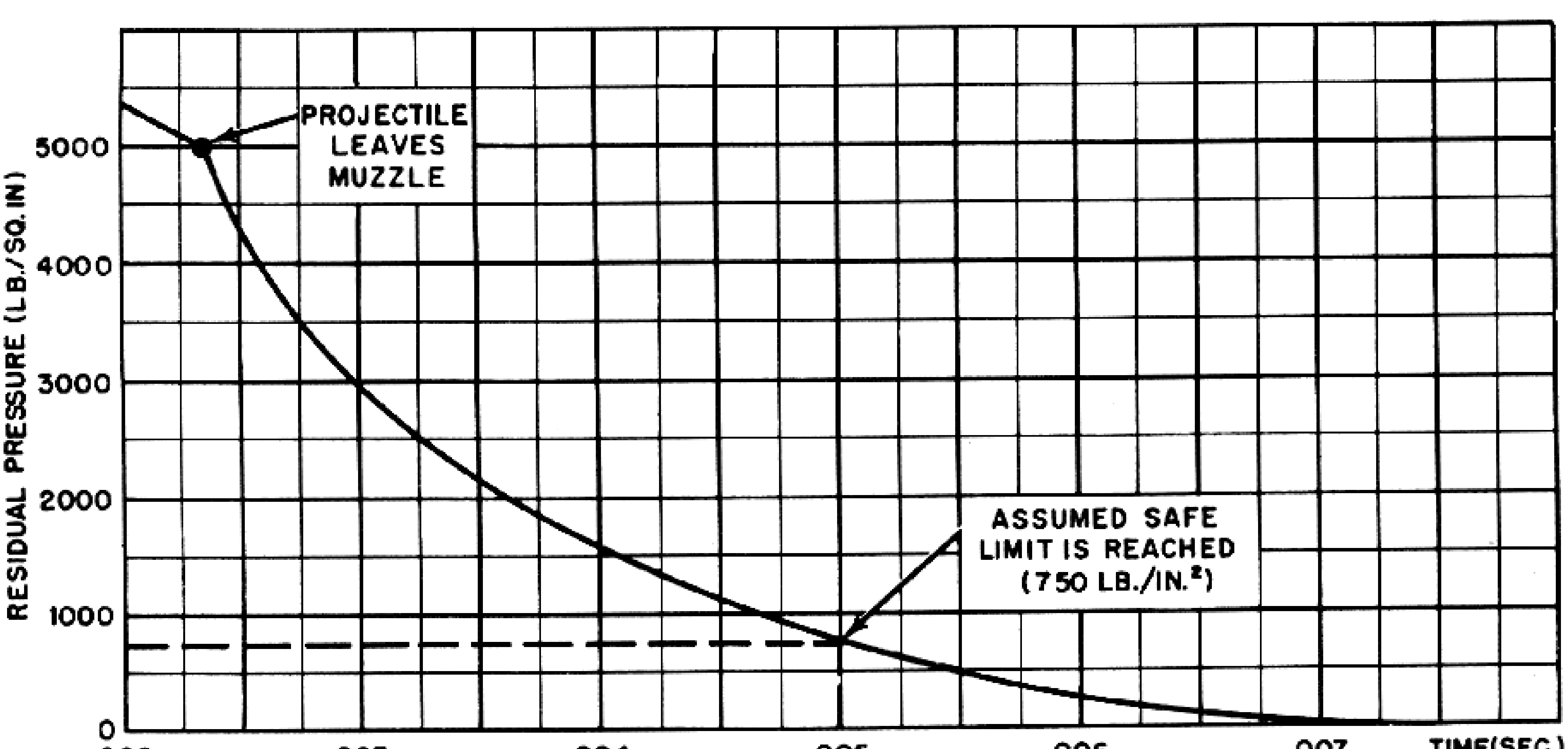

Figure 2–17. Graph of Residual Pressure Versus Time for a Typical 20 mm Gun.

The basic controlling factor is the limit on the allowable movement (0.250 inch). If the time in which this movement is accomplished is long, the average velocity of the movement will necessarily be low. However, if the time for the movement is made very short, the average velocity may be very large. For example, suppose the bolt is unlocked 0.002 second before the safe pressure of 750 pounds per square inch is reached at 0.005 second. The bolt can now travel the 0.250 inch in 0.002 second. That is to say, its average velocity for this interval can be:

$$V_{av}=\frac{D}{t}=\frac{.250}{12}\times\frac{1}{.002}=10.4\left(\frac{ft.}{sec.}\right)$$

Now assume that the bolt is unlocked only 0.001 second before the safe pressure is reached. It can then travel the 0.250 inch at an average velocity for the interval of:

$$V_{av}=\frac{D}{t}=\frac{.250}{12}\times\frac{1}{.001}=20.8\left(\frac{ft.}{sec.}\right)$$

The foregoing indicates that, by shortening the time for which the blowback operates before the safe pressure is reached, increased bolt velocity can be achieved without exceeding the allowable bolt movement.

Of course, it should be realized that shortening the time of blowback action reduces the blowback impulse available for producing the velocity. Thus, in order to gain an increase in allowable average velocity by reducing the time of action, it is necessary to reduce the bolt weight. To illustrate this point, if the velocity of 10.4 feet per second cited in the first example above was obtained with an 8-pound bolt, it would be necessary (with the same cartridge and gun) to reduce the bolt weight by a factor of at least 4, even if it is assumed that the average blowback pressure is the same for both examples. Actually, since the residual pressure decreases with time, the average pressure for the second example would be considerably less than for the first and therefore a further reduction in bolt weight would be required. The actual weight reduction factor would be more nearly in the neighborhood of 6, giving a bolt weight of only 1.3 pounds. (This would probably be much too light for a practical gun.)

Thus, it appears that a substantial gain in average allowable bolt velocity by means of reducing the time of blowback action can be achieved only by a drastic reduction in bolt weight. Although it is not practical to attempt to reduce bolt weight by an excessive amount, it is important to note that efficient utilization of blowback in a short recoil gun can be of great advantage in attaining the high bolt velocity necessary for a high rate of fire. However, this advantage can be gained only through precise timing of unlocking in combination with careful attention to minimizing bolt weight.

The third subject for consideration is the action of the accelerating device. From what has been said in the preceding paragraphs about the effects of blowback, it can be seen that the action of the accelerator should be delayed until after the residual pressure has dropped to the safe limit there specified (750 pounds per square inch for the sample conditions). If this delay is not provided, the effect of the accelerator will be wasted up until the time the pressure has dropped to the safe limit. As has been explained, the velocity of the bolt must be limited so that the bolt movement does not exceed 0.250 inch while the pressure is above 750 pounds per square inch. Since blowback alone can easily impart the velocity required to produce the 0.250-inch movement, assistance from the accelerator is not necessary or desirable. However, once the pressure has fallen below 750 pounds per square inch, rupture of the cartridge case will not occur and the need for limiting the bolt velocity no longer exists. At this point, then, the accelerator can start its action and further increase the velocity of the bolt.

There are several important points concerning the action of the accelerating device which should be considered at this time. First, the device should be designed carefully to act smoothly and positively so that it can transfer velocity to the bolt without excessive shock or friction. This is particularly necessary because even at best the action of the accelerator usually must be completed in a few thousandths of a second and will therefore be quite violent. If the action is not made as smooth as possible, battering of the parts, deformation of the mechanism, and frequent breakages will be unavoidable. Because of the extremely large forces involved in transferring the required energy so rapidly from the barrel mass to the bolt, the parts of the accelerator should be ruggedly dimensioned and properly heat-treated for maximum strength and wearing qualities.

There is no ideal design type for an accelerator and many different types have been used with good results. Accelerators of various types are illustrated in Part XI of this publication and therefore particular design configurations will not be treated in detail here. The present discussion is limited to the design factors affecting the use of acceleration in short recoil guns. The basic design requirements for an accelerating device can be enumerated as follows: The mechanism should, of course, be as simple as possible so that it can be manufactured with the least difficulty and is fundamentally reliable. The form of the mechanism should be such that its parts are compact and rugged and do not require delicate adjustment for effective functioning. If the foregoing requirements are satisfied, the next major consideration is one of "efficiency". In this connection, the term "efficiency" is used in a special sense. Since the object of using the accelerator is to speed up the bolt by making effective use of the kinetic energy in the recoiling barrel, the efficiency of the accelerator can be reckoned in terms of what percentage of the available energy is transferred to the bolt.

To analyze the factors involved in the transfer of energy from the barrel to the bolt, consider the type of accelerator shown in fig. 2–18. (This type of accelerator is known as a "catapult spring" device.) With this type of accelerator, as the barrel recoils, the catapult strikes a latch in the breech housing and the barrel compresses the catapult spring as it moves to the rear in recoil. At the same time, the bolt moves to the rear until a lug on the bottom of the bolt is engaged by a catch on the top of the catapult. The catapult latch is then released so that the compressed catapult spring will drive the bolt to the rear. Without becoming concerned with the complications involved in properly timing the various latching and unlatching operations and other practical considerations, assume that all of the kinetic energy of the recoiling barrel is stored in the catapult spring (that is, the catapult spring brings the barrel to a complete stop) and further assume that all of this energy is transferred to the bolt without loss.

Now take the barrel weight as 45 pounds and the bolt weight as 5 pounds. Assume that the velocity of the barrel before starting to compress the catapult spring is 20 feet per second and that the velocity of the bolt just before the catapult is released is 32 feet per second (allowing for the increase due to blowback). The initial kinetic energy of the barrel (the amount of energy assumed to be stored in the spring) is:

$$KE_1=\frac{1}{2}\frac{W_1}{g}V_1^2=\frac{1}{2}\times\frac{45}{32.2}\times 20^2=280 \text{ (ft. lb.)}$$

The kinetic energy of the bolt before the catapult action starts is:

$$KE_2=\frac{1}{2}\frac{W_2}{g}V_2^2=\frac{1}{2}\times\frac{5}{32.2}\times 32^2=79.5 \text{ (ft. lb.)}$$

Since it is assumed that all of the kinetic energy originally possessed by the barrel is transferred through the spring to the bolt, the final kinetic energy of the bolt will be:

$$KE_3=280+79.5=359.5 \text{ (ft. lb.)}$$

The final velocity of the bolt will then be:

$$V_3=\sqrt{\frac{(KE)\times 2g}{W}}=\sqrt{\frac{359.5\times 64.4}{5}}$$

$$=68.1\left(\frac{\text{ft.}}{\text{sec.}}\right)$$

Thus it appears that even under the ideal condition of 100 per cent efficiency of energy transfer, the factor by which the bolt velocity is increased for the stipulated values of mass and velocity is only approximately 2 times. The factor will vary depending on the ratio between the barrel and bolt masses (increasing with this ratio) and will also vary slightly depending on the values of the initial velocities. Nevertheless, the values assumed in the example are more or less representative of a typical 20-mm gun and it can be seen that there is a definite limit on the velocity gain that can be expected.

Under actual conditions, it is usually not practical to attempt to bring the barrel to a complete stop through the action of the accelerating device

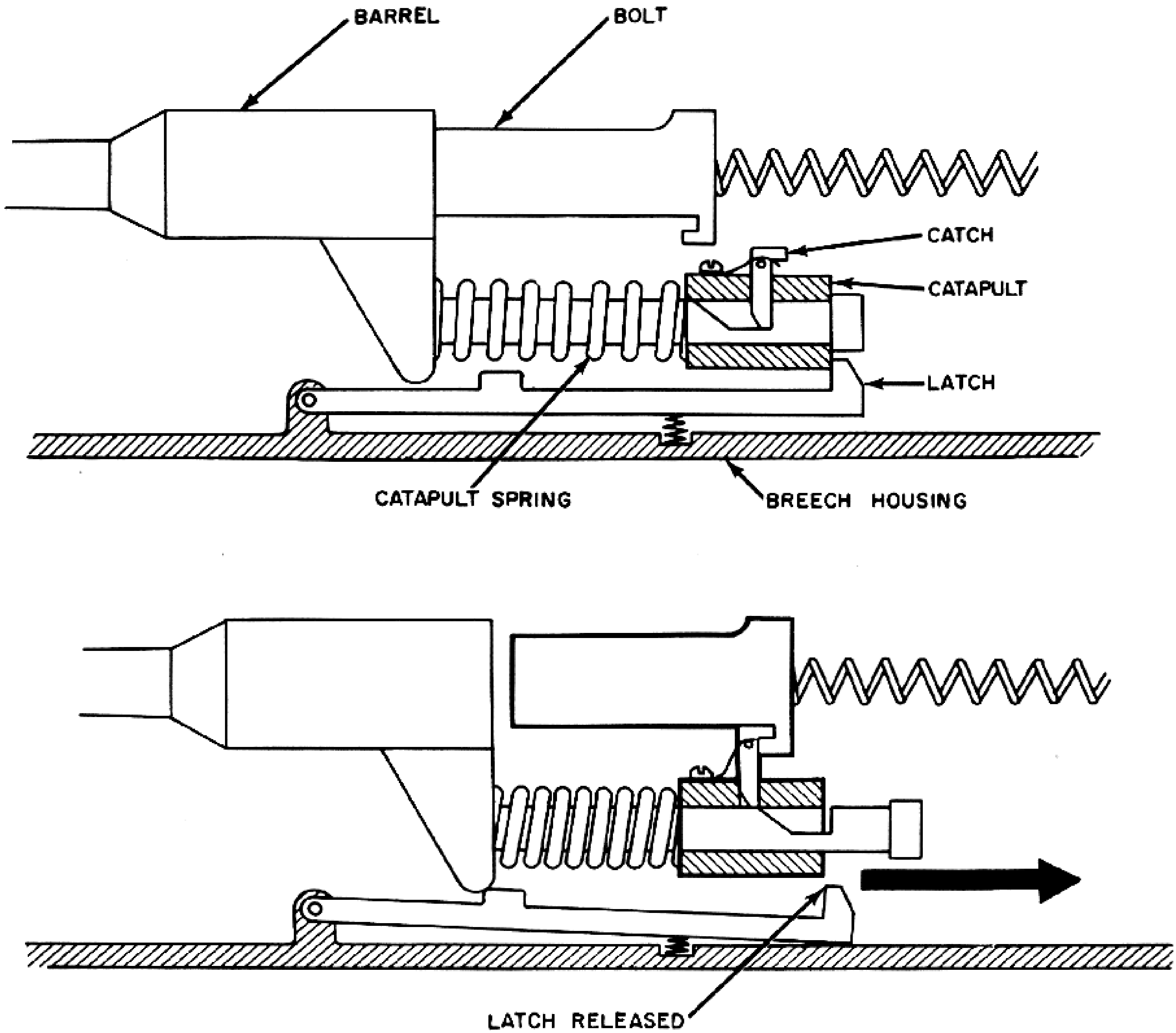

Figure 2–18. Action of a Catapult Spring Accelerating Device.

alone and this by itself reduces to a considerable extent the amount of energy transferred. Furthermore, there will be friction and impact losses and other inefficiencies in the mechanism which also will reduce the velocity gain factor. All things considered, the velocity gain in any practical, well designed mechanism will probably be such that the bolt velocity after acceleration will be approximately 1.5 times its velocity at the start of acceleration.

It is well to mention here that the same general conclusions apply to accelerators of the lever or cam type. Merely increasing the lever ratio in a lever-type accelerator will not result in a higher velocity gain. In the final analysis, there is only a certain amount of energy available in the recoiling barrel and no matter how efficiently this energy is transferred, the change it can produce in the velocity of the bolt is definitely limited. A lever ratio which is too high will result, not in a greatly increased bolt velocity, but in excessive strain and shock on the mechanism.

The preceding analysis has been concerned with the three basic factors which determine the bolt velocity in a short recoil gun. These factors are:

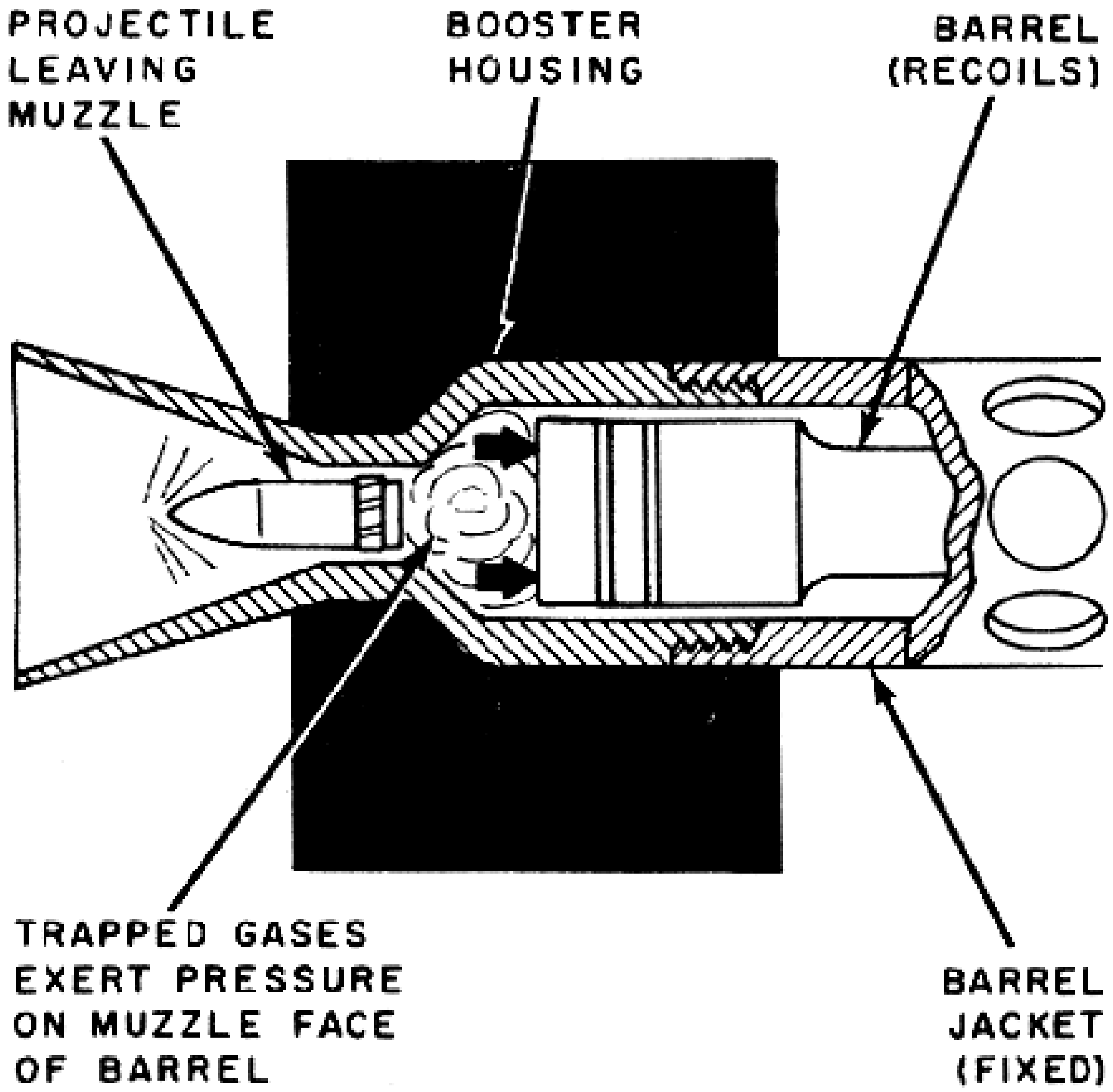

Figure 2–19. Example of a Muzzle Booster.

(1) the recoil velocity imparted to the barrel and bolt while these parts are still locked together, (2) the additional velocity imparted to the bolt by blowback after unlocking, and (3) the gain in bolt velocity produced by the accelerator. Since the principal reasons for using the short recoil system of operation is to obtain a high rate of fire, each of these factors is considered from the standpoint of how to achieve the highest possible bolt velocity consistent with safety and reliable functioning. The methods used to obtain a high bolt velocity may be summarized as follows: The total weight of the recoiling parts should be kept to a minimum so that the recoil velocity before unlocking will be high. Next, the bolt should be as light as possible and should be unlocked at the proper instant so that the blowback effect can produce a large increase in velocity without causing rupture of the cartridge case. Finally, the accelerating device should start to function just at the instant the residual pressure has reached a safe limit and should be designed to produce the maximum possible transfer of energy from the barrel to the bolt.

Another means of increasing the rate of fire in a short recoil gun is to employ a device known as a "muzzle booster" or "recoil intensifier". An example of a device of this type is shown in fig. 2–19 and other forms are illustrated in Part XI of this publication. The booster is installed at the muzzle of the gun and operates by trapping the muzzle blast in such a way as to apply a heavy thrust on the front face of the barrel. This additional thrust causes the recoiling parts to have a higher velocity and hence increases the velocity inherited by the bolt as well as increasing the energy available for acceleration of the bolt. Also in some designs, it is possible for the trapped gas to produce a slightly greater blowback effect than would be obtained without the booster. Although the muzzle booster can be used with good effect to increase the rate of fire of a short recoil gun, it is important not to employ excessive boosting action. If the booster acts too powerfully, extremely violent recoil will result with the consequent danger of severe shocks and pounding.

All of the foregoing analysis is related to the methods which can be used to impart a high initial velocity to the bolt. It is now appropriate to consider the motion of the bolt after this velocity is imparted. The bolt is given its initial velocity early in its rearward travel and then it completes its motion of its own momentum. To permit feeding, the bolt must move to the rear through a distance at least as great as the overall length of the complete cartridge and then its motion must be reversed to load the gun and close the breech. In some guns, this action is accomplished through the use of a relatively powerful driving spring which is compressed as the bolt moves in recoil. The spring absorbs the kinetic energy of the bolt over the full recoil travel, finally stopping the rearward motion of the bolt when all of the kinetic energy of the bolt has been absorbed. The spring is designed so that this occurs when the opening is sufficient to permit feeding. The compressed spring then drives the bolt forward to complete the operating cycle. This type of design has a serious drawback from the standpoint of speed of operation. Since the bolt is gradually slowed down by the spring, its velocity varies from maximum at the beginning of recoil to zero at the end of recoil. (See fig. 2–11, which is a graph showing how the bolt velocity varies with time under these conditions.) The fact that the bolt velocity varies from maximum to zero in the manner illustrated means that its average velocity will only be slightly greater than one-half its maximum velocity. In other words, if this type of action were used in a short recoil gun, in spite of all the pains taken to achieve a high initial bolt velocity, the overall travel of the bolt would be accomplished at a much lower average velocity.

To overcome this disadvantage, the bolt driving spring can be made relatively very light so that it offers a low retardation and will permit the bolt to move its entire recoil distance with little loss in velocity. In this case, the function of the driving spring is merely to provide a positive force which is just sufficient to insure that the bolt will close. Stopping the bolt at the end of its travel and reversing its motion can then be accomplished by causing the bolt to rebound from a so-called "backplate buffer". This device is in effect an extremely stiff spring which absorbs all of the kinetic energy of the bolt over a very short distance and then delivers energy back to the bolt to propel it forward. The reversing action produced by the backplate is so abrupt that the effect may be classified as an elastic impact.

In order to obtain a high rate of fire, it is also important for the bolt return to be accomplished at high velocity. If there were no energy losses involved in the reversing action, the forward velocity of the bolt after leaving the backplate would be equal to the velocity at which it strikes the backplate. This would be the ideal condition. However, in actual practice the coefficient of restitution for the bolt and backplate is usually considerably less than unity and the best that can be expected is a coefficient in the neighborhood of 0.60 or 0.70; that is, the velocity after impact will be 60 or 70 per cent of the velocity before impact. This represents satisfactory performance, but if the coefficient of restitution is too low as the result of poor backplate design, the return of the bolt will be sluggish and the rate of fire will be affected adversely. In this connection, it should be emphasized that the purpose of the backplate buffer is to reverse the motion of the bolt with as little loss of energy as possible. In many instances, the term "buffer" is used to refer to a device which has the primary purpose of dissipating impact energy rather than of conserving energy to produce an efficient rebound action. For this reason it might be better to refer to the backplate buffer as a "bolt deflector" or "rebound plate."

Another important consideration in the operation of a short recoil gun is related to the events which occur at the end of the return motion of the bolt during the transition from the completion of one operating cycle to the start of the next cycle. It is at this point that the timing of the various operations is particularly critical. The return of the bolt, which is moving at high velocity, and the return of the heavy barrel to battery can be attended by heavy shocks and severe vibrations if proper attention is not given to the problem of synchronizing the operations and dissipating the kinetic energy of the moving parts. The problems are multiplied in high rate of fire guns if firing of the fresh cartridge occurs before the vibrations resulting from firing the previous round have settled out. Under these conditions, the action of the gun may be extremely erratic and jerky and stresses may develop which will literally cause the gun to batter itself to pieces.

The value of proper timing is well illustrated by the type of mechanism used at the start of this section to serve as an example of a short recoil gun. In this mechanism, the barrel is latched in its rearward position after recoil and remains in this position while the bolt completes its movement to the rear and returns. Just before the bolt reaches the barrel on the return stroke, the barrel is unlatched and starts moving forward due to the force exerted on it by the barrel spring. Therefore, the barrel is already moving forward when the bolt re-engages with the accelerator lever. Now since the bolt is moving at a higher velocity than the barrel, the accelerator lever acts to slow down the bolt and to increase the velocity of the barrel. In a correctly arranged design, this action will be initiated with little shock and will smoothly decrease the relative velocity between the barrel and bolt to a much lower value than existed before the lever was engaged. Thus, when the bolt strikes the barrel and locks to it, the impact is reduced. Also, since the barrel is not latched and is free to move forward, the severity of the metal-to-metal shock which results when the bolt strikes the breech face is further decreased. Now both the barrel and bolt continue moving forward together and strike a counter-recoil buffer, but before the velocity of counter-recoil is brought to zero, the fresh round which has been loaded in the chamber is fired. The force of the propellant explosion then opposes the forward motion and this force quickly brings the recoiling parts to a stop and then propels them to the rear. Although this reversal of motion occurs with great rapidity, the cushioning effect of the explosion causes it to be accomplished smoothly and without vibration or any heavy metal-to-metal shock.

It should be noted that utilizing a portion of the explosive impulse for reversing the motion of the recoiling parts has the effect of decreasing the recoil velocity to some extent and therefore will tend to reduce the rate of fire. However, the loss is relatively slight and is more than compensated for by the resulting smoothness of operation.

Mathematical Analysis of Short Recoil

The details of the mathematical analysis of a design employing short recoil will depend to some extent on the particular forms of the mechanisms utilized for performing the various operational functions and therefore it is not feasible to set up an analytical method which will apply universally to all short recoil guns. However, the basic functions performed in all guns of this type are sufficiently similar to justify illustration of the general methods by analysis of a gun which is more or less representative of the type.

The following analysis employs methods which are similar to those used in the other portions of this publication with the addition of the special procedures required for handling the specific design problems related to the short recoil system of operation. Again, as for the other systems, the analytical methods treated here are concerned only with the basic bolt and barrel motions and the related forces. No attempt will be made to discuss the straightforward machine design methods by which the results are applied in arriving at the particular physical form of the mechanisms. Also, no detailed computations are made to cover the effects of such factors as friction or the incidental forces imposed on the breech mechanism by the auxiliary mechanisms such as the feeder, firing device, or locking device. These effects will have only a relatively slight influence on the bolt and barrel motions. In any case, they can be properly taken into account only in the advanced stages of a design when the form of the gun mechanism becomes fairly well established. At this point, the preliminary analysis of the bolt and barrel motion can easily be modified as desired.

The analysis which follows is based on the assumption that a particular cartridge with known characteristics is to be used and that the desired muzzle velocity and barrel length have been predetermined. It is also assumed that all necessary interior ballistics data are known and that graphs showing the time variation of projectile velocity and chamber pressure are available (figs. 2–4, 2–5, and 2–6).

> NOTE: For some design problems, all or part of this information may not be available. Analytical methods by which the required data and graphs can be approximated for use in preliminary studies may be determined by conventional interior ballistics computations.

In the preceding description of the factors involved in short recoil operation, considerable emphasis was placed on the importance of keeping the weight of the recoiling parts to a minimum in order to achieve a high rate of fire. As has been mentioned previously in this publication, the weight of the recoiling parts of any gun will be affected not only by requirements for strength, rigidity, and durability but will also depend to a large extent on the particular configuration selected by the designer. (To repeat the example previously cited, if the designer wishes to have the bolt slide in a long barrel extension, the recoiling parts might be heavier than they would be if the bolt moved on guide rails which were part of the receiver.) Therefore, the weight of the recoiling parts can not be determined with any accuracy until the barrel has been designed and the remainder of the mechanism has been laid out at least to the extent which will make it possible to make a fair preliminary estimate of what weights will be involved. In the process of planning the mechanism, it will also be necessary to determine what distances the parts must travel.

Of course, the final dimensions and weights of some of the recoiling parts can not be defined until complete consideration is given to the forces which act on these parts as the result of the accelerations and shocks to which they are subjected in operation and which yet remain to be determined. However, the estimated weights obtained from a carefully made preliminary design and layout should be accurate enough to serve as a starting point for the calculations necessary to determine the operating forces. It is these calculations which are the main concern of the following analysis.

As the analysis progresses, its applications will be illustrated by means of sample calculations. Although these calculations and the related graphs are for a specific 20-mm cartridge and barrel and are based on certain assumed weights and other characteristics, the general approach described is applicable to short recoil guns of any caliber. The calculations cover the following important points:

1. Determination of the conditions of free recoil.
2. Determination of correct time for unlocking.
3. Computation of data required for design of accelerator.
4. Selection of characteristics of barrel return spring and bolt driving spring and determination of data for design of backplate buffer.
5. Development of graphs showing how the velocity and travel of the barrel and bolt vary with time.

In the course of describing these calculations, the following fundamental formula will be developed and explained:

a. Momentum and velocity relation for time projectile is in bore.
b. Formula for determining velocity of free recoil.
c. Expression for duration of residual pressure.
d. Formulas for determining spring retardations.

(Because of the fact that before unlocking occurs there is no difference between the analysis of a short recoil gun and a long recoil gun, some of the explanations and derivations are identical for both systems of operation. In such cases, to avoid the inconvenience and confusion of attempting to refer back to the explanations given under long recoil, the material will be repeated here.)

1. *Conditions of free recoil*

Under the heading "Principles of Recoil" it was pointed out that, if a gun is mounted so that it can move freely without friction or any other restraint, the impulse of the recoil force will impart to the gun a rearward momentum equal to the total forward momentum of the projectile and powder gases. For the time the projectile is in the bore, this momentum relationship is expressed by the equation:

$$M_r v_{r_f} = M_p v_p + M_e v_e \qquad (2\text{-}17)$$

Since the powder gases will be thoroughly mixed by the turbulence created in the explosion, it is reasonable to assume that the center of mass of the gases moves forward at one-half the velocity of the projectile. Actually, this is not quite accurate because the presence of the enlargement at the chamber and the fact that the rifling does not extend the full length of the space occupied by the gases creates a condition in which the volume of the space is not uniformly distributed along its length. Nevertheless, the assumption is close enough for present purposes. Therefore equation 2–17 may be rewritten as:

$$M_r v_{r_f} = M_p v_p + M_e \frac{v_p}{2} = \left(M_p + \frac{M_e}{2}\right) v_p \qquad (2\text{-}18)$$

> NOTE: It should be pointed out here that the momentum equality expressed by equation 2–18 is not affected by the internal frictional forces opposing the motion of the projectile and powder gases or by the forces incident to engraving the rifling band and to imparting the rotational velocity of the projectile. Although all of these forces retard the forward motion of the projectile and powder gases, they produce equal and opposite reactions on the barrel which result in a corresponding retardation of the rearward movement of the gun. In other words, the internal resistances merely decrease the effective impulse producing motion but they do not cause any inequality in the forward and rearward momentums.

Solving equation 2–18 for v_{r_f} gives the velocity of free recoil for the time the projectile is in the bore as:

$$v_{r_f} = \frac{M_p + \frac{M_e}{2}}{M_r} v_p = \frac{W_p + \frac{W_e}{2}}{W_r} v_p \qquad (2\text{-}19)$$

Equation 2–19 can be used to plot a curve showing the free recoil velocity versus time for the period before the projectile leaves the muzzle. The weights of the projectile and powder charge are both known and it is assumed that the weight of the recoiling parts has been estimated in accordance with a preliminary design plan. Also, the velocity of the projectile at any time is known from the

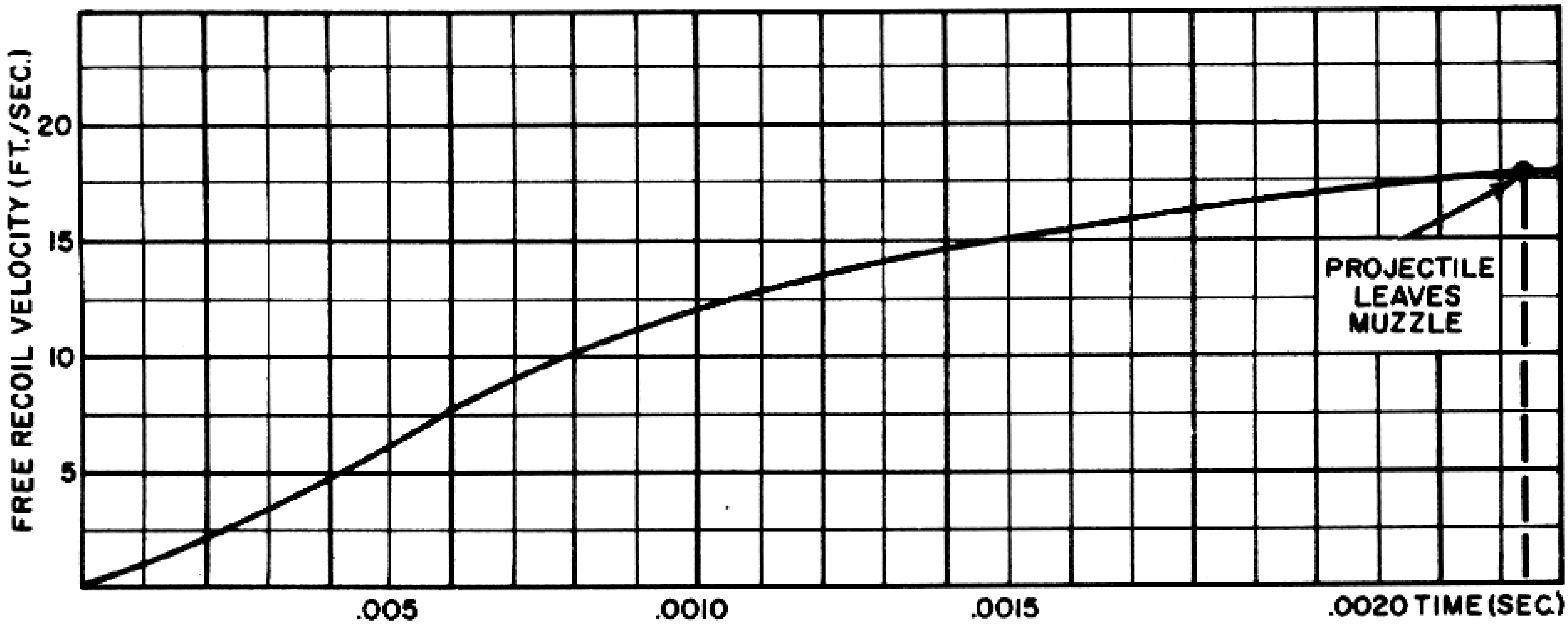

Figure 2–20. Free Recoil Velocity While Projectile Is in Bore.

available ballistic data (fig. 2–5). Therefore, the ordinate of the free recoil velocity curve at any time, t, can be found by multiplying the corresponding ordinate of the projectile velocity curve by the factor:

$$\frac{W_p+\frac{W_c}{2}}{W_r}$$

Assuming that in the 20-mm gun to be used as an example the estimated weight of the recoiling parts is 50 pounds and the weights of the projectile and powder charge are as shown in fig. 2–5, the value of the multiplying factor is:

$$\frac{W_p+\frac{W_c}{2}}{W_r}=\frac{.29+\frac{.070}{2}}{50}=.00650$$

Therefore, before the projectile leaves the muzzle, the free velocity of the recoiling parts is:

$$v_{r_f}=.00650\ v_p\left(\frac{\text{ft.}}{\text{sec.}}\right)$$

The curve obtained by using this relation is shown in fig. 2–20 and is also shown in fig. 2–21 as the portion between t=0 and t=.00234 second. (In fig. 2–21, the time axis is compressed in order to show how the velocity varies after the projectile leaves the muzzle.)

The manner in which the free recoil velocity varies after the projectile leaves the muzzle can not be determined from equation 2–19 because the projectile and a portion of the powder gases are no longer part of the system. Since the effect of the residual pressure can not be expressed in simple terms, a special method is used to extend the curve obtained from equation 2–19. This method is based on the fact that the results of experimental firings of various guns show that the maximum velocity of free recoil may be closely approximated as:

$$V_{r_f}=\frac{W_pV_p+4700\ W_c}{W_r} \qquad (2\text{–}20)$$

This relationship is equivalent to saying that the maximum momentum imparted to the recoiling parts is equal to the sum of the muzzle momentum of the projectile and the momentum of the powder gases, assuming that the powder gases leave the gun at an average velocity of 4700 feet per second. For the gun used as an example:

$$V_{r_f}=\frac{.29\times2750+4700\times.070}{40}=22.5\left(\frac{\text{ft.}}{\text{sec.}}\right)$$

A line representing this value of the maximum velocity of free recoil is drawn on the velocity graph (fig. 2–21) and the curve previously drawn from equation 2–19 is extrapolated until it becomes tangent to the line. The point at which the curve becomes tangent represents the time at which the residual pressure becomes zero and therefore imparts no further velocity to the recoiling parts. Although an error in locating the exact point of tangency will not have any serious effect on the accuracy of the results, it may be of some assistance in plotting to

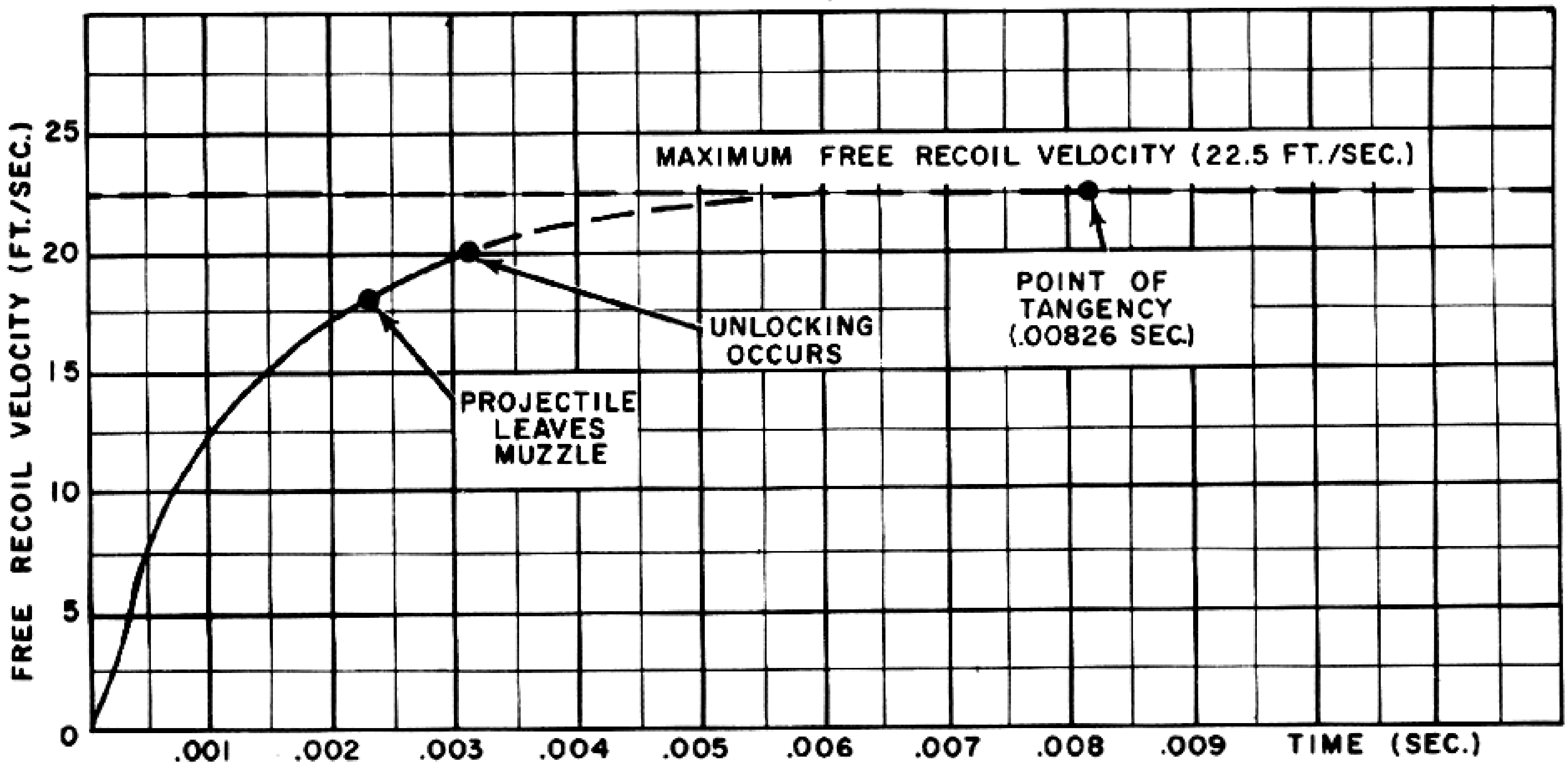

Figure 2–21. Free Recoil Velocity Before Unlocking.

determine this point by using Vallier's formula for approximating the duration of the residual pressure:

$$T_{res}=\frac{M_c}{AP}(9400-V_p) \qquad (2\text{–}21)$$

For the sample cartridge and barrel:

$$T_{res}=\frac{.070}{32.2\times\frac{\pi}{4}(.790)^2\times 5000}(9400-2750)$$

$$=.00592 \text{ (sec.)}$$

To obtain the total time of action of the powder gases, this value is added to the time at which the projectile leaves the muzzle:

$$T_{res}=.00234+.00592=.00826 \text{ (sec.)}$$

Extending the original curve until it is tangent at this point gives the complete free recoil velocity curve shown in fig. 2 21. Actually, the entire curve shown in the figure does not apply to the actual recoil conditions in a short recoil gun because unlocking occurs before the residual pressure has become zero.

2. *Effect of blowback before acceleration and computation of unlocking time*

The next point for consideration is the effect on the bolt velocity of the blowback action which occurs between the time that unlocking occurs and the time that the accelerator starts to operate. As pointed out in the analysis of short recoil, the ideal condition for this portion of the blowback action is that the bolt should move 0.250 inch with respect to the barrel by the time that the residual pressure has dropped to the safe limit of 750 pounds per square inch. (These figures are based on assumed safe values for a typical 20-mm cartridge and should be checked experimentally for any specific cartridge.)

For purposes of determining the blowback effect, it is only necessary to consider the velocity of the bolt with respect to the barrel. After the bolt is unlocked, the residual pressure has no further effect on the barrel but merely imparts motion to the bolt with respect to the barrel. It will be assumed here that the bolt weight, as estimated from a preliminary layout of the mechanism is 5 pounds.

Fig. 2–17 which is a graph of the residual pressure versus time for the sample gun, shows that the residual pressure reaches 750 pounds per square inch at 0.005 second. The problem is to decide how long before this point the bolt should be unlocked so that its motion with respect to the barrel will be 0.250 inch at 0.005 second. This problem can be solved using the data in fig. 2–21. If the ordinates of the velocity curve in fig. 2–21 are multiplied by the mass of the recoiling parts, the resulting

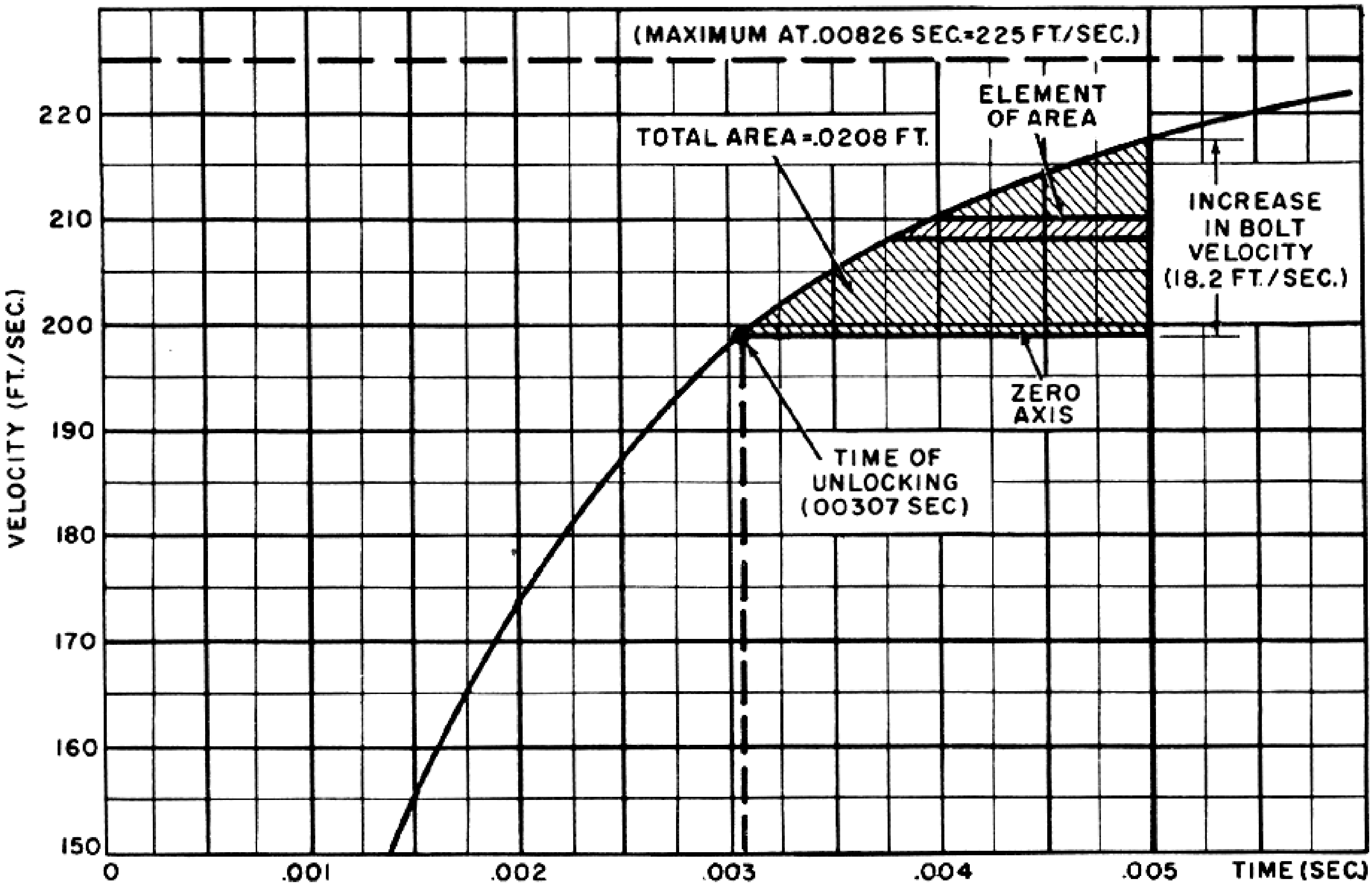

Figure 2–22. Changes in Bolt Velocity Imparted by Blowback and Determination of Time for Unlocking.

curve will show the momentum of these parts at any instant or, since the momentum is equal to the applied impulse, the curve will also show the impulse applied up to any instant. Now, after unlocking occurs, the impulse shown by this curve will be applied in changing the velocity of the bolt and therefore it is possible to divide each ordinate of the impulse curve by the bolt mass to obtain the new curve shown in fig. 2–22. (Only a portion of the vertical scale is shown in order to produce the significant portion of the curve in a large size.) The actual velocity values shown by this curve are meaningless but between any two values of time, the curve does show accurately what *change* in bolt velocity would be produced by the impulse.

Having the curve of fig. 2–22, it is only necessary to determine where to place the zero velocity axis so that the area between this axis and the curve up to 0.005 second is equal to 0.250 inch or 0.0208 foot. (Since this is a velocity-time graph, areas under the curve represent displacement.) The zero axis can be located quite simply by drawing a line along the 0.005-second ordinate and measuring the area between this line and the curve, taking the elements of area as shown in the figure and working downward until the area is equal to 0.0208 foot. The abscissa of the point where the line bounding the lower limit of this area intersects the curve is the required time of unlocking (0.00307 second). Ordinates measured above the lower bounding line are equal to the free recoil velocity, with respect to the barrel, imparted to the bolt by blowback. The curve shows that the gain in free bolt velocity between the time of unlocking and 0.005 second is 18.2 feet per second.

It should be noted that although this computation neglects the retarding effect of the bolt driving spring, the resulting error is extremely small and entirely insignificant.

The data shown in fig. 2–22 are used in the computations for completing the bolt motion curves up to 0.005 second. The manner in which the data are used is explained in paragraph 4 in connection with the plotting of the theoretical time-travel and time-velocity curves before acceleration.

3. *Selection of spring characteristics*

Since the only purpose of the barrel return spring and the bolt driving spring is to assist the barrel and bolt to return to battery and neither spring is required to absorb all of the recoil energy of the parts, the values of the forces exerted by the springs are not critical. For this reason, the characteristics of these springs may be selected more or less arbitrarily.

The barrel assembly is assumed to weigh 45 pounds and to return this relatively heavy mass quickly to battery a fairly strong spring is indicated. As will appear, such a spring will not have any great effect on the recoil motion and therefore the resistance of the spring can be made quite high. On this basis the initial compression of the spring will be selected as 250 pounds and the spring constant as 300 pounds per inch.

The bolt spring will be made very light so that it will not offer a high retardation to the five-pound bolt. An initial compression of 25 pounds and a spring constant of 10 pounds per inch will provide adequate force for assisting the closing of the bolt.

4. *Theoretical time-travel and time-velocity curves before acceleration*

Because of the complexities resulting from the multiplicity of actions during the recoil and counter-recoil movements in a short recoil gun, it is not practical to attempt to derive analytically expressions for the time to recoil and time to counter-recoil. Also, such derivations would be extremely complicated unless it is assumed that the initial kinetic energy is transferred instantaneously to the recoiling parts, ignoring the detailed effects which occur during the action of the powder gas pressures. However, in high-rate-of-fire guns employing the short recoil system, the time of action of the powder gases is extremely significant and must be given due consideration in plotting the bolt motion curves. A detailed analysis of this type is particularly important because most of the critical actions and high accelerations occur during the progress of the propellant explosion and it is therefore highly desirable to determine what motion characteristics may be expected in the initial portion of the recoil stroke.

Since the effects of the powder gas pressure can not be expressed by simple equations, a special method is employed to account for these effects in plotting the bolt motion curves. The method consists essentially of first plotting a curve of free recoil velocity versus time and then subtracting from each ordinate of this curve the velocity loss resulting from the retarding effects of the springs.

The curve showing the velocity of free recoil versus time for the time interval before unlocking was developed previously and is shown in fig. 2–21. This curve will be used to illustrate the following description of the method.

To determine the retarding effects of the springs, use is made of the law expressed by the equation:

(2–22) $$F\,dt = M\,dv$$

This law states that the change in the momentum of a mass is equal to the applied impulse (the product of the force and the time for which it is applied). Solving for dv gives:

$$dv = \frac{F\,dt}{M}$$

To obtain the variation of the change in velocity with respect to time, this expression is integrated.

(2–23) $$v = \int_0^t \frac{F\,dt}{M} = \frac{1}{M}\int_0^t F\,dt$$

In accordance with equation 2–23, the retarding effect of a force on a given mass can be determined as follows:

1. Plot a curve showing the variation of the force with respect to time.
2. Measure the area under the curve between $t=0$ and some time t_1.
3. Divide the measured area by the mass. This gives the ordinate of the retardation curve for the time t_1.
4. Repeat steps 2 and 3 for other values of t and plot the retardation curve.

Applying this procedure using the mass of the recoiling parts and the combined resistance of the barrel return spring and the bolt driving spring produces a curve showing the loss in recoil velocity resulting from the action of the springs up to the time of unlocking. Since the free recoil velocity curve shows the gain in velocity resulting from the thrust of the powder gases, the difference between the curves will be the net recoil velocity, or in other words the velocity of retarded recoil.

The foregoing method would be very simple if the retarding force were constant or if the variation of this force with respect to time were known. However, when the force varies with recoil travel as it does with the springs assumed for purposes of analysis, a difficulty is encountered. In order to plot a graph showing the variation of the retarding force with respect to time, it is necessary to have a curve showing the variation of the recoil travel with respect to time, and the latter curve is one of those which yet remain to be determined.

This difficulty can be overcome by employing a process of successive approximation. While the powder gas pressures are acting, the loss in velocity resulting from the retarding effect of the springs will be relatively small and will be almost entirely due to the constant effect of the initial compression. The varying force due to the spring constant during this interval of time will almost certainly be negligible but, if necessary it can be approximated very closely.

The procedure for plotting the velocity and travel curves for the time before unlocking occurs is as follows:

1. Plot the curve of free recoil velocity versus time (fig. 2–22).
2. The loss in velocity due to the initial compression of the springs is equal to:

$$\frac{(F_{o_1}+F_{o_2})\ t}{M_r}$$

Determine the velocity loss for various values of t, subtract each from the corresponding ordinate of the free recoil velocity curve and draw a curve through the resulting points. If the effect of the spring constant proves to be negligible, this curve is the retarded velocity curve.
3. Integrate under the curve drawn in step 2 to obtain the displacement curve.
4. Assume that the curve drawn in step 3 represents the actual time-travel curve and use this curve to determine the retardation due to the spring constant. (Use the combined spring constant for the barrel return spring and the bolt driving spring, K_1+K_2.) Ordinarily, it will be found that this retardation is so small that it will not have any effect worthy of consideration.
5. In the event that the retardation determined in step 4 is sufficient to affect the velocity, use it to modify the curve drawn in step 2 and then integrate under the new curve to obtain a corrected displacement curve.
6. Steps 4 and 5 can be repeated as often as is necessary until no significant change occurs in the displacement curve. Actually, this process of successive approximation should never be necessary and satisfactory results should be obtained in the first three steps or at least in the first five steps.

Fig. 2–23 shows the curves obtained for the gun of the example for the interval before unlocking. The total loss in velocity due to the combined effect of the initial compressions of the springs during this interval (0 to 0.00307 second) is:

$$V=\frac{(F_{o_1}+F_{o_2})t}{M_r}=\frac{(250+25).00307\times 32.2}{50}$$

$$=.543\left(\frac{\text{ft.}}{\text{sec.}}\right)$$

The loss due to the combined effect of the spring constants as determined by the method of step 4 is only about 0.115 feet per second. The final curves shown in fig. 2–23 are the result of performing step 3. Since the velocity loss due to the effect of the spring constants is so small, step 5 need not be taken.

After unlocking occurs, the bolt and the barrel are independent of each other and each is affected only by its own spring. Since the bolt is unlocked, the barrel is no longer affected by the pressure of the powder gases and therefore its free recoil characteristic is to continue moving at the same velocity it had at the instant of unlocking. This is indicated in fig. 2–24 by the fact that the free barrel velocity curve after unlocking is a horizontal line.

The retarding effects of the barrel return spring and bolt driving spring up to the time of acceleration (0.005 second) are determined by the same general method as used before unlocking. However, at the instant of unlocking, the springs have been compressed 0.0414 foot (fig. 2–23). This means that in consideration of the period after unlocking, the initial compression of each spring must be increased by the effect of its spring constant for this deflection. That is:

$$F_{o_1}=250+.0414\times 300\times 12=250+149=399\ \text{(lb.)}$$

and;

$$F_{o_2}=25+.0414\times 10\times 12=25+5=30\ \text{(lb.)}$$

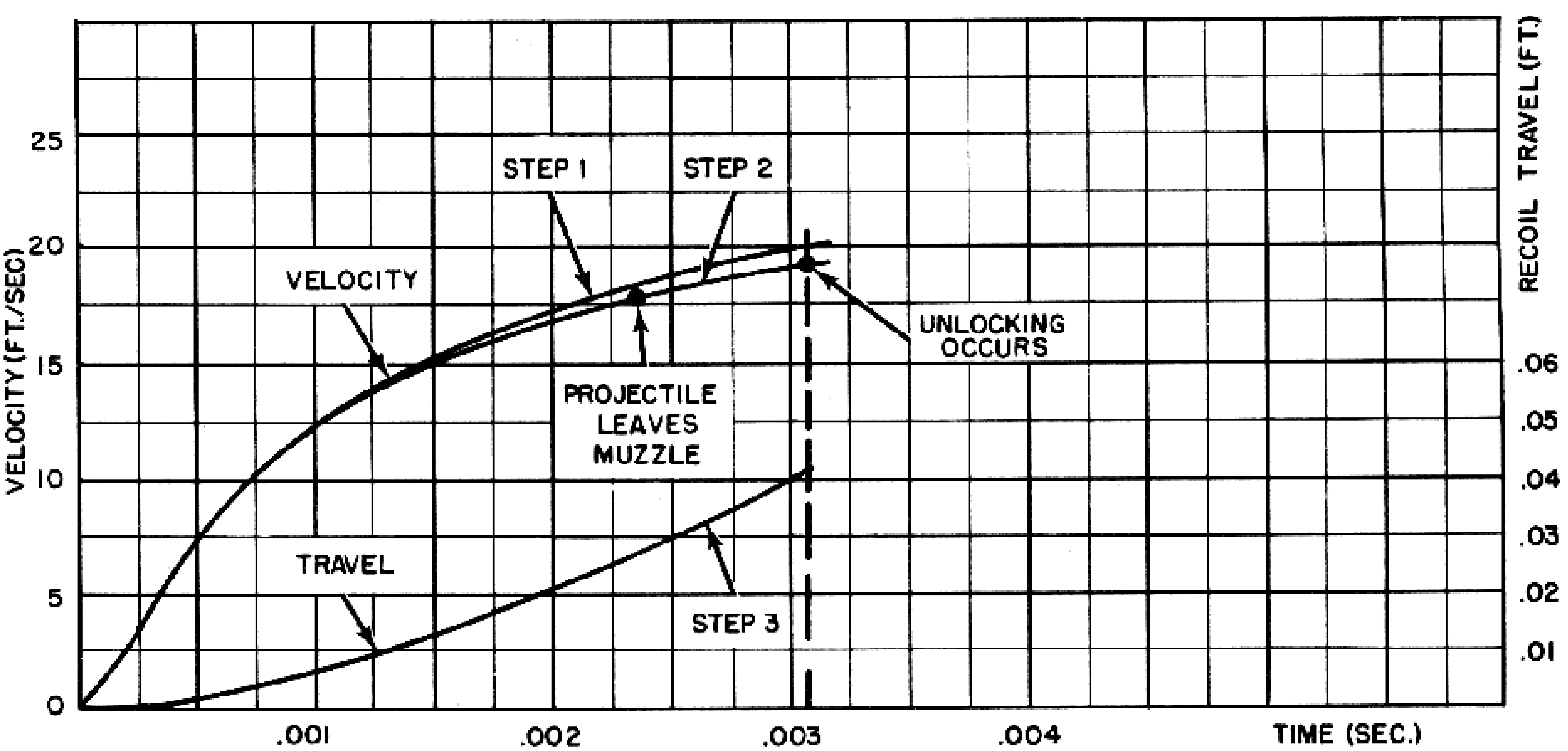

Figure 2–23. Development of Time-Travel and Time-Velocity Curves for Period Before Unlocking.

The total loss in barrel velocity due to the corrected initial compression of the barrel return spring during the interval between unlocking at 0.00307 second and the start of acceleration at 0.005 second (an interval of .005—.00307=0.00193 second) is:

$$V=\frac{F_{o_1}}{M_1}t=\frac{399\times.00193\times32.2}{45}=.550\left(\frac{\text{ft.}}{\text{sec.}}\right)$$

The loss due to the effect of the spring constant as determined by the method of step 4 is only about 0.089 foot per second. The final barrel motion curves shown in fig. 2–24 are the result of performing steps 2 and 3. Since the velocity loss due to the effect of the spring constant is so small, it is not necessary to take step 5.

Having the final barrel motion curve for the interval between unlocking and the start of acceleration, it is now possible to draw the free bolt velocity curve for this interval. This portion of the free bolt velocity curve is plotted from the data shown in fig. 2–22 by adding to the ordinates of the retarded barrel velocity curve the corresponding ordinates of the curve in fig. 2–22, measuring these ordinates above the zero axis. The resulting free bolt velocity curve is shown in fig. 2–24.

The retarding effect of the bolt driving spring is determined by the same methods employed for the barrel motion curves. The loss in bolt velocity due to the corrected initial compression of the bolt driving spring is:

$$V=\frac{F_{o_2}}{M_2}t=\frac{30\times.00193\times32.2}{5}=.373\left(\frac{\text{ft.}}{\text{sec.}}\right)$$

The loss due to the effect of the spring constant as determined by the method of step 4 is, in this case, only about 0.053 foot per second. The final bolt motion curves shown in fig. 2–24 are the result of performing steps 2 and 3. Since the velocity loss due to the effect of the spring constant is so small, it is not necessary to perform step 5. Note that the displacement between the barrel at bolt at 0.005 second (as indicated by the travel curves) is 0.0208 foot or 0.250 inch as required. The retarded velocity curves for the bolt and barrel show that at the instant acceleration starts, the velocity of the bolt is 36.7 feet per second and the velocity of the barrel is 18.5 feet per second.

5. *Motions during period of bolt acceleration*

When the cycle of operation has progressed for 0.005 second as described up to this point, the residual pressure has decreased to the assumed safe operating limit of 750 pounds per square inch and it is now possible to increase the velocity of the bolt without danger of rupture of the cartridge case. It should be noted that at 0.005 second, the residual powder gas pressure has not yet reached zero and

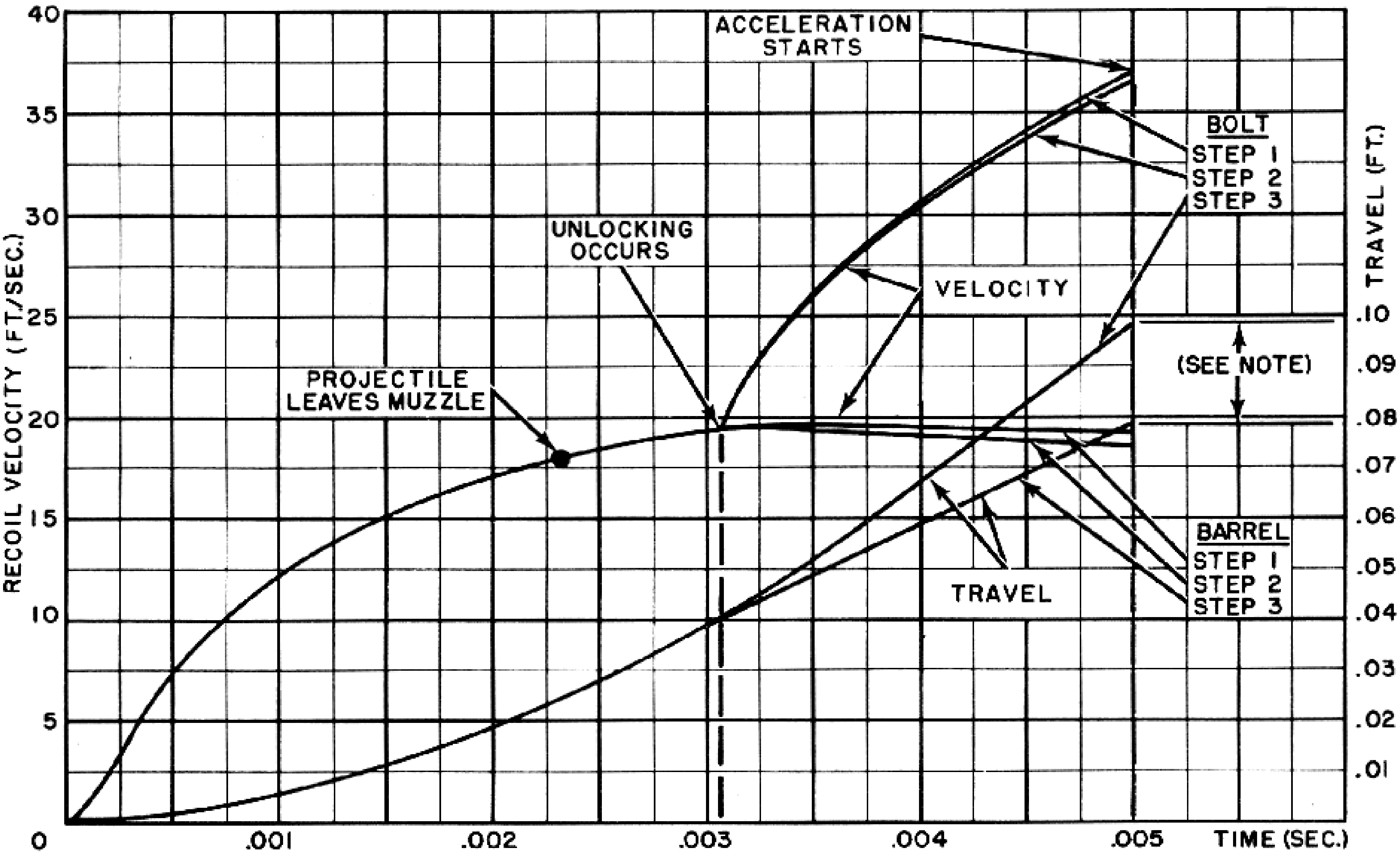

Figure 2–24. Development of Time-Travel and Time-Velocity Curves for Period Between Unlocking and Start of Acceleration.

therefore there will be some small additional blowback effect which will occur simultaneously with the action of the accelerator.

The first point to consider is the amount of kinetic energy available from the moving mass of the barrel. Since the barrel weighs 45 pounds and at 0.005 second is moving at a velocity of 18.5 feet per second, the kinetic energy possessed by the barrel mass is:

$$KE = \frac{1}{2} MV^2 = \frac{1}{2} \times \frac{45}{32.2} \times 18.5^2$$
$$= 239 \text{ (ft. lb.)}$$

These 239 foot pounds of barrel energy do not constitute all of the energy which can be utilized to accelerate the bolt because some work will be done on the bolt as the result of the force exerted by the residual pressure. Although this force can be determined at any instant from the graph of residual pressure versus time (fig. 2–17), it is not possible at this time to determine the work done by this force because the bolt displacement for the interval of acceleration is not yet known. However, the distance moved by the bolt during the 0.003 second for which the residual pressure will continue to act will certainly be quite short and the average force exerted by the powder gas pressure during this movement will also be relatively small. These conditions indicate that the work done on the bolt by the last portion of the residual pressure will be of little consequence when compared with the 239 foot pounds of energy available from the barrel mass. A rough estimate indicates that the work which can be done on the bolt by the remaining blowback action will be in the order of only 10 or 15 foot pounds. Since this amount of work is so small, little error is likely to occur if it is assumed for the present that the energy available for acceleration is 250 foot pounds.

It is of interest to consider what the result would be if the efficiency of energy transfer during acceleration were 100 per cent (that is, if all of the available energy could be transferred to the bolt without any loss). At the instant acceleration starts, the velocity of the bolt is 36.7 feet per second. Since the bolt weighs 5 pounds, the kinetic energy possessed by the bolt is:

$$KE=\frac{1}{2}MV^2=\frac{1}{2}\times\frac{5}{32.5}\times36.7^2$$
$$=104.5 \text{ (ft. lb.)}$$

Assuming that all of the available 250 foot pounds of energy is transferred to the bolt, the kinetic energy of the bolt after acceleration will be:

$$KE=104.5+250=354.5 \text{ (ft. lbs.)}$$

Having this kinetic energy, the velocity of the bolt after acceleration would be:

$$V=\sqrt{\frac{2(KE)}{M}}=\sqrt{\frac{2\times354.5\times32.2}{5}}$$
$$=66.7\left(\frac{\text{ft.}}{\text{sec.}}\right)$$

Since the bolt velocity before acceleration was 36.7 feet per second, this represents a velocity gain factor of 1.815 times. It should be realized that this velocity gain factor is the theoretical maximum based on a 100 per cent efficiency in transferring the available energy from the barrel to the bolt and therefore the bolt velocity in this particular design could never exceed 66.7 feet per second regardless of what type of accelerating device is used.

In actual practice, an energy transfer efficiency of 100 per cent can not be attained because there will always be unavoidable losses which decrease the amount of energy transferred. One of these losses is due to the fact that it is impractical to attempt a design in which the action of the accelerator alone brings the barrel to a complete stop. Therefore there will always be some energy remaining in the barrel after the accelerating function is completed. There will also be losses due to friction, impact, and extraction of the cartridge case and some energy will be absorbed by the barrel return spring and bolt driving spring. Without having a definite mechanical design to work with and in the absence of detailed design data, there is no positive way to arrive at accurate specific values for these losses and accordingly it will be necessary here to select arbitrarily values which are reasonable practical estimates. Let it be assumed that residual barrel velocity after acceleration is 6 feet per second and that the other incidental losses amount to 50 foot pounds.

On this basis, the residual kinetic energy in the barrel after acceleration will be:

$$KE=\frac{1}{2}MV^2=\frac{1}{2}\times\frac{45}{32.2}\times6^2=25.1 \text{ (ft. lbs.)}$$

Subtracting this energy and the incidental losses of 50 foot pounds from the available 250 foot pounds of energy gives the energy actually transferred as 175 foot pounds. Adding this energy to the initial kinetic energy of the bolt (104.5 foot pounds) produces a final kinetic energy of 280 foot pounds in the bolt. With this kinetic energy the final velocity of the bolt after acceleration will be:

$$V=\sqrt{\frac{2(KE)}{M}}=\sqrt{\frac{2\times280\times32.5}{5}}$$
$$=60\left(\frac{\text{ft.}}{\text{sec.}}\right)$$

The velocity gain factor is now:

$$\frac{60}{36.7}=1.63$$

The efficiency of energy transfer is:

$$\frac{175}{250}\times100=70 \text{ percent}$$

This appears to be a value which reasonably could be expected under practical conditions.

Having established the fact the action of the accelerator will speed the bolt up from 36.7 feet per second to 60 feet per second (a velocity gain of 24.3 feet per second) and will slow the barrel down from 18.5 feet per second to 6 feet per second (a velocity loss of 12.5 feet per second), the problem now is to design the accelerator which will produce these changes in velocity. The major consideration in this design is to arrange the accelerator mechanism so that the required transfer of energy will be accomplished without heavy shock or excessive acceleration forces and the velocities of the barrel and bolt will vary smoothly.

The basic characteristics of the motions which occur during the action of the accelerator will depend on whether the accelerator is of the catapult spring type or of the lever or cam type. Either type may be analyzed readily, but for purposes of the present discussion, it will be assumed that the accelerator to be used is of the lever type.

The first point of interest in designing the accelerator is the time which should be allowed for the completion of the transfer of kinetic energy. From the standpoint of attaining a high rate of fire, it would be desirable to accomplish the transfer rapidly for two reasons. First, this would quickly bring the bolt to a high velocity, thus decreasing the time required for the completion of the bolt movement. Second, the barrel velocity would be reduced quickly with the result that the rearward travel of the barrel would be relatively small. This would be advantageous because it would reduce the distance the bolt must move to produce an opening large enough to permit feeding.

On the other hand, quick transfer of kinetic energy requires a high acceleration of the bolt and rapid deceleration of the barrel and the resulting inertia reactions will cause large forces to act on the accelerator mechanism. Increasing the time allowed for the transfer of energy will reduce the acceleration and the forces on the mechanism but will also result in decreasing the rate of fire.

Considering the above factors, the time allowed for energy transfer should be some moderate value; not so short that excessive forces will be produced and not so long that the rate of fire will be reduced seriously. For the gun of the example a value of 0.004 second should be acceptable.

After the selection of the length of time which will be allowed for the action of the accelerating device, the next step is to decide what motion characteristics are desired for this interval. In order for the energy transfer to occur with minimum shock, it would be reasonable to arrange the mechanism so that the forces on the parts will at first be zero and then will increase smoothly to the higher values required to produce rapid acceleration and deceleration. Such a force variation will result in a condition in which the displacements and velocities, as well as the accelerations, will vary in a smooth manner.

Except for the relatively small amount of kinetic energy expended in compressing the bolt driving spring and barrel return spring during the period of acceleration, and except for the small gain in energy due to the remaining blowback action and the slight incidental losses in the operation of the mechanism, the sum of the kinetic energies contained in the recoiling system consisting of the barrel and bolt will remain constant. Therefore, the characteristics of the bolt and barrel movements will depend mainly on the properties of the accelerating mechanism. Since the accelerating mechanism can be designed to establish the relationships between the movements of the recoiling parts, these movements can be controlled as desired. In other words it is possible to approach the design of the accelerator by first specifying the desired variation in barrel velocity. The corresponding velocity variations for the bolt can then be determined by taking into consideration the kinetic energy obtained from the barrel, the energy imparted by the remaining blowback action, and the energy lost in operating the gun mechanism. The variations of bolt velocity and barrel velocity being known, the accelerating device can be designed so that these velocity variations will be produced.

The basic procedure by which the accelerator may be designed is as follows: First, the desired characteristics of the barrel velocity are established by drawing, arbitrarily, a suitable barrel velocity curve for the interval of acceleration. The shape of the curve should be similar to that shown in fig. 2–25 so that the deceleration (and consequently, the force required to produce the deceleration) will start at zero and increase smoothly to the maximum value at the end of the interval. Note that the barrel velocity curve selected for the example indicates a residual velocity of 6 feet per second at the end of the acceleration interval.

The barrel velocity curve is now used to compute, for each instant, the decrease in barrel kinetic energy as indicated by the decrease in barrel velocity. This computation is made on the basis of the relationship:

$$\Delta\ (KE) = (KE)_0 - \frac{1}{2}\,Mv^2$$

which states that the change in kinetic energy up to any instant is equal to the initial kinetic energy minus the kinetic energy resulting from the velocity v which exists at that instant. For the barrel of the gun of the example:

$$\Delta\ (KE) = 239 - \frac{1}{2} \times \frac{45}{32.2}\ v^2$$
$$= 239 - .700\ v^2$$

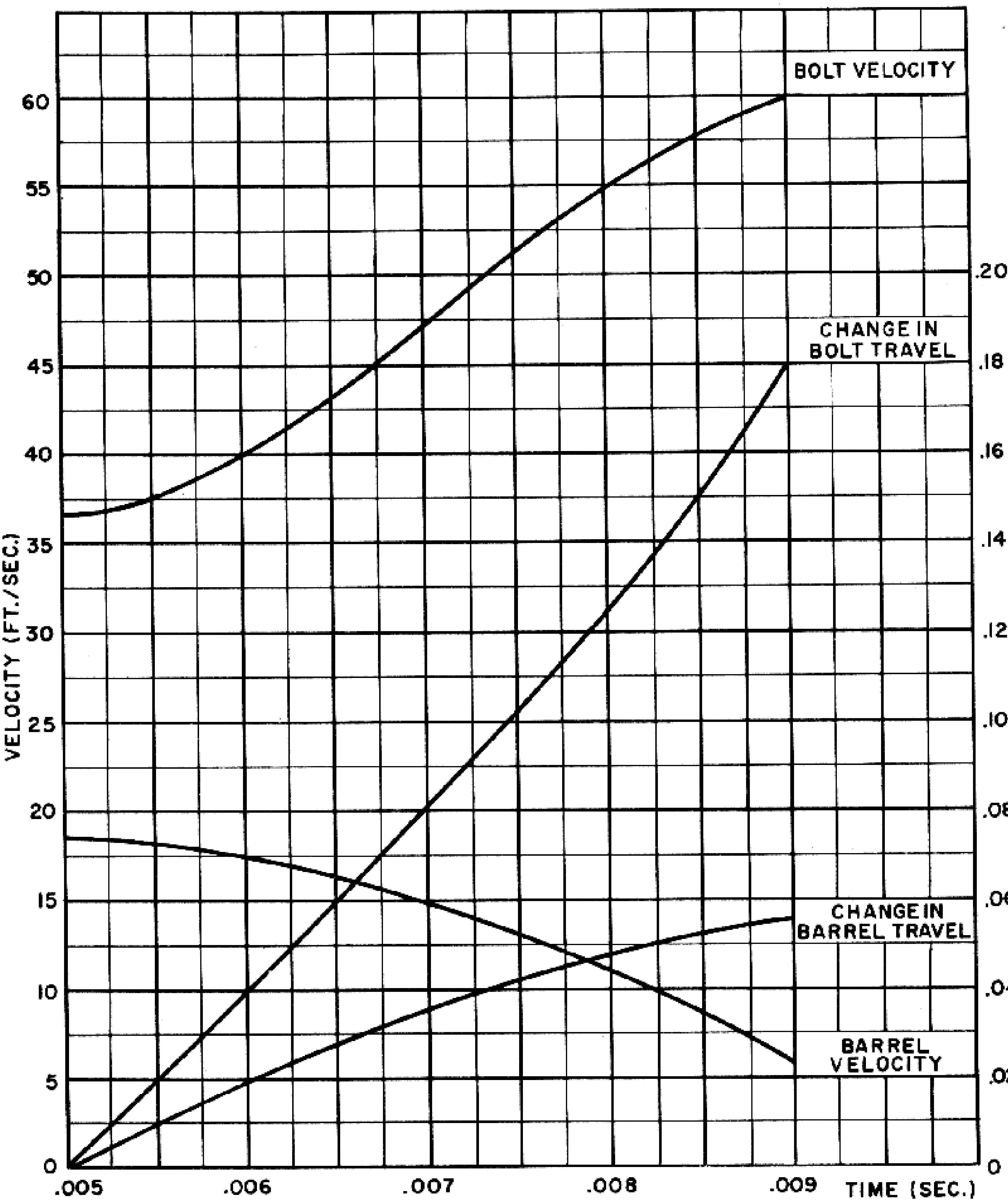

Figure 2–25. Effect of Acceleration on Travel and Velocity of Barrel and Bolt.

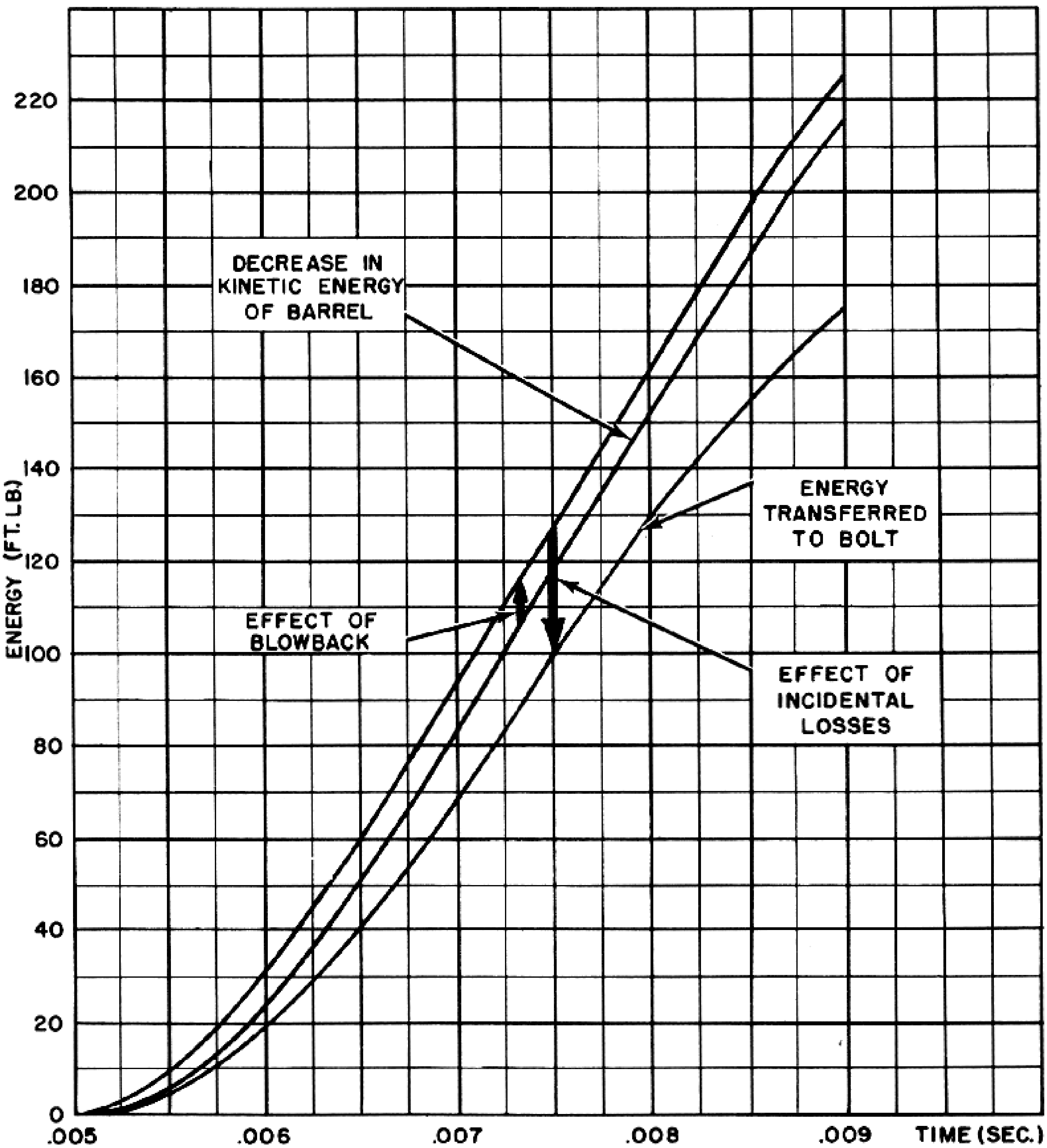

Figure 2–26. Energies Affecting Motion of Bolt During Action of Accelerating Lever.

Fig. 2–26 shows the curve obtained by using this relationship to determine the decrease in the kinetic energy of the barrel. This curve does not represent the energy transferred to the bolt because the remaining blowback action and the incidental losses still must be considered. The effects of the blowback action and of the incidental losses can not be determined precisely at this time because the bolt motion has not yet been determined. However, both effects are not very great and can be estimated with a sufficient degree of accuracy to insure small error in the computations. In an actual design problem, the result obtained by using these estimates could be considered to be a first approximation which can be refined if necessary. It was previously estimated that the effect of blowback up to 0.00826 second (when the residual pressure becomes zero) would perform a total work of 11 foot pounds on the bolt. Fig. 2–26 shows how this energy is assumed to be added to the kinetic energy obtained from the barrel. The incidental losses, which have been estimated as 50 foot pounds, are mainly due to the retardation offered by the barrel spring and bolt driving spring. These losses must be subtracted from the total available energy and for purposes of this analysis, it will be sufficiently accurate to assume that the losses occur at a constant rate over the interval of acceleration. That is, for the sample conditions, since there is a total loss of 50 foot pounds of kinetic energy over the interval of 0.004 second, it may be assumed that energy is lost at the constant rate of 50/.004—12,500 foot pounds per second during the acceleration process. The lowest curve in fig. 2–26 shows the result of this subtraction and gives the energy transferred to the bolt at any instant.

The values of the energy transferred to the bolt, as shown in fig. 2–26, are used to determine the bolt velocity curve shown in fig. 2–25 as follows: The velocity of the bolt at the start of acceleration is 36.7 feet per second and its kinetic energy at that time has been computed to be 104.5 foot pounds. For any instant during acceleration, this value is added to the amount of energy transferred to the bolt up to that instant (from fig. 2–26). This total kinetic energy of the bolt is then used to compute the bolt velocity according to the relationship:

$$V=\sqrt{\frac{2g\,(KE)}{W}}$$

For the conditions of the example, W=5 pounds and therefore:

$$V=\sqrt{\frac{2\times 32.2(KE)}{5}}=\sqrt{12.88(KE)}$$

The next step is to integrate under the velocity curves to obtain curves showing the changes in barrel travel and bolt travel during the period of acceleration. These travel curves are also shown in fig. 2–25. The values given by these curves are added to the barrel travel and bolt travel which exist at the beginning of the acceleration in order to extend the time-travel curves to 0.009 second. Fig. 2–27 shows the complete time-travel and time-velocity curves up to this point.

All of the data of interest in designing the accelerator lever may either be found in fig. 2–27 or may be derived directly from this figure. Fig. 2–28 shows data which may be used for the accelerator design. The barrel deceleration and bolt acceleration curves were obtained by measuring the slopes of the velocity curves. The curves showing the relative travel and relative velocity between the barrel and bolt were derived by noting the difference between the heights of the ordinates of the travel and velocity curves. The velocity ratio curve was obtained by dividing the bolt velocity by the barrel velocity.

Having the data shown in figs. 2–27 and 2–28, the shape of the accelerating lever can be plotted by the conventional methods employed for cam layout. In designing the lever, it should be noted that the lever ratio which exists at any instant must be equal to the velocity ratio shown for that instant in fig. 2–28. Also, to minimize wear on the contact surfaces, these surfaces should be designed as far as possible to have a rolling action, and sliding contact at the surfaces should be held to a minimum. Since the details of the layout process will depend largely on the space requirements of a particular design and because it is not the intent in this publication to describe conventional machine design procedures, no attempt will be made here to explain the layout of the lever. The general shape and action of a lever for one particular design is shown in fig. 2–15. However, it should be realized that the shape of the lever for a different gun may differ considerably from that shown in fig. 2–15, depending on the arrangement of the mechanism and the desired motion characteristics.

Before the analysis of the accelerating action is concluded, it is interesting to note the magnitude of the forces which act on the barrel and bolt during acceleration. Fig. 2 28 shows that the maximum deceleration of the barrel mass is equal to 5600 feet per second per second (at 0.009 second). Since the barrel weighs 45 pounds, the force required to produce this deceleration is:

$$F=Ma=\frac{45}{32.2}\times 5600$$
$$=7820\ \text{(lbs.)}$$

Although this force is large, it is not excessive.

The maximum acceleration of the bolt occurs at 0.00705 second and is equal to 8000 feet per second per second. Since the bolt weighs 5 pounds, the force required to produce this acceleration is:

$$F=Ma-\frac{5}{32.2}\times 8000$$
$$-1245\ \text{(lbs.)}$$

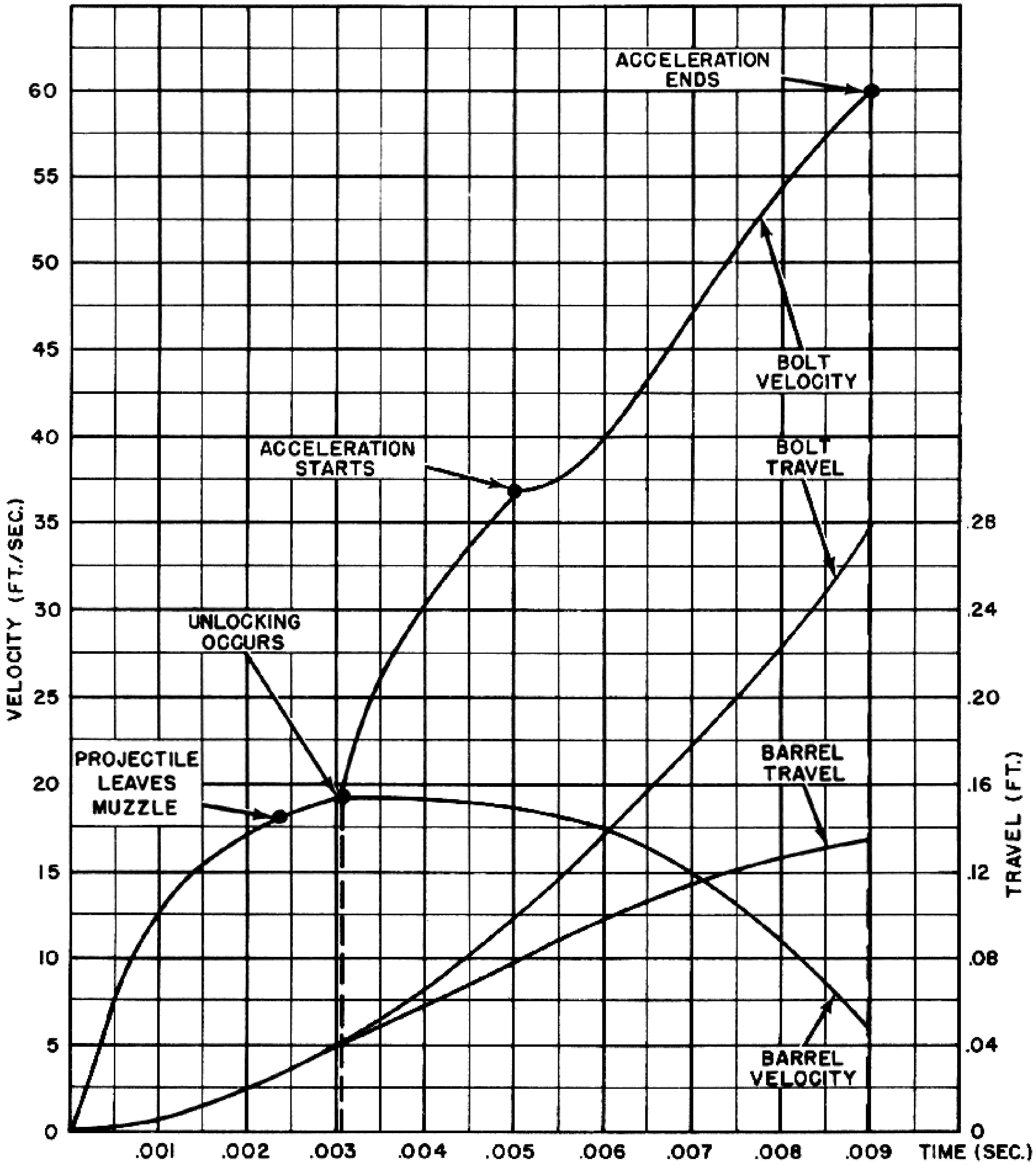

Figure 2–27. Time-Travel and Time-Velocity Curves Up to End of Acceleration Period.

6. *Barrel recoil motion after acceleration*

After the action of the accelerating device has been completed, the barrel must be stopped and latched, and the bolt must continue its rearward travel until the opening between the barrel and bolt is sufficient to permit feeding of a fresh cartridge.

At the end of the acceleration period, the barrel of the gun used as example is moving at the rate of 6 feet per second. Since the accelerating device is no longer acting, the barrel motion will now be impeded only by the barrel return spring. As shown in fig. 2–27, the barrel travel at 0.009 second is 0.135 foot, and at this displacement the force of the barrel spring is:

$$F_{o_1} + K_1 D = 250 + 300 \times .135 \times 12 = 736 \text{ (lb.)}$$

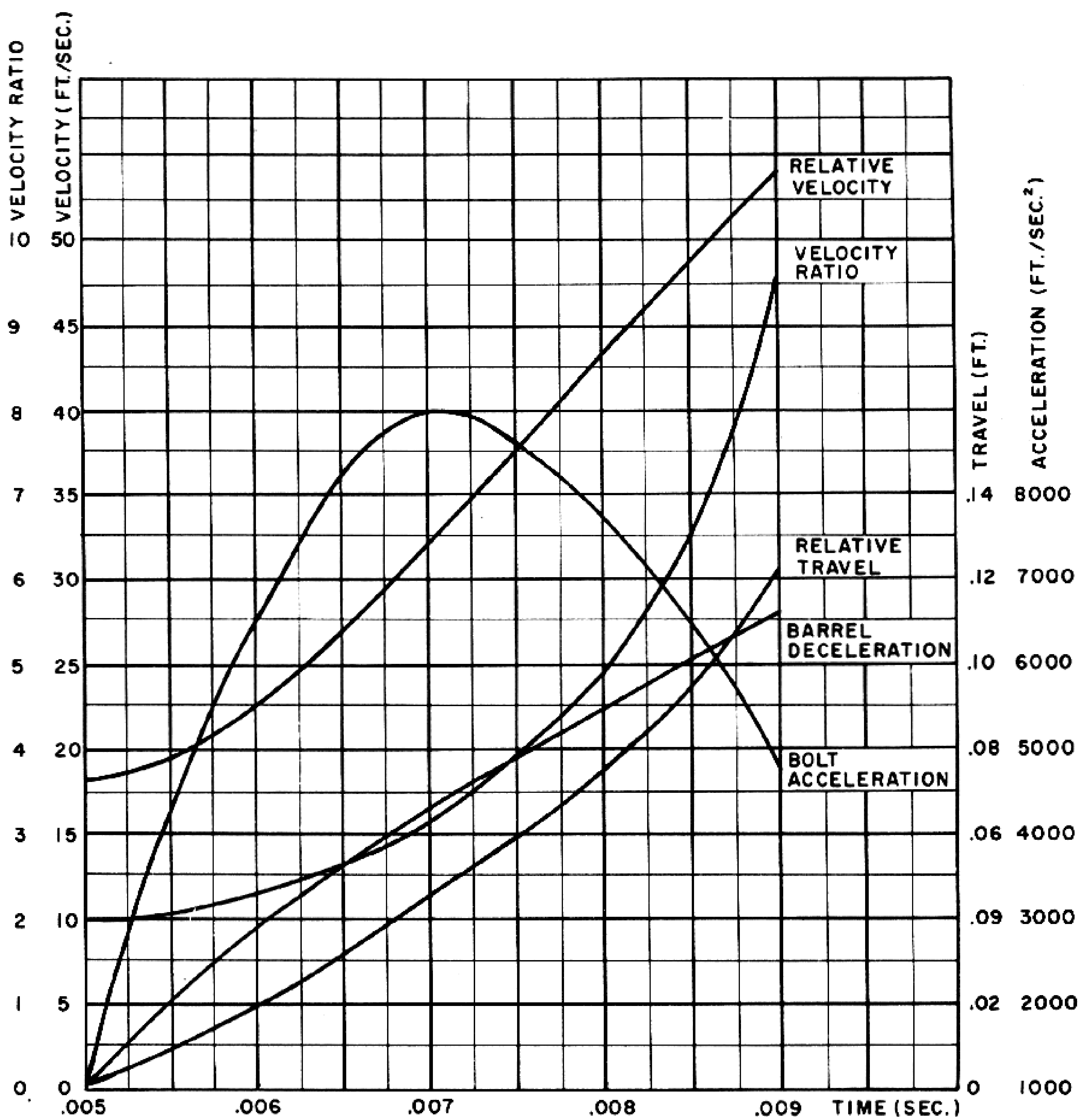

Figure 2–28. Data Pertaining to Action of Accelerating Lever.

For purpose of determining the barrel motion from 0.009 second on, this force of 736 pounds can be considered to be the initial compression of the spring and the retarding effect of the spring can be computed by the same methods used for developing the motion curves for the period before acceleration. The velocity loss due to the initial compression will be:

$$V=\frac{F_0}{M}\,t=\frac{736\times32.2}{45}\,t$$
$$=527\,t$$

That is, the effect of the initial compression causes the barrel velocity to decrease at the rate of 527 feet per second per second. This loss is shown in fig. 2–29 by the curve designated as step 2. The

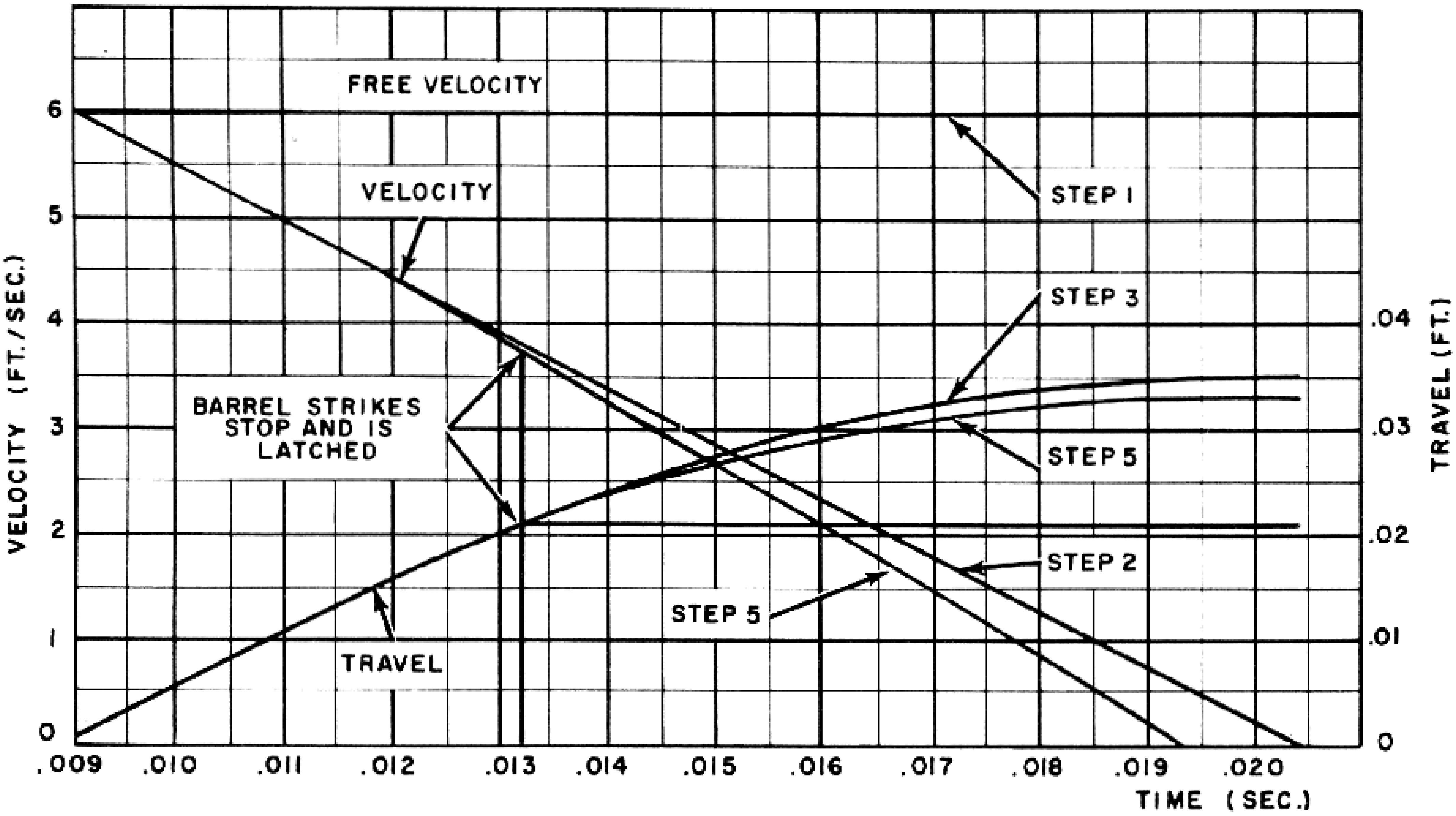

Figure 2–29. Effect of Barrel Return Spring on Barrel Motion After Acceleration.

loss due to the effect of the spring constant is determined by the method of step 4 of the procedure previously described and the modified curves are designated as step 5. Since the performance of step 6 produces a negligible change in the curves, the curves drawn in accordance with step 5 represent the effect of the barrel spring on the barrel motion. The curves show that if the barrel spring alone resists the barrel motion after the acceleration action is completed, the barrel will move an additional 0.033 foot (0.40 inch) and will come to a stop at 0.0193 second. Both this distance and the time are a little too great since it is desirable to stop the barrel as soon as possible. Therefore, a stop will be provided to limit the barrel movement to 0.250 inch (0.0208 foot) after acceleration is completed. As indicated in fig. 2–29, this movement occurs at 0.132 second. At this point the velocity of the barrel is only 3.70 feet per second and therefore has a kinetic energy of only 9.55 foot pounds, indicating that the shock of hitting the stop will be relatively light. After being halted by the stop, the barrel is latched in place so that it remains in its rearmost position. This is shown in fig. 2–29 by the fact that the barrel travel curve is a horizontal line after 0.132 second. The data from fig. 2–29 are used to extend the barrel motion curves on the graph (fig. 2–30) showing the motion curves for the complete cycle.

7. Bolt recoil motion after acceleration

At the end of the acceleration period, the bolt is moving with a velocity of 60 feet per second and its motion from this point on is resisted only by the bolt driving spring. As shown on fig. 2–30, the barrel is latched at a displacement of 0.156 foot (1.875 inches). Since it has been assumed that the opening between the barrel and bolt must be 10 inches in order to permit feeding, the bolt must travel a total of 11.9 inches (0.993 foot) before it is stopped by the backplate buffer. Fig. 2–27 shows that the bolt travel at the end of the acceleration period is 0.280 foot and the bolt must travel an additional 0.173 foot.

The motion of the bolt after acceleration may be determined by the same methods as used for the barrel motion. (Cf. fig. 2–31.) The first step is to draw a horizontal line at 60 feet per second to show the free bolt velocity. At the end of the

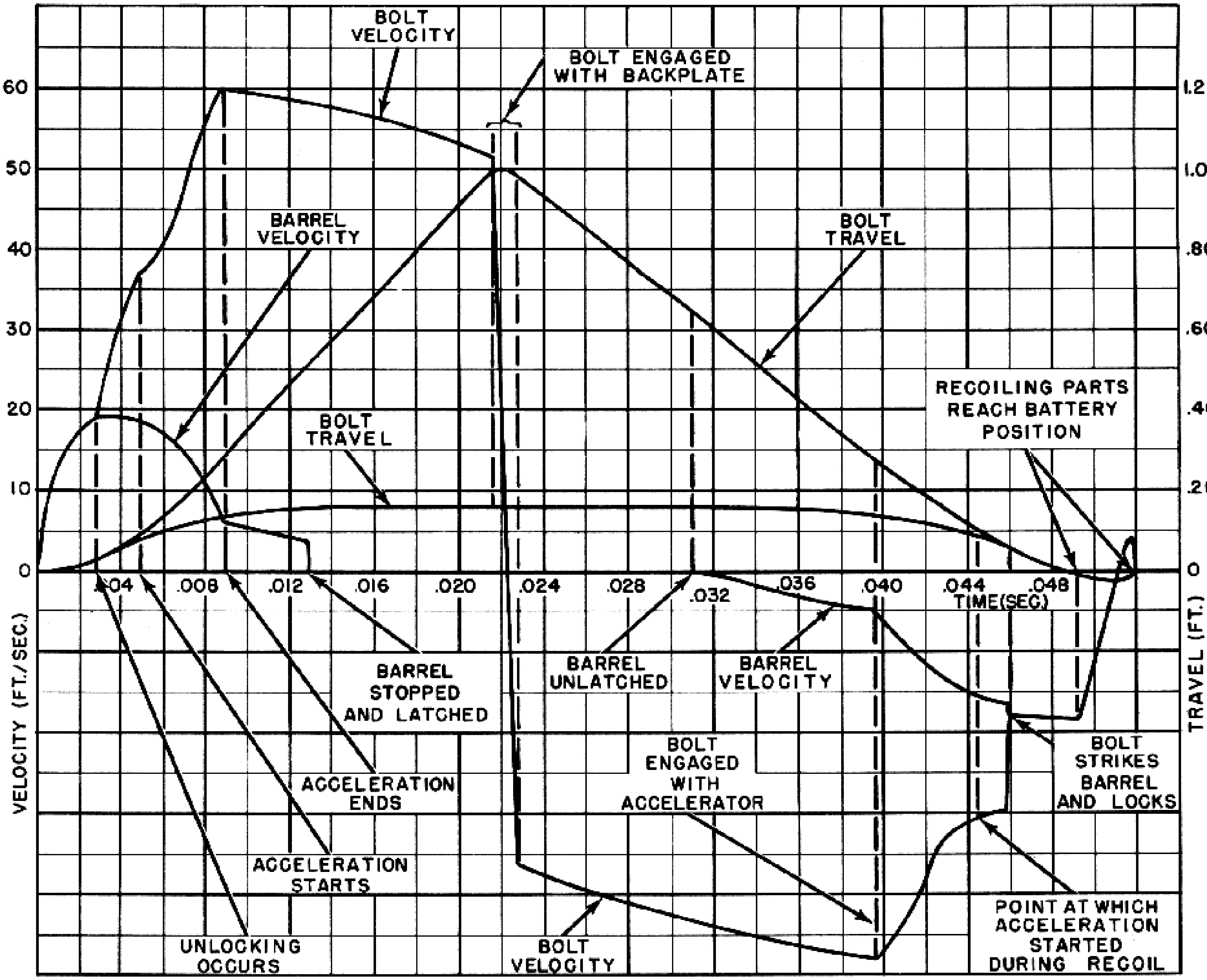

Figure 2–30. Time-Travel and Time-Velocity Curves for Complete Cycle of Operation.

acceleration period, the bolt travel is 0.280 foot and therefore the force on the bolt driving spring must be

$$F_{o_2}+K_2D=25+.280\times10\times12=25+33.6$$
$$=58.6 \text{ (lb.)}$$

Taking this force as the initial compression of the spring for the time after acceleration, the velocity loss due to this force will be

$$V=\frac{F_o}{M}t=\frac{58.6\times32.2}{5}t$$
$$=378\ t$$

The effect of this loss is shown in fig. 2–31 by the curve designated as step 2. The loss due to the effect of the spring constant is determined by the method of step 4 and the modified curves are designated as step 5. The performance of step 6 produces no significant change in the curves and therefore the curves designated as step 5 represent the effect of the bolt driving spring on the bolt motion. The curves show that the bolt reaches the required additional travel of 0.713 foot at 0.216 second and it is at this point that the bolt reaches the backplate buffer. Note that the striking velocity is 51.5 feet per second. The data from fig. 2–31 are used to extend the bolt motion curves in fig. 2–30 up to the time the backplate buffer is struck.

8. *Reversing action of backplate buffer*

The purpose of the backplate buffer is to reverse the bolt motion at the end of the recoil stroke with

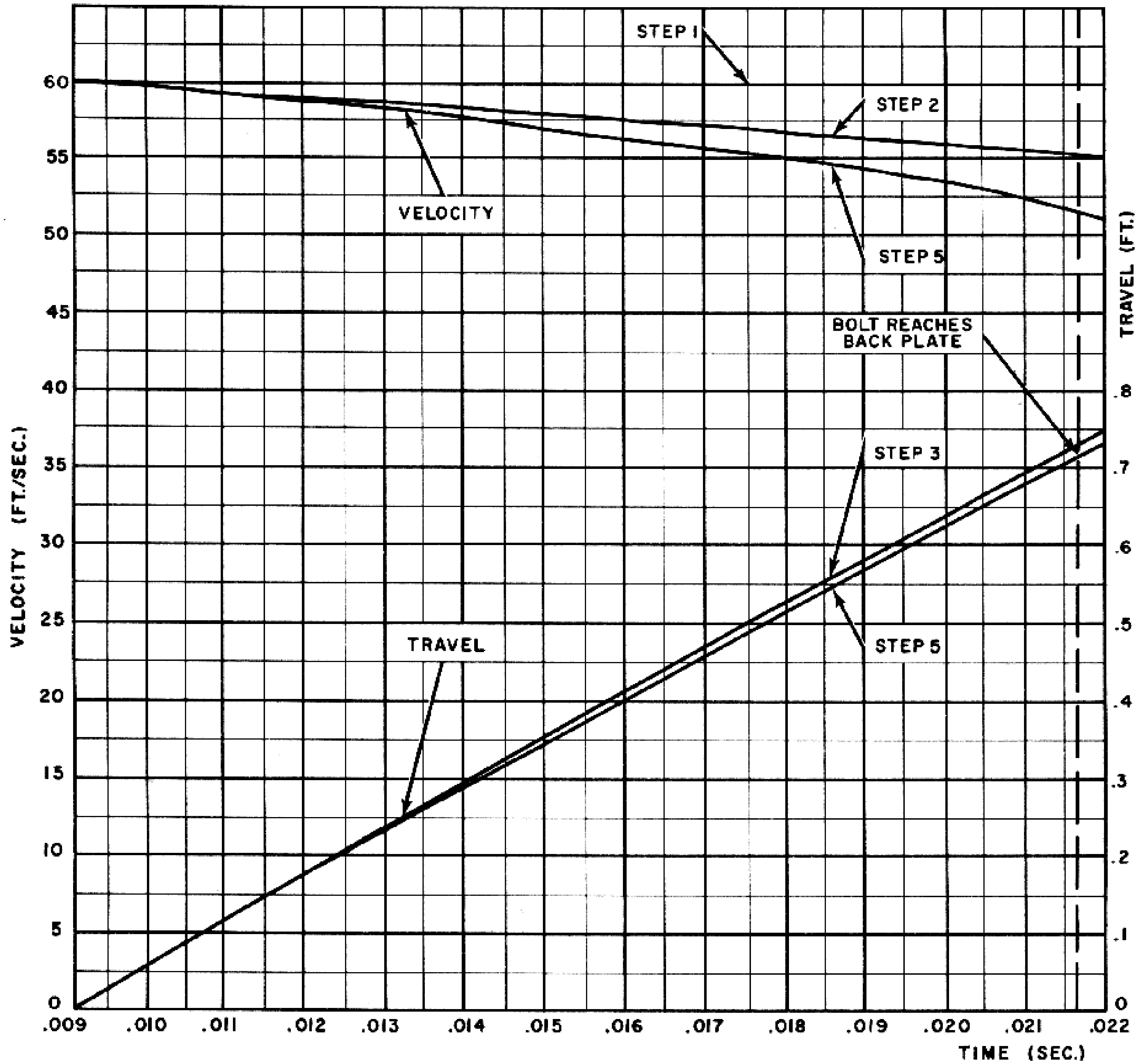

Figure 2–31. Effect of Bolt Driving Spring on Bolt Motion After Acceleration.

the minimum possible loss of time and energy. In the analysis of short recoil it was pointed out that, although the reversing action is accomplished almost instantaneously by causing the bolt to rebound from an extremely stiff elastic member, the impact is accompanied by a loss of energy with the result that the velocity of the bolt after impact will be at best approximately 70 per cent of its striking velocity.

Since the velocity of the bolt before striking the backplate is 51.5 feet per second, the momentum of the bolt is:

$$MV = \frac{5}{32.2} \times 51.5 = 8.00 \text{ (lb. sec.)}$$

Assuming that the coefficient of restitution of the backplate is .70, the velocity of the bolt after impact will be:

$$V = .70 \times 51.5 = 36.0 \left(\frac{\text{ft.}}{\text{sec.}}\right)$$

The momentum of the bolt will then be:

$$MV = \frac{5}{32.2} \times 36.0 = 5.77 \text{ (lb. sec.)}$$

Thus, in the reversing action of the backplate, the change in bolt momentum is equal to 8.00+5.77=13.77 (lb. sec.). If the entire reversing action occurs in 0.001 second, the average force exerted on the backplate must be:

$$\frac{13.77}{.001}=13{,}700 \text{ (lb.)}$$

The striking energy of the bolt is:

$$KE=\frac{1}{2}MV^2=\frac{1}{2}\times\frac{5}{32.2}\times 51.5^2=206 \text{ (ft. lb.)}$$

If it is assumed for purposes of estimation that the backplate offers a constant resistance of 13,700 pounds, the deflection of the elastic member under the impact will be:

$$\frac{206}{13{,}700}=.015 \text{ (ft.) or approximately } 3/16 \text{ (inch)}$$

The data derived in the preceding analysis are used to complete the motion curves of fig. 2–30 for the 0.001 second interval during which the backplate buffer acts.

9. *Motion of bolt after reversal at backplate*

The bolt leaves the backplate with a velocity of 36.0 feet per second, and as it moves in counter-recoil, its motion is aided by the compressed driving spring. This action will continue until the bolt re-engages with the accelerator lever when the bolt displacement from the firing position is equal to 0.28 foot.

The bolt motion under the influence of the driving spring can be determined by essentially the same method previously employed for analyzing the effect of the springs. (Cf. fig. 2–32.) The first step is to draw a horizontal line at minus 36 feet per second to represent the free bolt velocity. In this case, the subsequent procedure must be slightly modified because the action of the spring is aiding the motion of the bolt rather than retarding it. At the start of the return motion of the bolt, the bolt driving spring is compressed 1.008 feet and hence the initial compression of the spring is:

$$F_o+KD=25+10\times12\times1.008=25+121$$
$$=146 \text{ (pounds)}$$

The velocity gain due to this force would be:

$$V=\frac{F_o}{M}t=\frac{146\times32.2}{5}t$$
$$=940\ t$$

The effect of this gain in velocity is shown in fig. 2–32 by the curve designated as step 2. The curve designated as step 3 shows the change in bolt travel that would result from this velocity. Since the bolt is now moving forward, the effect of the spring constant is to decrease the force on the bolt. Therefore, the change in velocity determined by the method of step 4 must be subtracted from the curve obtained in step 2. The modified curves are designated as step 5. Since the change in the travel curve is so slight, it is not necessary to perform step 6 and the curves designated as step 5 represent the effect of the bolt driving spring on the bolt motion.

NOTE: The validity of the foregoing method may be seen by examining the equation expressing the change in velocity of the bolt due to the effect of the driving spring:

$$V=\int_o^t\frac{Fdt}{M}=\int_o^t\frac{F_o+K(D-d)}{M}dt$$

where: D is the total distance the spring is compressed at the start of the forward motion

and d is the forward movement of the bolt from its rearmost position.

$$\Delta V=\frac{1}{2}\int_o^t(F_o+KD)\,dt-\frac{1}{2}\int_o^t(Kd)\,dt$$
$$=\frac{F_o+KD}{M}t-\frac{K}{M}\int_o^t(d)\,dt$$

This is the equation defining the procedure followed in obtaining the curves in fig. 2–32.

Since the bolt leaves the backplate at a displacement of 0.993 foot and the bolt will re-engage the accelerating lever at a displacement of 0.280 foot from the firing position, the bolt must move .993—.280=.713 foot up to the time the lever is engaged. Fig. 2–32 shows that the time at which the lever is engaged is 0.0396 second and that the velocity of the bolt at this instant is minus 48.0 feet per second. The data from fig. 2–32 are used to extend

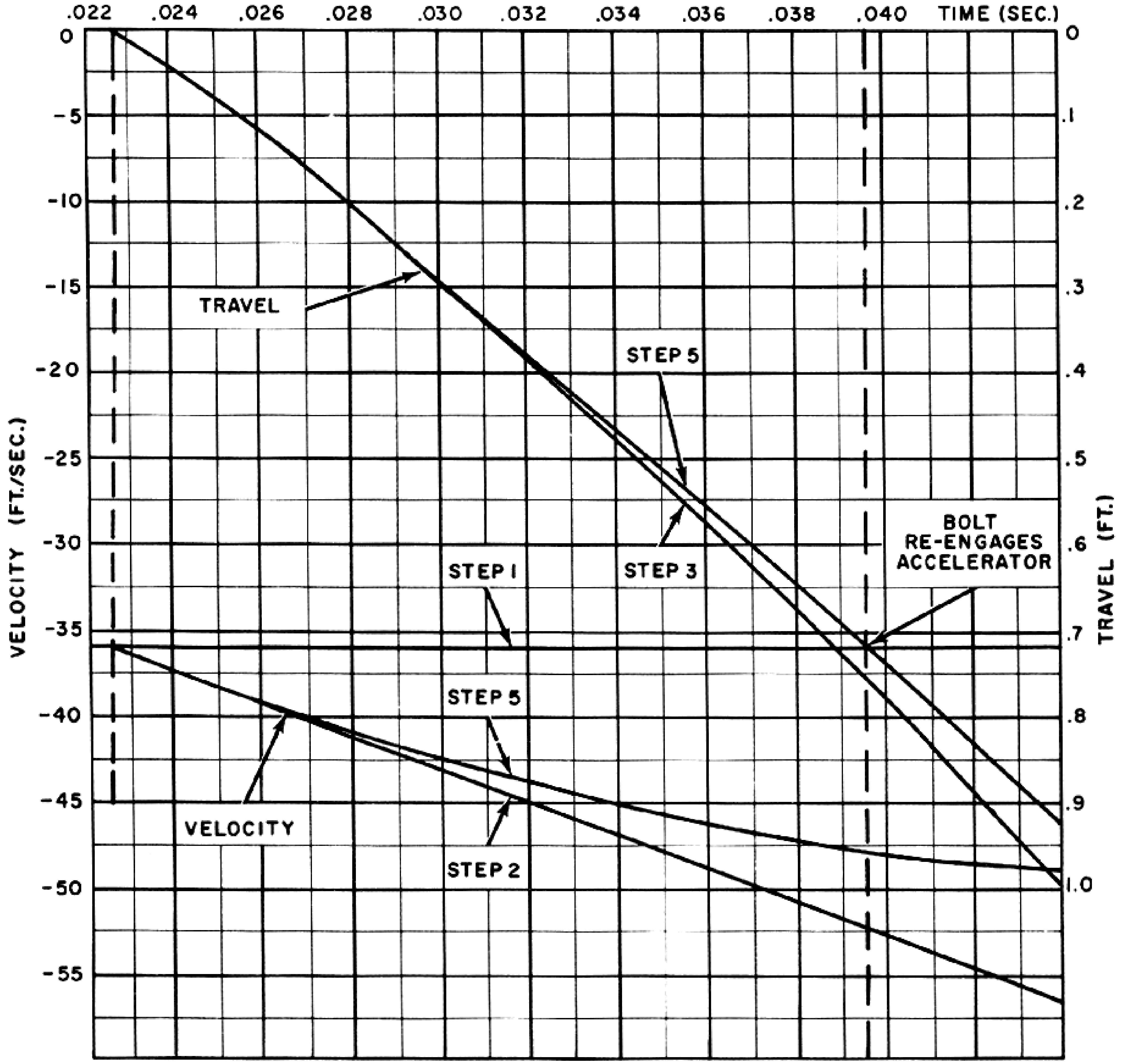

Figure 2–32. Effect of Bolt Driving Spring on Motion of Bolt After Reversal of Motion at Backplate.

the bolt motion curves in fig. 2–30 up to the time that the bolt strikes the accelerating lever.

10. *Motion of barrel before accelerator is reengaged*

In order to give the barrel return spring a chance to start the barrel moving before the bolt reaches the accelerator lever, the barrel should be unlatched while the bolt is still some distance from the point at which the accelerator will be engaged. For smoothest action, the time the barrel is unlatched should be set so that the barrel will move ahead to the position it occupied at the instant that the original acceleration of the bolt was completed. (This position is 0.135 foot from the firing position, as shown in fig. 2–27.) Depending on the configuration of the accelerating lever, it may be necessary to provide a means to insure that the returning bolt will pick up the lever, in order to make certain that the lever will assume its proper position between the bolt and barrel.

At this point in the analysis, the problem is to determine the effect of the barrel return spring on

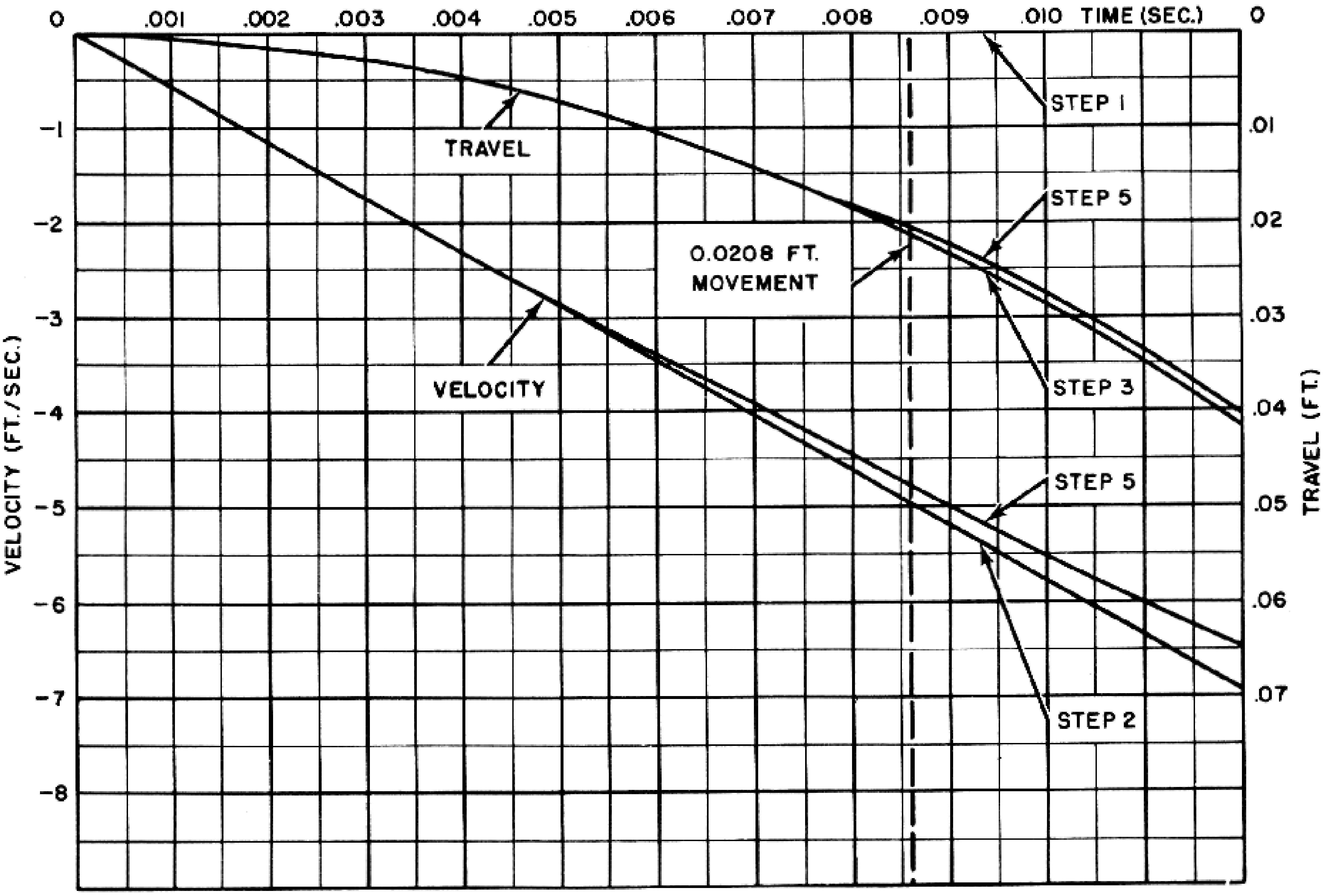

Figure 2–33. Effect of Barrel Spring on Barrel Motion After Unlatching.

the barrel motion and to find the time at which the barrel should be unlatched to satisfy the requirements of the preceding paragraph. The analysis of the barrel return motion is conducted in the same way as for the bolt return motion. (Cf. fig. 2–33.)

In this case, the initial velocity of the barrel is zero and therefore the free-velocity curve coincides with the zero axis. Since the barrel is latched at a displacement from the firing position of 0.160 foot, the initial compression of the barrel return spring is:

$$F_o + KD = 250 + 300 \times 12 \times .156 = 250 + 562$$
$$= 812 \text{ (pounds)}$$

The velocity gain due to this force would be:

$$V = \frac{F_o}{M} t = \frac{8 + 2 \times 32.2}{45} t$$
$$= 580\ t$$

This gain in velocity is shown in fig. 2–33 by the curve designated as step 2. The barrel travel which would result from this velocity is shown by the curve designated as step 3. Step 4 is performed by the same method as for the bolt return motion and the modified curves are designated as step 5. The change in the travel curve is so slight that it is not necessary to perform step 6 and therefore the curves designated as step 5 represent the effect of the barrel return spring on the barrel motion.

Since the bolt is latched at a displacement of 0.156 foot and is required to move forward to a displacement of 0.135 foot, the required movement is .156 − .135 = .0208 foot. The curves in fig. 2–33 show that this movement is accomplished in 0.0086 second from the time of unlatching. It has already been specified that the barrel must reach the displacement of 0.135 foot at the instant the bolt reaches a displacement of 0.280 foot, which occurs at 0.0396 second, and therefore the barrel must be unlatched 0.0086 second before this time, or at 0.310 second. The data in fig. 2–33 are used to complete the barrel return motion curves up to 0.0396 second.

11. *Return motion of barrel and bolt during action of accelerating lever*

During the return motion of the barrel and bolt, the effect of the action of the accelerating lever is to transfer kinetic energy from the bolt to the barrel, thus gradually slowing the motion of the bolt and accelerating the motion of the barrel. This action has the beneficial effect of greatly reducing the shock which would occur if the bolt, which is returning at high velocity, merely collided with the rear face of the barrel.

The analysis of the motion of the barrel and bolt during the action of the accelerating lever in counter-recoil is considerably more complicated than for recoil. This is because of the fact that the lever has already been designed and the velocity of the barrel or bolt can no longer be selected as desired but will be determined by the characteristics of the lever.

The analysis during the action of the accelerating lever is conducted on the basis of equating the energies in the system. The energy relationship may be expressed as:

Initial KE+Work done by springs—Energy losses=Barrel KE+Bolt KE.

This relationship, considered together with the fact that the lever causes a known relative motion between the barrel and bolt and also causes a known ratio between their velocities, is used as follows in determining the motions:

At the start of the action of the lever, the velocities of the barrel and bolt are known. That is (from fig. 2–30) $V_1=4.8$ feet per second and $V_2=48$ feet per second. Note that the ratio between these velocities is 10:1 which is the same as the lever ratio of the accelerator at the instant it is engaged. (Cf. fig. 2–28.) This is a desirable condition because it means that the action of the lever will start without a large shock. With the stated velocities, the initial energies in the barrel and bolt will be:

$$\text{For barrel: } E=\frac{1}{2}MV^2=\frac{45}{2\times 32.2}\times 4.8^2$$

$$=16.1 \text{ (ft. lb.)}$$

For bolt:

$$E=\frac{1}{2}MV^2=\frac{5}{2\times 32.2}\times 48$$

$$=178.9 \text{ (ft. lb.)}$$

Therefore, the total initial energy is equal to 16.1+178.9=195 foot pounds.

The energy delivered by the springs can not be determined as a function of time because the relationships between the motions and time have not yet been established. However, it is possible to express the energy delivered by the springs in terms of the distances moved from the start of the accelerating lever action. For a movement from a displacement D_1 to a smaller displacement D_2, the energy delivered by a spring is equal to the average spring force times the displacement.

That is:

$$E=\frac{(F_o+KD_1)+(F_o+KD_2)}{2}(D_1-D_2)$$

(2–24)

$$E=\frac{2F_o+K(D_1+D_2)}{2}(D_1-D_2)$$

During the action of the accelerator, the bolt moves from an initial displacement of 0.280 foot to a final displacement of 0.105 foot and the barrel moves from an initial displacement of 0.135 foot to a final displacement of 0.080 foot. (These values are taken from fig. 2–27.) For the barrel, $F_o=250$ pounds and $K=3600$ pounds per foot. For the bolt, $F_o=25$ pounds and $K=120$ pounds per foot.

Now the bolt travel may be divided into any desired number of increments between 0.280 foot and 0.105 foot and then the corresponding increments of the bolt travel may be found from fig. 2–27 and the results can be tabulated. For later use, the velocity ratio corresponding to each set of increments can be obtained from fig. 2–28 and added to the tabulation. For example, see Table 2–1.

Table 2–1

Increments of Travel and Velocity Ratio

Bolt travel (feet)	Barrel travel (feet)	Velocity Ratio
.280	.135	10.00
.245	.132	6.22
.210	.124	4.30
.175	.112	2.90
.140	.100	2.35
.105	.080	2.00

The values shown in Table 2–1 can be used to determine the values for (D_1+D_2) and (D_1-D_2) in equation 2–8 and the equation can be employed to compute the energy delivered by each spring in moving from the initial displacement to each displacement indicated in Table 2–1. For example, in moving from a displacement of 0.280 foot to 0.245 foot, the bolt spring delivers:

$$E=\frac{2\times25+120\ (.280+.245)}{2}\ (.280-.245)$$

$$=1.98\ \text{(ft. lb.)}$$

The energy delivered by the barrel spring for the corresponding displacement is:

$$E=\frac{2\times250+3600\ (.135+.132)}{2}\ (.135-.132)=2.19$$

The procedure is repeated for the other displacements.

The next point is to consider the energy losses in the action of the lever. To be consistent with the assumption made for the action during recoil, the total loss for the period of action will be taken as 6 foot pounds. This value is so small that it will have little effect, and therefore it can arbitrarily be distributed equally over the period, allowing the loss to increase by 1.2 foot pounds for each of the five increments being used for computation. Since all of the required energy values have now been determined, the velocities of the barrel and bolt for each displacement can be computed as follows:

The energy in the moving parts at any point in their travel is

$$E=\frac{1}{2}M_1V_1^2+\frac{1}{2}M_2V_2^2$$

But $V_2=RV_1$, where R is the velocity ratio shown in fig. 2–28.

Therefore:

$$E=\frac{1}{2}M_1V_1^2+\frac{1}{2}M_2\ (RV_1)^2$$

$$E=\frac{1}{2}(M_1+M_2R^2)\ V_1^2$$

Solving for V_1:

$$V_1^2=\frac{2}{M_1+M_2R_2}\ E$$

But the total energy in the barrel and bolt at any time must be equal to the initial energy plus the energy delivered by the springs minus the losses.

Therefore:

$$V_1^2=\frac{2}{M_1+M_2R^2}\ (\text{Initial KE}+\text{energy from springs}-\text{losses})$$

This computation will be illustrated by using the values for the first increment in Table 2–1.

$$V_1^2=\frac{2\times32.2}{45+5\times6.22^2}\ (195+1.98+2.19-1.2)=53.5$$

$$V_1=\sqrt{53.5}=7.32\ \text{(ft./sec.)}$$

But

$$V_2=RV_1=6.22\times7.32$$

$$V_2=45.5\ \text{(ft./sec.)}$$

The same procedure is followed for the other values shown in Table 2–1, in each case using the correct velocity ratio, energy from spring, and losses. The resulting values of barrel velocity and bolt velocity are then plotted against the corresponding values of displacement to give the velocity curves shown in figs. 2–34 and 2–35. Since the independent variable in these graphs is travel instead of time, the curves can not be used directly to extend the time-travel and time-velocity curves in fig. 2–30. However since:

$$V=\frac{dD}{dt}\ \text{(where D is travel)},$$

$$dt=\frac{dD}{V}$$

Thus, values of the time required to produce a displacement from D_1 to D_2 can be determined by the relation

$$t=\int_{D_1}^{D_2}\left(\frac{1}{V}\right)dD$$

The first step in determining the time values is to plot a reciprocal velocity curve, as shown in figs. 2–34 and 2–35. Since the barrel and bolt are returning to battery, the displacement is decreasing. Therefore the values of time are determined by integrating under the 1/V curve from right to left.

Having the time versus travel curves, it is now possible to find the travel and velocity corresponding to each value of the time and to use this data to

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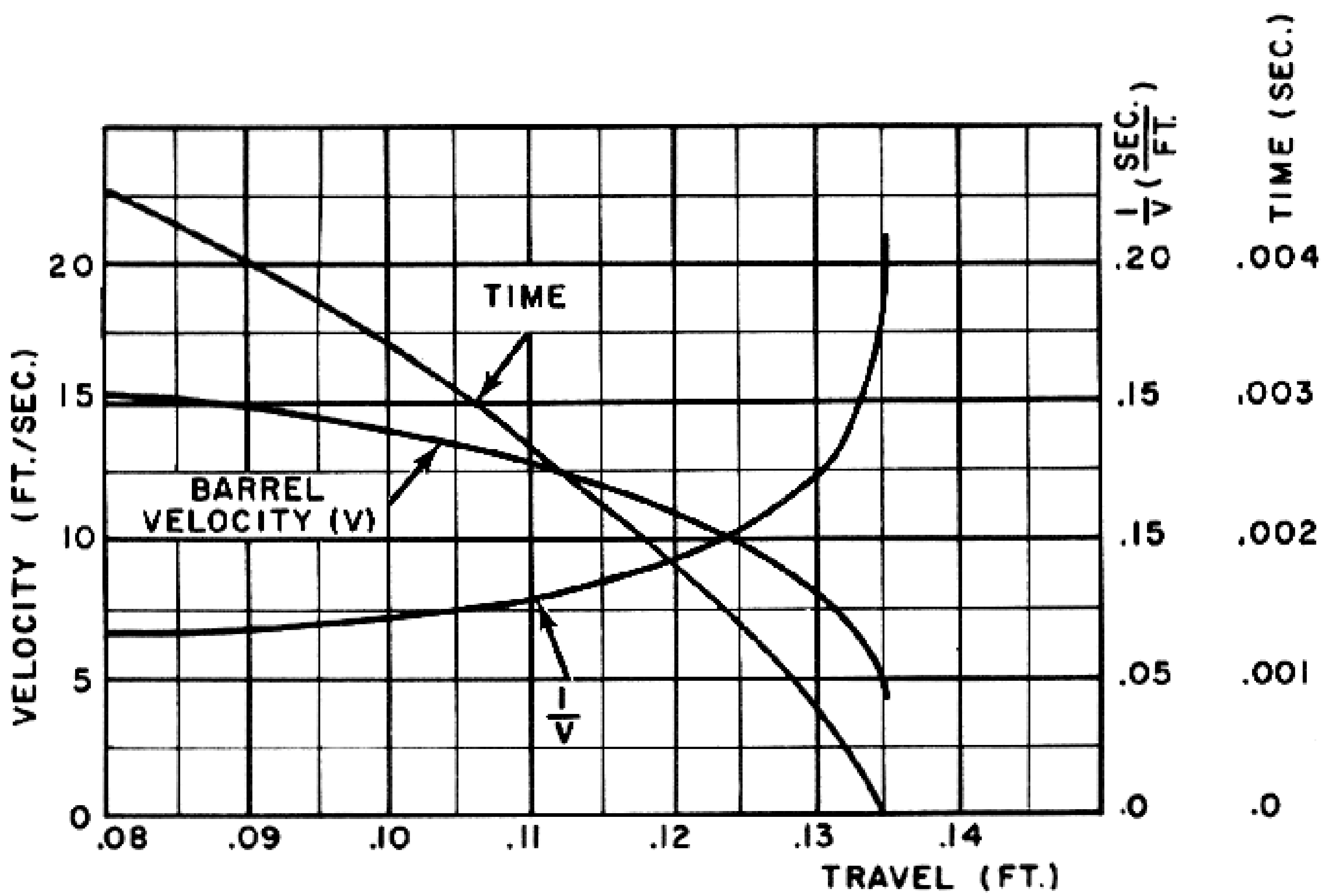


Figure 2–34. Barrel Velocity and Time Versus Barrel Travel During Action of Accelerator in Counter-Recoil.

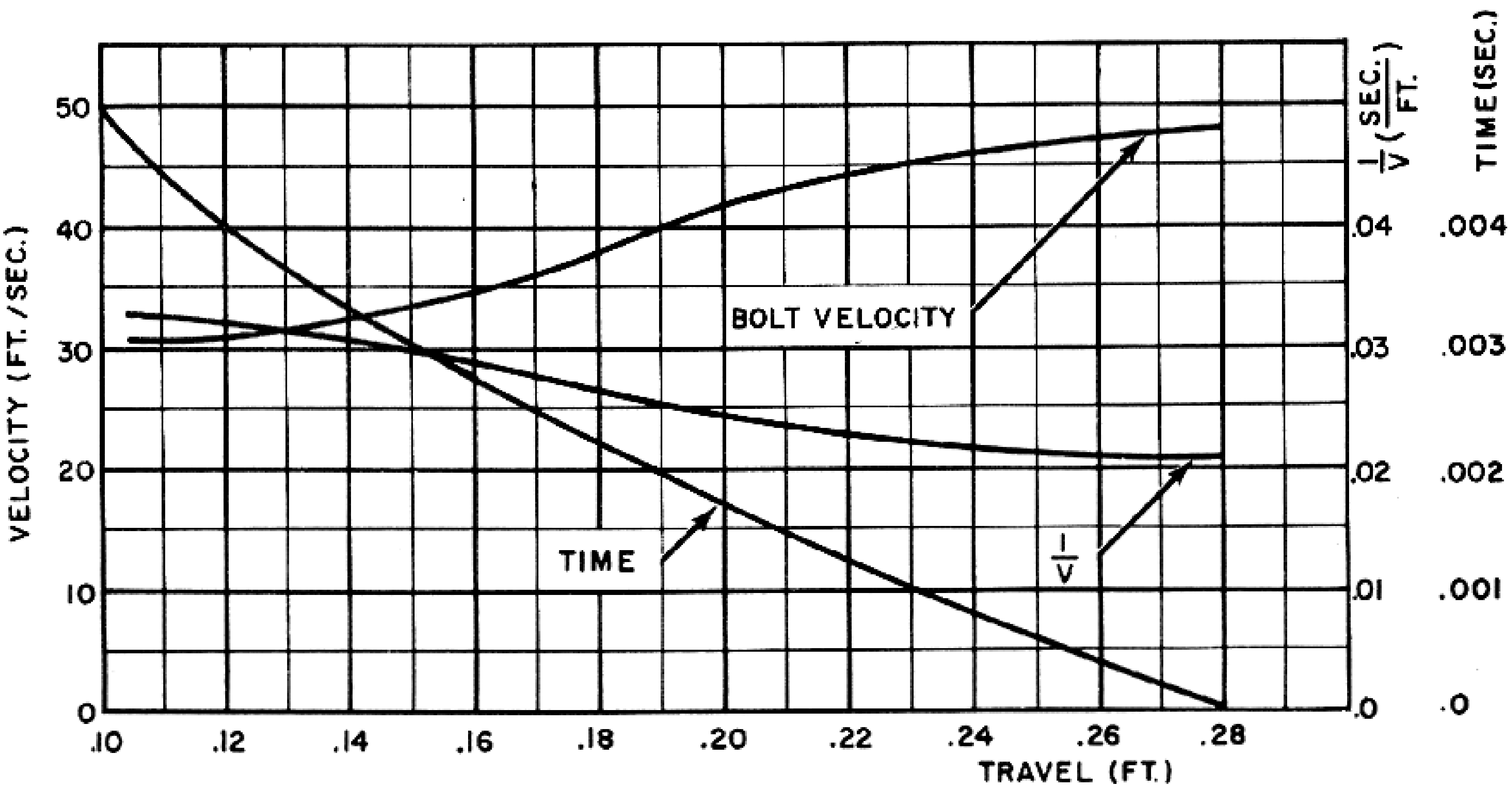


Figure 2–35. Bolt Velocity and Time Versus Bolt Travel During Action of Accelerator in Counter-Recoil.

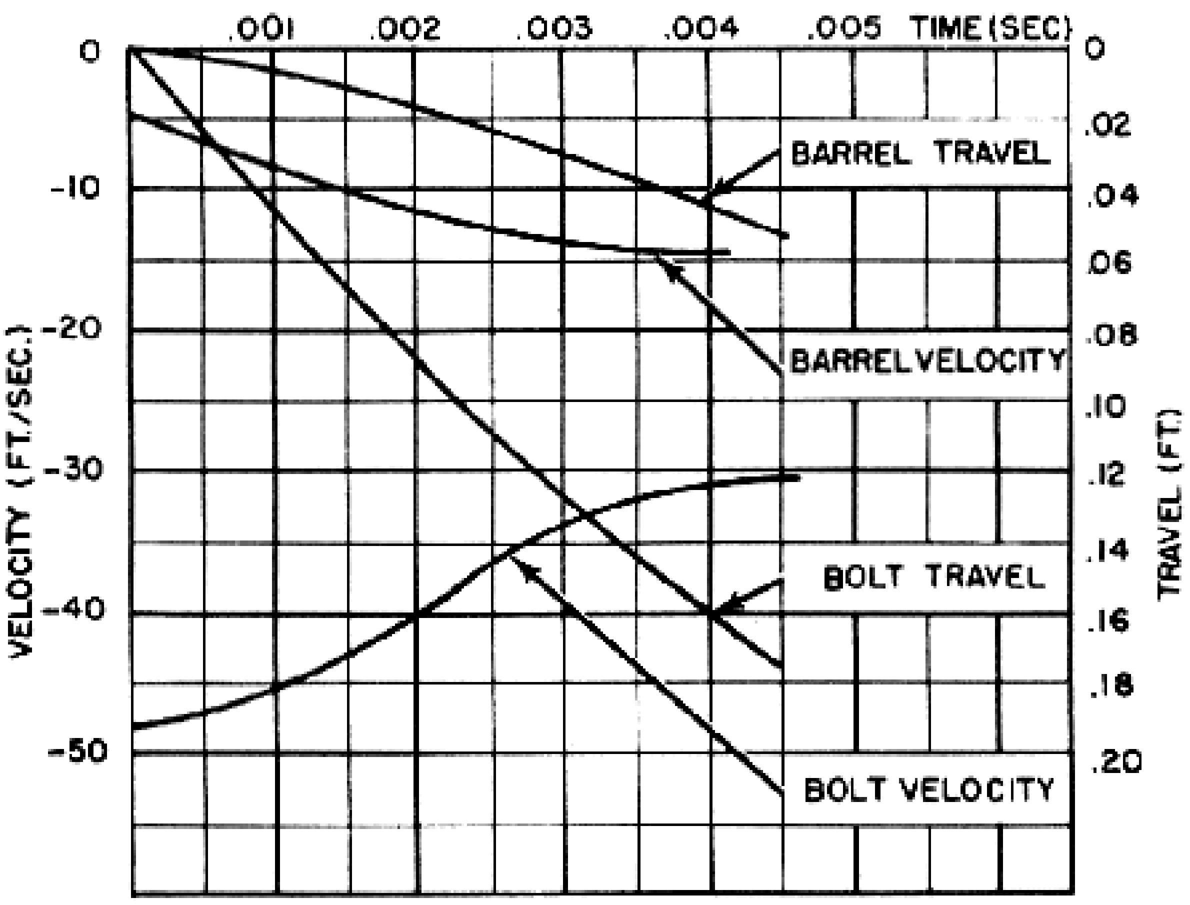


Figure 2–36. Barrel and Bolt Motion Versus Time During Action of Accelerator During Counter-Recoil.

plot curves showing the variation of the velocity and travel with respect to time. These curves are shown in fig. 2–36. The data from these curves can now be used to extend the time-travel and time-velocity curves of fig. 2–30. Note that the action of the accelerating lever increases the barrel velocity from 4.8 feet per second to 15.0 feet per second and decreases the bolt velocity from 48 feet per second to 30 feet per second and that this result is accomplished in 0.0045 second. The total time from the beginning of the cycle up to this point is 0.0441 second.

12. *Barrel and bolt motion after 0.0441 second*

At the point reached in the preceding analysis, the relative displacement between the barrel and bolt is equal to 0.0208 foot (0.250 inch) and the parts are located at the same position in which the acceleration action began during recoil. However, the action of the accelerator does not stop at this point during counter-recoil because the level is still between the barrel and bolt and will continue to act until the bolt reaches the barrel and locks in place. The remaining movement is so small that it will be accomplished in a very short time (approximately 0.0015 second) and therefore the shape of the small portion of the lever which acts during this interval is not critical. On this basis, it is assumed that after 0.0441 second the barrel and bolt velocity curves will follow the same trends as before this time. For the subsequent interval of approximately 0.0015 second, the average bolt velocity as shown in fig. 2–30 will be about 16 feet per second and the average bolt velocity will be about 30 feet per second. This means that the average relative velocity between these parts will be approximately 14 feet per second and the time required for the barrel to strike the bolt will be:

$$t = \frac{D}{V_{av}} = \frac{0.0208}{14} = 0.001485 \text{ second}$$

Thus, the barrel and bolt will meet at 0.0456 second at a displacement from battery of approximately 0.06 foot.

When the bolt and barrel meet, the bolt locks to the barrel. At the instant of impact, the velocity of the bolt is 29.5 feet per second and the velocity of the barrel is 16.5 feet per second. Since the bolt locks to the barrel, the parts will assume some common velocity. The value of the common velocity is determined by the fact that the momentum of the combined mass after impact wil be the same as the total momentum before impact. That is:

$$M_r V_3 = M_1 V_1 + M_2 V_2$$

For the conditions of the example:

$$\frac{50}{32.2} V_3 = \frac{45}{32.2} \times 16.5 + \frac{5}{32.2} \times 29.5$$

$$V_3 = 17.6 \text{ (ft./sec.)}$$

As the barrel and bolt move to battery, this velocity will be increased slightly by the combined force of the barrel return spring and bolt driving spring. Since the remaining motion is so short (0.06 foot), it will be sufficiently accurate to estimate the effect of this force by assuming that the average force will be the force which exists at a displacement of 0.03 foot. This force is:

$$F = F_{o_1} + F_{o_2} + .03\ (K_1 + K_2)$$

$$= 250 + 25 + .03\ (3600 + 120)$$

$$= 387 \text{ (pounds)}$$

The increase in velocity produced by this force will be:

$$V = \frac{F}{M} t$$

$$= \frac{387 + 32.2}{50} t$$

$$= 250\ t$$

This increase in velocity is indicated by sloping the velocity curve after locking occurs by an amount corresponding to a velocity increase of one foot per second in 0.004 second. (See fig. 2–30.) Since the average velocity of the recoiling parts shortly after locking is approximately 18 feet per second, the time required to complete the remaining 0.060-foot movement to battery will be:

$$t=\frac{D}{V_{av}}=\frac{.06}{18}=.0033 \text{ (second)}$$

Therefore, the recoiling parts reach the battery position at 0.0490 second. Note that the velocity of the recoiling parts at the battery position is 18.2 feet per second.

With a velocity of 18.2 feet per second, the kinetic energy of the recoiling parts will be:

$$KE=\frac{1}{2}MV^2=\frac{50}{2\times 32.2}\times 18.2^2=257 \text{ (ft. lb.)}$$

This is a relatively large amount of energy and could cause an extremely severe shock if an attempt were made to stop the recoiling parts merely by permitting the barrel to strike the breech casing. One way to handle this energy would be to provide a heavy buffer which is designed to dissipate a large percentage of the striking energy of the recoiling parts. An idea of the character of this buffer can be obtained by considering what average force it would be required to produce if it is to stop the recoiling parts within 0.250 inch (0.0208 foot). This force would be

$$F_{av}=\frac{KE}{D}=\frac{257}{.0208}=12{,}350 \text{ pounds}$$

It must be emphasized that the buffer should be of a type which dissipates practically all of the energy it absorbs so that the recoiling parts will be braked to a stop and will not tend to rebound from the buffer. If the buffer does not dissipate the striking energy, the residual energy may cause instability of action and may give rise to oscillations which can cause serious damage to the weapon.

As explained in the analysis of the short recoil system of operation, the problem of handling the kinetic energy possessed by the recoiling parts as they return to battery can be greatly simplified by timing the ignition of the next round so that the round is fired while the recoiling parts are still moving forward. In this way, the large forces exerted in the early part of the propellant explosion can be utilized to stop the recoiling parts or at least can be used to aid the buffer.

Although the force of the propellant explosion is capable of stopping and reversing the motion of the recoiling parts without the assistance of a buffer, there is an important point to consider. The final counter-recoil velocity of the gun used as an example is 18.2 feet per second and therefore the momentum of the 50-pound mass is:

$$MV=\frac{50}{32.2}\times 18.2=28.3 \text{ (lb. sec.)}$$

Early in this analysis, it was pointed out that the total impulse which can be produced by the sample cartridge is only 35 pound seconds. Therefore, it appears that if the propellant explosion were used alone to stop the forward motion of the recoiling parts after firing the first round, the impulse remaining to produce recoil would be only 35.0—28.3= 6.7 (pound seconds). Since the impulse producing recoil is now reduced so greatly, the next cycle of operation would be much slower than the first. However, if the gun continued to operate, it would soon settle down to some intermediate rate at which a dynamic equilibrium is established. The exact nature of the process is not important here, but the significant point to be noted is that the rate of fire of the gun will be decreased because of the fact that a considerable portion of the explosive impulse of the propellant is used to stop the forward motion of the recoiling parts. Thus the advantage gained by utilizing the force of the explosion to provide a buffer action can be obtained only by sacrificing speed of operation.

To avoid excessive loss of firing rate, it is generally advisable to stop the forward motion of the counter-recoiling parts by means of the explosive force of the next round. A buffer should also be used so that the momentum of counter-recoil will be partly cancelled before the next round is fired. With this combination of actions, the forward motion of the recoiling parts can be stopped smoothly without the necessity of having an impractically heavy buffer and without the excessive loss of the explosive impulse required for producing a high recoil velocity.

Proper functioning under these conditions will require high precision in timing the firing. Firing too soon will mean that the buffer will not contribute its full share of braking action and too much of the explosive impulse will be utilized to stop the counter-recoil motion. The subsequent recoil will therefore be weak. If, on the other hand, firing occurs too late, the buffer may be overtaxed and too much of the explosive impulse will be available for producing recoil. Recoil will then be too violent. If the effects of small variations in the time of firing prove to be troublesome, these effects can be minimized by utilizing a buffer which is compressed through a greater distance, thus allowing a greater amount of time for the action of the retarding force. For example, it has been shown above that a 50-pound mass moving at 18.2 feet per second will produce a 0.250 inch compression in a buffer exerting an average force of 12,350 pounds. The time for this action can be computed as follows:

$$MV = F_{av}t$$

$$t = \frac{MV}{F_{av}} = \frac{28.3}{12{,}350} = .00229 \text{ (second)}$$

If the compression of the buffer were 0.500 inch instead of 0.250 inch, the necessary average force would be one-half of 12,350 or would be equal to 6,175 pounds. The time of action would then be

$$t = \frac{MV}{F} = \frac{28.3}{6175} = .00458 \text{ (sec.)}$$

Thus, by increasing the length of the stroke of the buffer, the retarding action happens more slowly and a small error in timing will not have as great an effect.

In the computations leading to the time-travel and time-velocity curves shown in fig. 2–30, it was assumed that the recoiling parts were not moving at the instant of firing. Therefore these curves represent the conditions obtained if the buffer alone acted to stop the forward motion of the recoiling parts. On this basis, let it be assumed that the buffer used exerts an average force of 12,350 pounds and that therefore it is compressed 0.0208 foot, bringing the recoiling parts to a stop in 0.00229 second (as previously computed). The recoiling parts are then returned quickly to battery by elastic action as the buffer regains its original dimensions. (As pointed out previously, most of the striking energy of the recoiling parts is dissipated in the buffer, so that there is no tendency for the recoiling parts to rebound.) This action is indicated by the last portions of the curves in fig. 2–30. Note the small overtravel of the recoiling parts past the battery position. The total time to complete the operating cycle is 0.0522 second and therefore the theoretical rate of fire for this particular design is:

$$N = \frac{60}{.0522} = 1150 \text{ rounds per minute}$$

If the design were arranged so that a small part of the explosive force of the next round would be utilized to assist in stopping the forward motion of the recoiling parts, the curves would not be quite the same as in fig. 2–30 because there would be some loss in the impulse producing recoil. However except for this small difference, the computations and procedures would be the same as for fig. 2–30. In making the computations for such a design, it would only be necessary to determine in advance what amount of momentum is to be cancelled by the explosion and then to subtract this momentum from the momentum imparted to the recoiling parts at any instant.

CHAPTER 3

GAS OPERATION

PRINCIPLES OF GAS OPERATION

In all machine guns, the fundamental source of operating energy is the high-pressure gas created by the explosion of the propellant charge. This is true, in a general sense, of guns operated by the blowback system, recoil system, or any other system of "true automatic operation" as the phrase is defined in this publication. However, in spite of the fact that the ultimate source of operating energy in all machine guns is the pressure of the powder gases, the term "gas operation" is reserved for a particular type of operating system in which the pressure of the powder gases is employed in a specific way.

In a typical gun which uses the system of gas operation, an opening (or "port") is provided in the side of the barrel as shown in fig. 3–1. When the projectile has passed this opening, some of the high-pressure powder gases behind the projectile are tapped off through the hole and pass through an orifice to act upon a piston or some similar device for converting the pressure of the powder gases to a thrust. This thrust is then utilized through a suitable mechanism to provide the energy necessary for performing the automatic functions required for sustained fire. These functions include unlocking the bolt, retracting the bolt, and operating the other portions of the gun mechanism.

The gas operating mechanism can take very many forms. The most commonly used device consists of a simple gas cylinder and a piston which is driven rearward to transfer its energy to the bolt by direct

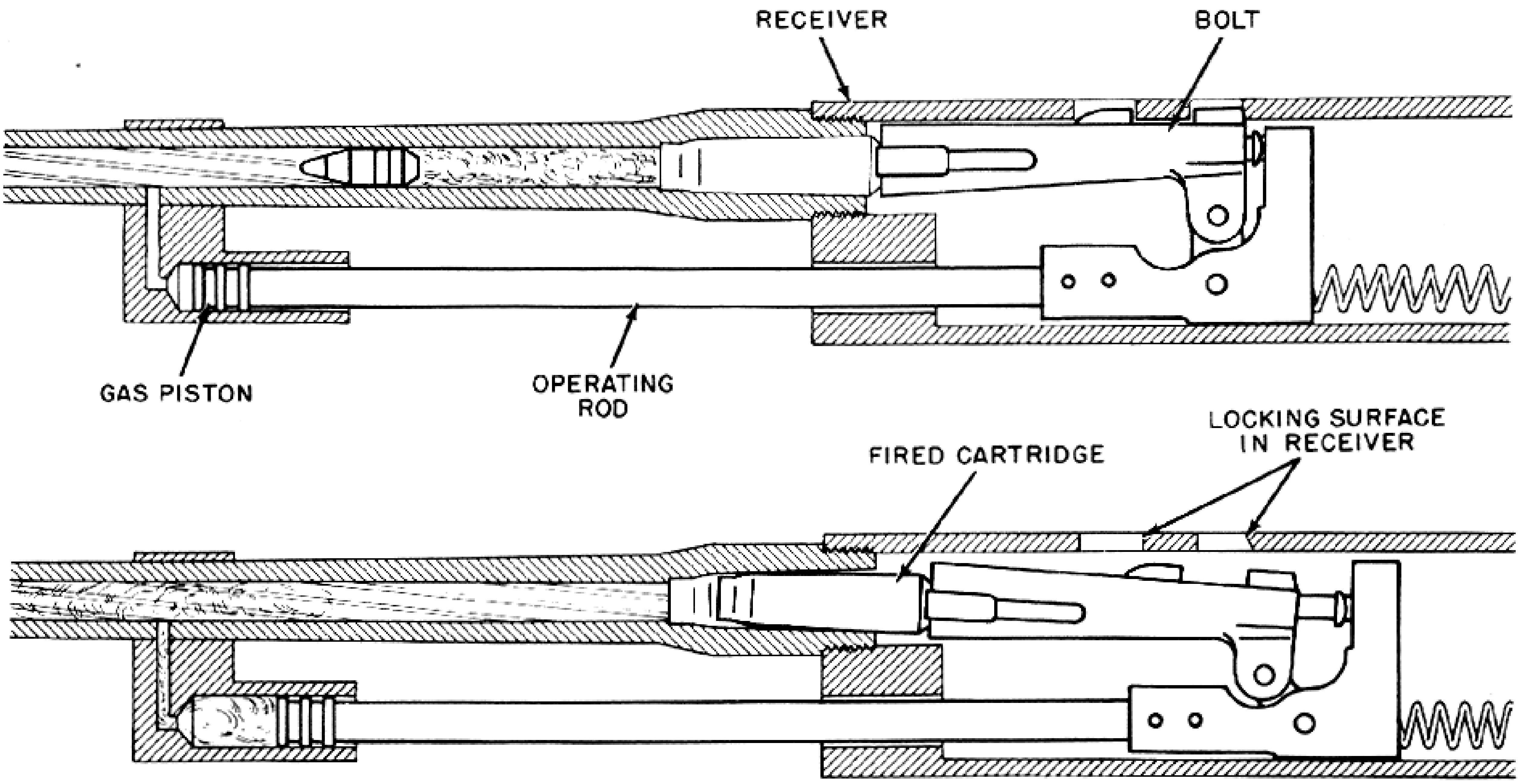


Figure 3–1. Typical Gas Operated Gun.

impact. In some cases, the piston may be driven forward instead of rearward, but this does not involve any significant change in the principle of operation. Even the nature of the member which is acted upon by the gas pressure is subject to great variation. Instead of being a conventional piston, this member can be in the form of a sleeve, slide, or other device arranged to receive an impulse from the gas pressure. In fact, it is interesting to note that the floating chamber (such as is used in the caliber .22 modification of the Browning machine gun) is in reality a special form of gas piston.

The methods used for transferring energy from the piston to the gun operating mechanism are also extremely diverse in form and function. Instead of transferring energy directly to the bolt, the piston itself sometimes moves through a very short stroke and transfers its energy by impinging on an intermediate sliding member or lever. A large number of devices have been designed to minimize the shock involved in the energy transfer through the use of levels, links, or cams. In certain instances, the shock of transfer is reduced by causing the piston to load intermediate springs which subsequently transfer their stored energy to the mechanism.

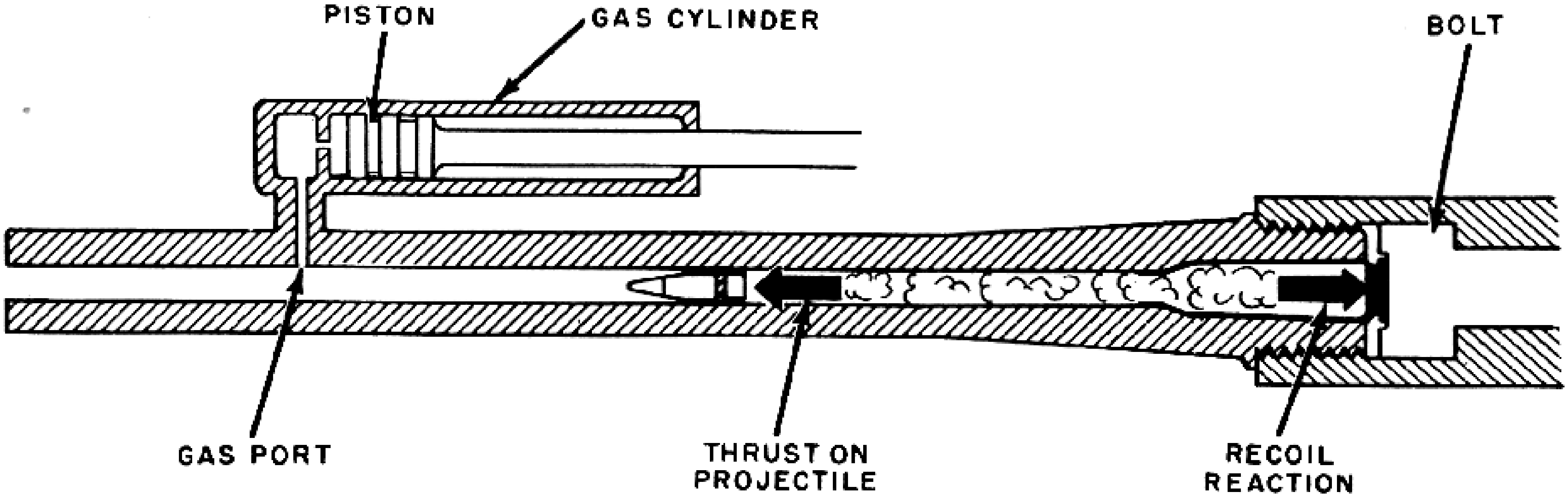
The basic principles involved in gas operation can be outlined by considering the general character of the pressures and forces which result from the firing of the cartridge in an elementary gun provided with a gas port and a piston. Fig. 3–2A shows the condition which exists immediately after the cartridge is fired. The bolt is rigidly locked to the barrel in order to support the base of the cartridge case against the thrust produced by the explosion of the propellant charge. This thrust, acting on the base of the projectile, drives the projectile forward. As the projectile moves through the bore of the gun, the gases expanding behind the projectile also move so that the center of mass of the products of combustion travels forward at a speed nearly equal to one-half the projectile velocity. The same force which moves the projectile and powder gases forward produces an equal and opposite reaction which tends to drive the entire gun to the rear. This reaction is known as the recoil force.

The nature of the recoil force and the manner in which it varies with time are described in considerable detail in Chapter 2. These principles, as stated, are applicable to any gun (including gas-operated weapons) in which the bolt remains locked to the barrel for all or a portion of the time the powder gas pressures act. Therefore, the principles of recoil will not be repeated here.

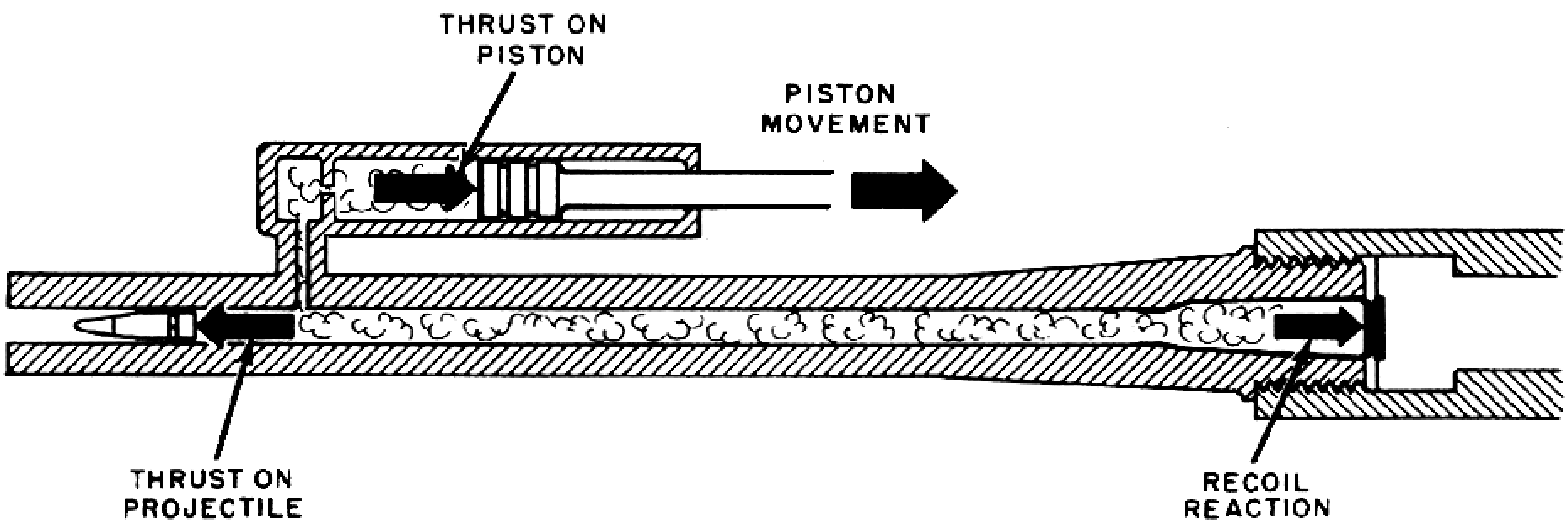
As soon as the projectile has passed the gas port, as shown in figure 3–2B, the high-pressure gases behind the projectile start to flow into the gas cylinder and to build up a pressure against the piston. For any given barrel and cartridge, the rate at which this pressure builds up depends on a number of factors. If the orifice is relatively large, the gases will flow through it freely and easily but if it is small in diameter, it will produce a marked throttling effect and restrict the flow of gas so that the pressure will build up more slowly. The shape of the orifice, as well as its size, will affect the gas flow through it. The rate of pressure increase will also be affected by many other things, such as the pressure difference between the barrel and cylinder, the volume of the cylinder space into which the gases flow, and the rate of change of this volume as it is influenced by the motion of the piston. The force exerted on the piston will be equal to the gas pressure in the cylinder multiplied by the area of the piston. It should be pointed out that ordinarily the amount of gas which flows into the cylinder is relatively very small and will have no significant effect on the muzzle velocity of the projectile.

After the projectile has passed the gas port, and as it moves through the bore and leaves the gun, the pressure within the barrel decreases. The manner in which the pressure decreases for a given propellant charge will be influenced by the length of the barrel. For example fig. 3–3 shows the variations of pressure with time for a typical 20-mm gun with a barrel length of slightly less than five feet and fig. 3–4 shows how the bore travel of the projectile varies with time in the same gun.

Assuming that the gas port in the gun of the example is located 2.5 feet from the point used as the reference for measuring the bore travel of the projectile, the points marked on the curves show the time at which the projectile passes the gas port (0.0016 second after ignition of the propellant charge). Note that the pressure in the barrel at this instant is 11,000 pounds per square inch. At the time the projectile leaves the muzzle at 0.00234 second, the barrel pressure has decreased to 5000 pounds per square inch and the residual pressure continues to act as shown until it falls to zero at about 0.0080 second.



CONDITION BEFORE PROJECTILE PASSES GAS PORT



CONDITION AFTER PROJECTILE PASSES GAS PORT

Figure 3–2. Action of Gas Cylinder and Piston.

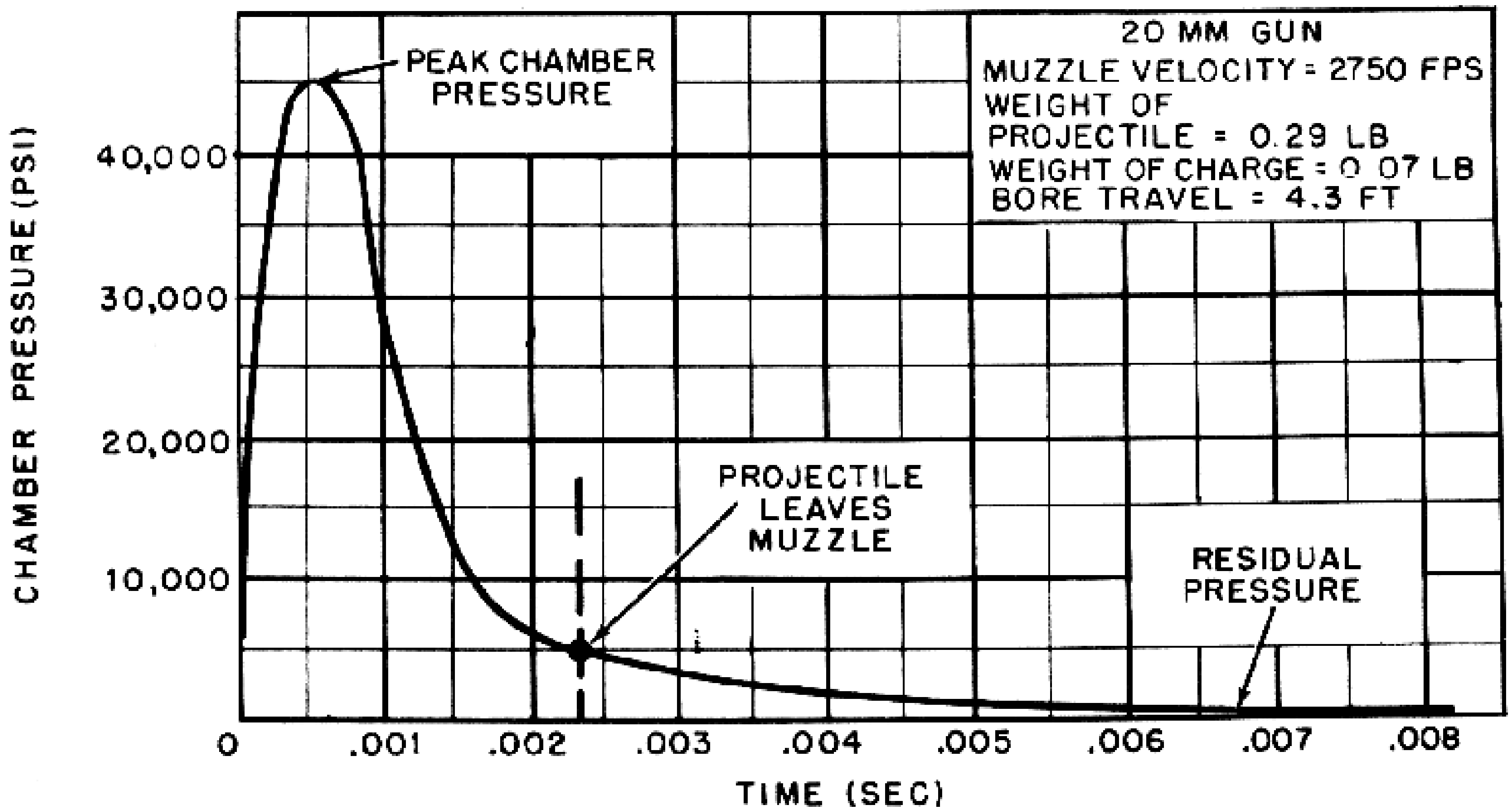


Figure 3–3. Variation of Chamber Pressure With Time.

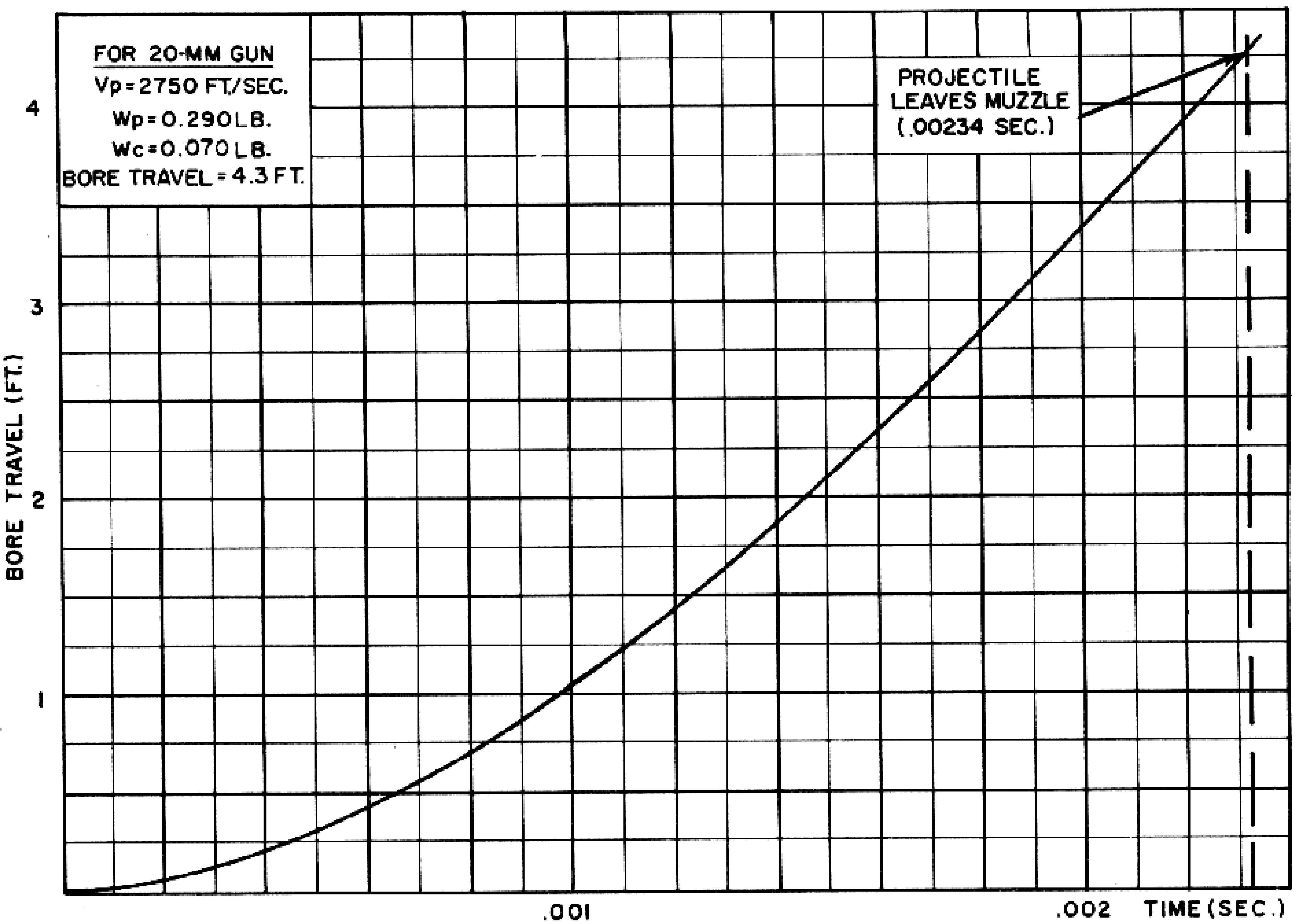


Figure 3–4. Graph of Projectile Bore Travel Versus Time (20 mm Gun).

The barrel pressure curve is reproduced in fig. 3–5. The other curve shown in this figure is the pressure in the gas cylinder. This curve was drawn under the assumption that the amount of gas which flows into the cylinder is too small to have any appreciable effect on the pressure in the barrel and also that the orifice is fairly large so that the pressure in the cylinder builds up rapidly to a value which is practically equal to the barrel pressure. Since the barrel pressure decreases smoothly, the pressure in the cylinder will remain very close to the barrel pressure. If the gas port remains open after the projectile has passed, the pressure in the gas cylinder will become zero at essentially the same time the residual barrel pressure becomes zero. (Ordinarily, however, the orifice is relatively small and produces a throttling effect which causes the pressure in the cylinder to remain considerably lower than the barrel pressure for most of the time of action.)

Examination of fig. 3–5 will show that the gas piston is subjected to a driving force for only a very short interval of time. The pressure starts to act on the piston when the projectile passes the port at 0.00166 second and ceases to act at about 0.008 second when the residual barrel pressure has reached zero. Therefore the total time of action is 0.00800—0.00166=0.00634 second. For the assumed conditions, it is during this brief interval that the piston absorbs the impulse imparted to it by the powder gases. Since the powder gas pressure exists for such a short time, it is not practical to at-

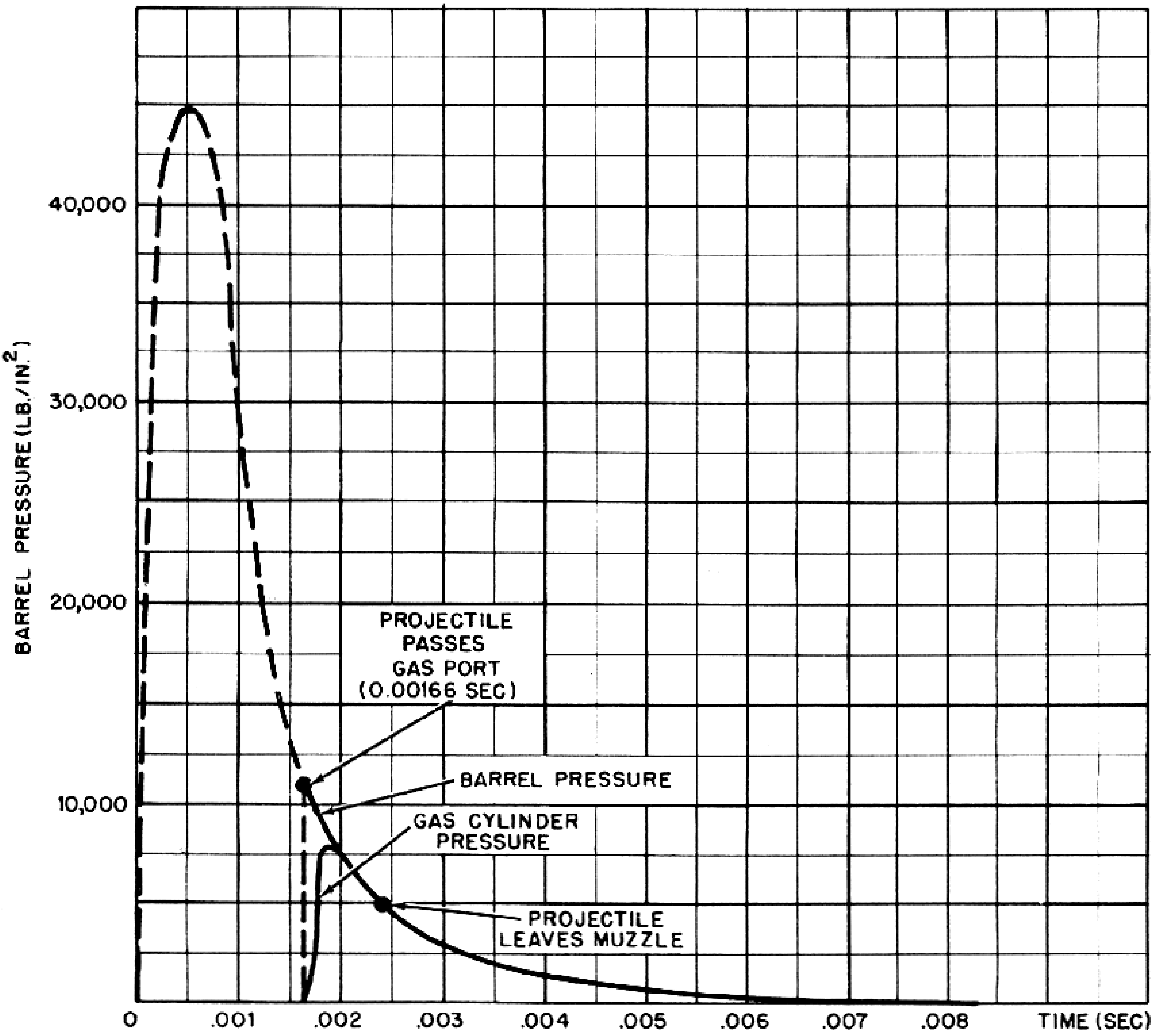


Figure 3–5. Barrel Pressure and Pressure in Gas Cylinder.

tempt to use the force on the piston directly for actuating the gun mechanism. This is particularly true because the bolt must remain locked for a considerable portion of the time during which the powder gas pressures are acting. Therefore, the impulse of the pressure is utilized to impart a velocity to the piston mass and then, by virtue of the kinetic energy thus stored in the piston, the piston can perform the necessary automatic functions even after the powder gas pressure is gone.

Since the force produced on the piston by the gas pressure in the cylinder depends on the area of the piston, the magnitude of the impulse absorbed by the piston will also depend on the piston area; the larger the piston, the greater will be the impulse. The magnitude of the impulse will also depend on the amount of the pressure and the duration of the pressure and therefore will be greatly influenced by the size and location of the orifice. Moving the gas port closer to the chamber and increasing the size of the orifice will cause the impulse to be greater because the pressures applied to the piston will then be higher and these pressures will act for a longer time.

The amount of energy stored in the piston as the result of the applied impulse will be determined by the mass of the piston. The lighter the piston, the greater will be the energy produced by a given impulse. Thus it appears that the conditions of pressure, the location of the gas port, the size and shape of the orifice, the piston area, and the piston mass all have an influence on the amount of energy which can be obtained from the action of the piston. By proper selection and control of these factors, the piston energy can be regulated as desired so that low values or very high values of energy can be achieved. In fact, it is comparatively easy under practical conditions to achieve extremely high values of piston energy in a gas-operated gun. Unless the gas operation is carefully controlled, the action of the piston may be so violent that it can literally smash the breech mechanism.

In the following paragraphs, the gas system of operation is described and analyzed by considering the sequence of events which occur in the automatic cycle of operation. As with the other systems treated in this publication, this analysis is concerned only with the general factors affecting design. (Detailed descriptions of the mechanisms used in actual guns employing the gas system will be referenced where applicable.)

GAS SYSTEM OF OPERATION

As previously mentioned, the gas system of operation can employ many types of gas actuating devices. Although the functional characteristics of a weapon will depend to some extent on the particular type of actuating device employed, all gas-operated guns are basically similar in their operation. Since the gas piston is the most common form of actuating device, it will be used here for purposes of illustration.

Fig. 3–6A shows schematically the essential elements of a gun which operates by the gas system. These elements consist of the bolt, an arrangement for locking the bolt to the barrel and unlocking it, a backplate buffer, a driving spring for returning the bolt to battery, the gas cylinder and piston, a cradle which permits the entire gun mechanism to move in recoil, and a barrel spring which returns the gun to battery. Associated with the barrel spring are buffers which stop the recoil and counter-recoil motions of the gun. The other portions of fig. 3–6 show different stages during the cycle of operation.

Cycle of Operation

The operating cycle of a typical gas-operated gun occurs as follows:

The cycle of operation starts with a cartridge in the chamber and with the bolt locked to the barrel (fig. 3–6A). When the cartridge is fired, the pressure of the powder gases drives the projectile and gases forward through the bore and at the same time drives the entire gun mechanism to the rear in recoil. During the action of the powder gas pressure, the retardation offered by the barrel spring is relatively small so that the only really significant factor in limiting the recoil acceleration is the mass of the recoiling parts.

> NOTE: Although this is a gas-operated gun, it is necessary to permit the barrel and locked bolt to move in recoil in order to reduce the force on the gun mounting. In a 20-mm gun with a maximum chamber pressure of 45,000 pounds per square inch, the maximum recoil

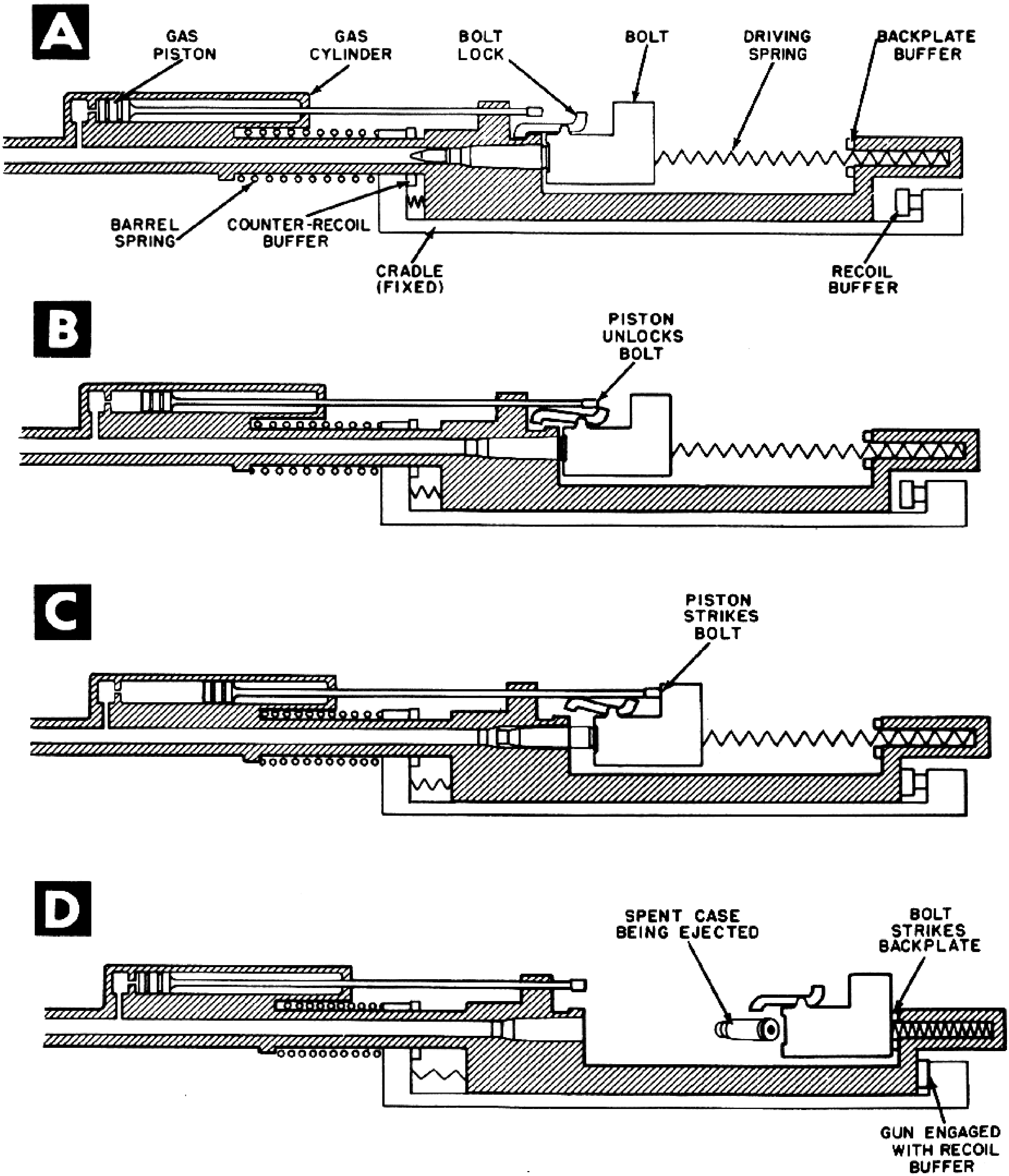


Figure 3–6. Elements of a Gas Operated Gun (Schematic).

force driving the gun to the rear while the bolt is locked is near 22,000 pounds. This force is so large that it would be impractical to attempt to hold the barrel in a rigid mounting.

The time at which the projectile passes the gas port in the barrel will depend on the location of the port. Ordinarily, this will occur from 0.001 to 0.002 second after ignition of the propellant. As soon as the projectile passes the port, the powder gases will start to flow into the cylinder and start to apply a pressure to the piston, thus driving the piston to the rear. The action of the piston is controlled in the design so that the bolt is not unlocked immediately but unlocking is delayed until the pressure in the barrel has dropped to a safe operating limit, 0.001 or 0.002 second after the projectile leaves the muzzle (fig. 3–6B).

After unlocking occurs, the residual pressure (which has still not reached zero) continues to exert a force on the piston and also creates a blowback action on the cartridge case. Shortly after the instant of unlocking, the piston strikes the bolt, so that the kinetic energy stored in the piston is transferred, thus imparting a high acceleration to the bolt (fig. 3–6C). After the piston has acted, the barrel and barrel extension assembly strikes a buffer stop which absorbs whatever recoil energy was not previously absorbed by the barrel return spring. When the barrel and barrel extension assembly has been stopped, it is immediately driven forward by the compressed barrel return spring, and is brought to rest at the battery position by the counter-recoil buffer.

At the instant of unlocking, the bolt already has a considerable rearward velocity because of the recoil movement which occurred before unlocking. This "inherited" bolt velocity is increased by the combined action of blowback and of the gas piston so that a high final bolt velocity is produced. The bolt then continues to move to the rear by its own momentum until the opening between the barrel and bolt is sufficient to permit feeding. As the bolt moves back, the spent cartridge case is extracted from the chamber and ejected and the bolt driving spring is compressed. This spring is relatively light and its only function is to assist the return movement of the bolt. Therefore, the driving spring does not absorb any great portion of the kinetic energy of the recoiling bolt and the bolt moves through its entire recoil distance at high velocity. The bolt then strikes the backplate buffer and rebounds (fig. 3–6D). The forward velocity of the bolt immediately after leaving the backplate buffer is somewhat lower than the velocity at which it strikes the backplate because the impact is not purely elastic and some energy is lost as heat in the exchange.

NOTE: It is important to realize that the velocity with which the bolt strikes the backplate buffer will depend on the condition of motion of the gun at the instant of impact. If the gun happens to be moving forward at this instant, the impact velocity will be higher than if the gun were stationary or moving rearward. It can be seen that if the gun motion is not controlled to insure uniform velocity at the instant of contact, the bolt impact will be entirely unpredictable and will vary widely from shot to shot. This could give very erratic performance and may result in a high incidence of parts breakage.

As the bolt moves forward after rebounding from the backplate buffer, its motion is aided by the driving spring. The bolt picks up a fresh cartridge from the feed mechanism and loads this cartridge into the chamber. The bolt then locks into the barrel. Usually it is desirable to time the operation of the weapon so that the bolt returns and locks to the barrel before the gun has reached the battery position. Then, shortly before the recoiling parts reach their most forward position, the firing mechanism is actuated and a new cycle begins. Since the cartridge is fired before the counter-recoil motion is completed, the forward velocity of the recoiling parts is first checked by the initial part of the rearward thrust exerted by the exploding propellant charge and the recoiling parts are then driven to the rear. (Timing the firing in this way eliminates the need for a heavy counter-recoil buffer to absorb and dissipate the forward kinetic energy of the recoiling parts.)

Analysis of Gas Operation

From the theoretical point of view, the gas system of operation has many features which make it adaptable to a wide variety of weapon designs. This flexibility of application is due primarily to the fact that by proper selection of design values, the functioning of the gas actuating device can be controlled

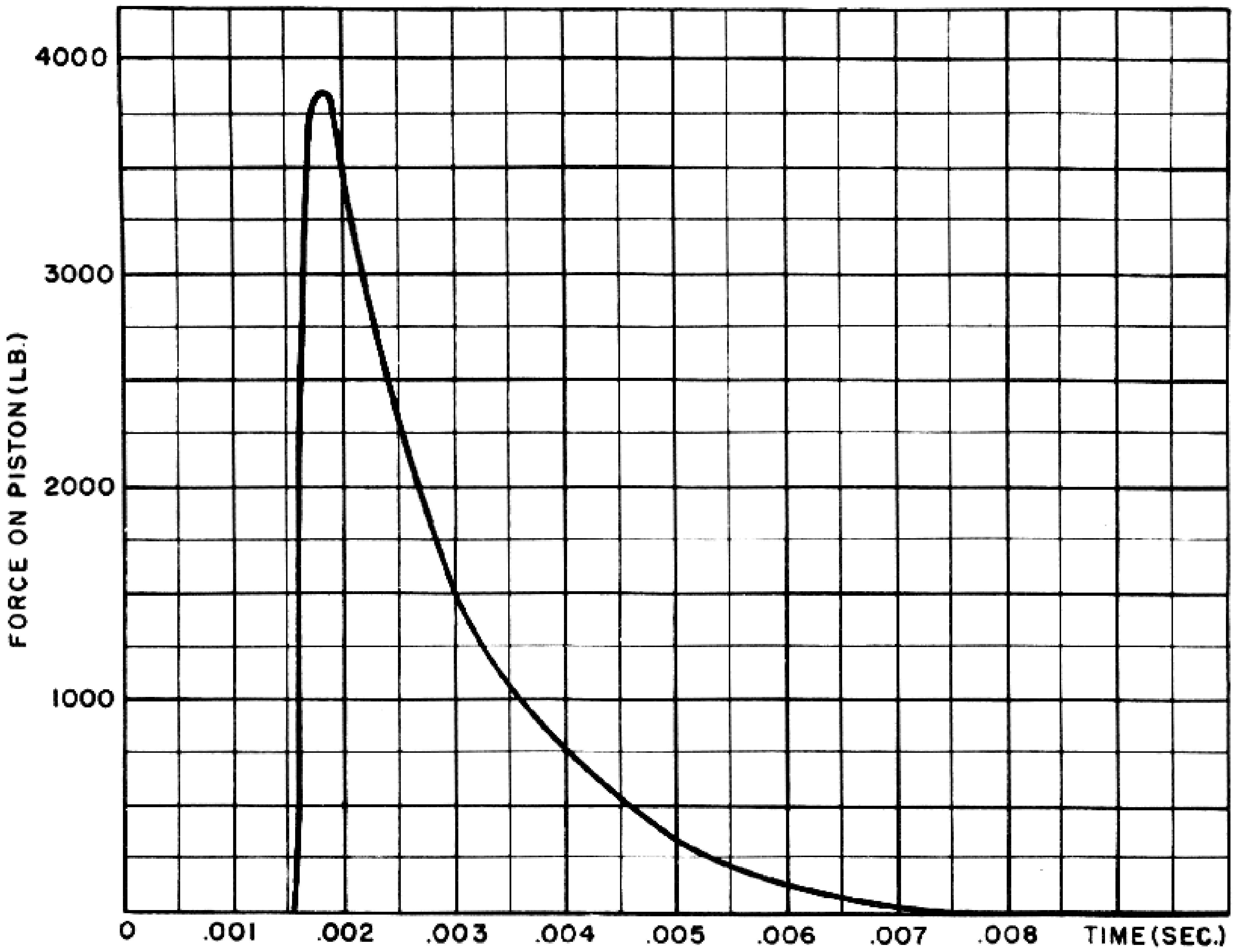


Figure 3–7. Force Exerted on Piston.

to produce small or very large operating forces and the timing of these forces can be regulated as desired. However, there are also certain disadvantages inherent in the gas system of operation and any successful design must take these disadvantages into account and make suitable allowances for them. In the following paragraphs, gas operation is analyzed to evaluate both the advantages and disadvantages of the system.

One of the principal features of the gas system of operation is the large amount of operating energy which can be obtained from the gas actuating device. This energy is available because the gas system makes it possible to tap into the high gas pressure which exists during the propellant explosion and to apply this pressure to a relatively light operating member while the bolt still remains locked. Thus, energy can be accumulated for later use without the necessity for sacrificing rigid support behind the cartridge case during the early phases of the propellant explosion.

NOTE: By way of comparison, it should be pointed out here that energy is also accumulated in the recoiling parts of a gun employing the recoil system of operation. Although this energy is also accumulated during the early phases of the propellant explosion while the bolt is locked, the parts which absorb the explosive impulse in this case are fairly heavy. Therefore, the amount of energy accumulated for a given impulse will be relatively small when compared with the energy imparted by the same impulse to a very light gas piston.

An idea of the magnitude of the energies and velocities which can be achieved by gas operation may be obtained by considering a specific example. In the preceding explanation of the principles of gas operation, a curve (fig. 3–5) was developed to show the variation of pressure with time in the gas cylinder of a sample 20-mm gas-operated gun. (This gun has a barrel length of slightly less than five feet and the gas port is located 2.5 feet from the chamber.

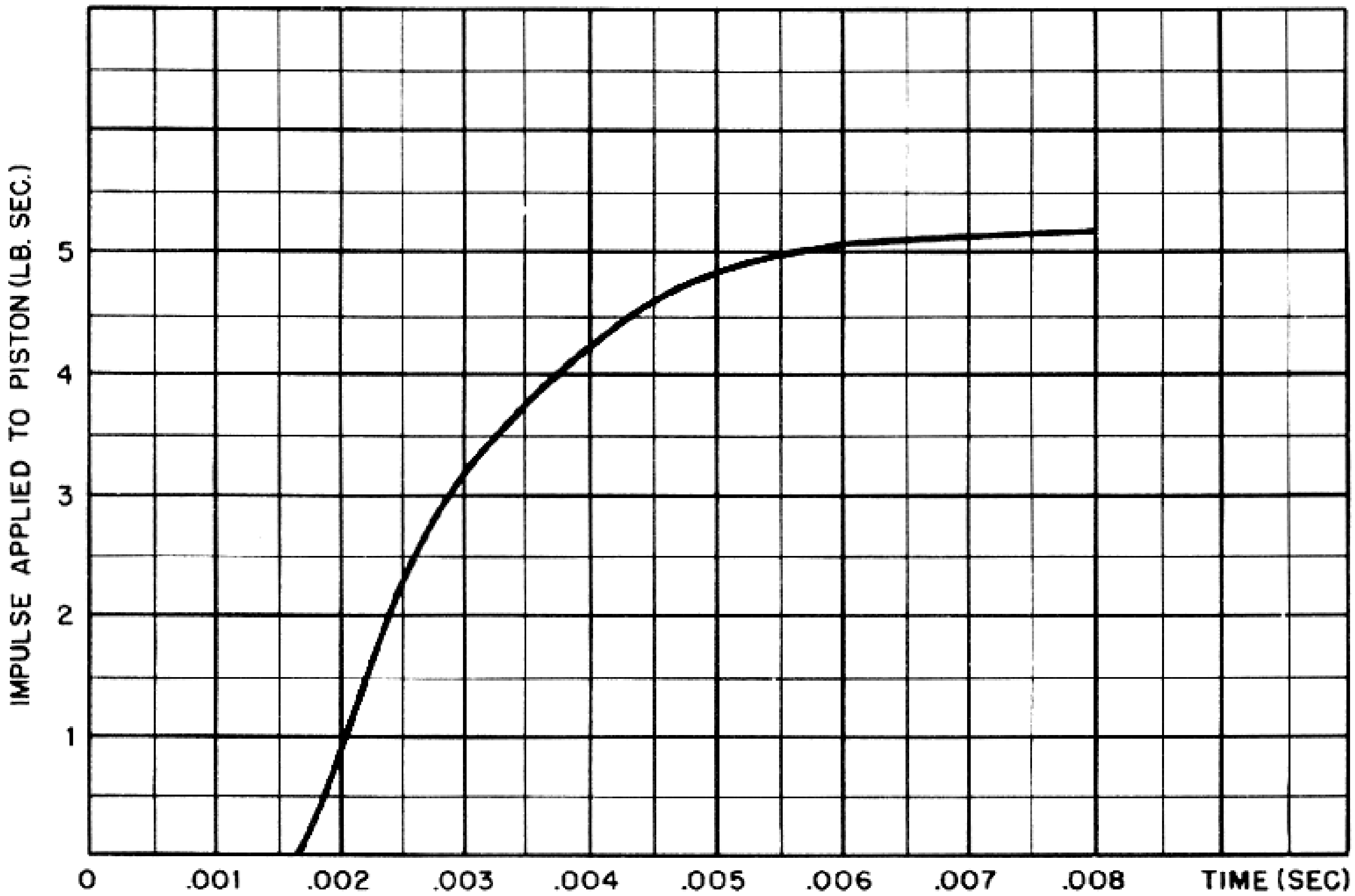


Figure 3–8. Impulse Imparted to Piston.

The projectile passes the gas port 0.00166 second after ignition of the propellant charge. The orifice is assumed to be quite large so that the cylinder pressure quickly becomes practically equal to the barrel pressure.)

In order to determine the impulse applied to the gas piston, let it be assumed that the diameter of the piston in the example gun is equal to the bore diameter, or approximately 0.79 inch. (This is the rule of thumb often used in the design of gas-operated weapons.) The area of the piston will then be approximately 0.5 square inch. The force exerted on the piston at any instant can now be determined by multiplying this area by the pressure for that instant shown in fig. 3–5. The force-time curve which results from plotting these values is shown in fig. 3–7.

If it is considered that the only significant force initially acting on the piston is the pressure of the powder gases, the total impulse applied to the piston up to any instant can be found by measuring the area under the curve of fig. 3–7 up to that instant. The resulting values of impulse can then be used to plot the impulse curve shown in fig. 3–8. Note that the total impulse applied to the piston for the sample conditions is equal to 5.13 pound seconds.

The amount of energy imparted to the piston by this impulse will depend on the mass of the piston. The lighter the piston, the greater will be the energy produced by a given impulse.

NOTE: This can be seen by considering the basic expressions for kinetic energy and impulse:

(3–1) $$KE=\frac{1}{2}MV^2$$

(3–2) $I=MV$ (where I is the impulse)

Solving equation 3–2 for V and substituting the result in equation 3–1 gives:

$$KE=\frac{1}{2}M\left(\frac{I^2}{M}\right)=\frac{1}{2}\frac{I^2}{M}$$

which shows that the kinetic energy produced by a given impulse is inversely proportional to the mass of the object to which the impulse is applied.

If it is assumed that the piston of the sample gun weighs 1.5 pounds, the final velocity imparted to the piston at 0.008 second is determined by dividing the total impulse of 5.13 pound-seconds by the piston mass: That is:

$$V=\frac{I}{M}=\frac{5.13\times 32.2}{1.5}=110\ \text{(ft./sec.)}$$

The kinetic energy corresponding to this velocity is:

$$KE=\frac{1}{2}MV^2=\frac{1}{2}\times\frac{1.5}{32.2}\times110^2=282 \text{ (ft. lb.)}$$

These values show that with the assumed conditions of pressure, gas port location, orifice size, piston area, and piston mass, the piston velocity and piston energy obtained are relatively high values. It can also be seen that changing any of these factors can have a marked effect on the values of energy and velocity. For example, these values could be increased tremendously by moving the gas port closer to the chamber, increasing the piston area, and decreasing the piston mass. Conversely, the piston velocity and energy could be drastically reduced by moving the gas port closer to the muzzle, decreasing the size of the orifice to produce a throttling effect, increasing the mass of the piston, and decreasing the piston diameter. Thus it is evident that, theoretically, the design of a gas-operated gun can be set up readily to achieve almost any desired magnitude of piston energy.

It is of interest from the practical standpoint to note that the gas port must be located in the center of one of the rifling grooves. This is important because of the fact that when the rotating band of the projectile is engraved by the rifling lands, fairly large burrs or flashes of copper are formed at the rear of the rotating band. There is a relief recess behind the band to accommodate these burrs while the projectile passes through the bore. (This recess is sometimes erroneously thought to be provided for crimping the case to the projectile.) If the port were in the land of the rifling, the burr formed by that land would be blown into the gas port by the high-pressure gases behind the projectile as the projectile passes the port. After one or several shots, this could cause the gas orifice to become clogged or could interfere with the operation of the piston.

Since the port must be located in a groove of the rifling, it is necessary in the design of the gun to be sure that the angular position of the barrel will be correctly related to the gun mechanism. For this reason, it is practically impossible, without redesign, to change the location of a gas port in a gun which has already been built. This same consideration also precludes the possibility of simply rotating the barrel in its threaded mounting in order to adjust the gun for correct headspace.

In gas-operated guns, the headspace can be controlled only by selective assembly, using parts in which the dimensional variations permitted under the manufacturing tolerances will combine in such a way as to produce the required headspacing. Because of the difficulty of producing and maintaining correct headspacing in a gas-operated gun, it is necessary to use lubricated ammunition in order to avoid cartridge case separations which otherwise would inevitably result. This is a very serious disadvantage which is inherent in the gas system of operation and its importance can not be overemphasized.

Another real difficulty in most gas-operated guns is that the throttling effect produced by the orifice is extremely critical in determining the operating characteristics. The size and shape of the orifice must therefore be selected with great care and must be controlled precisely in manufacture. In order to reduce the maintenance problem, it is also important to take steps in the design to protect the orifice from enlargement by erosion and from clogging as the result of fouling. To simplify maintenance, many guns are provided with orifice plates which can be removed readily for cleaning or replacement. In some instances, the gun is equipped with a built-in arrangement for substituting orifices of slightly different size so that the gun can be adjusted readily to compensate for changes in performance due to bore wear and other causes. In regard to orifice erosion, it should be noted that the problem of erosion increases tremendously as the gas port is placed closer to the chamber. Although the use of orifice inserts of stellite, molybdenum, or similar materials is of some help in reducing erosion, the severe washing effect of the high-temperature, high-velocity gas encountered in the initial part of the propellant explosion still places definite limit on how close the gas port can be to the chamber.

The preceding points are primarily concerned with the amount of energy available from gas operation and with the design factors related to the position of the gas port. Another important consideration in gas operation is concerned with how the action of the piston can be timed so that unlocking and the subsequent transfer of energy to the bolt will occur in the correct time relation to the variation of the chamber pressure. Before entering into the methods whereby this timing is accomplished, it is appropriate to consider first what conditions of timing will produce the greatest functional efficiency.

First, the mechanism should be arranged so that the bolt will be unlocked as soon as the chamber pressure has reached a safe operating limit. This will aid in obtaining a high rate of fire by eliminating any unnecessary delay and will also make it possible to derive useful bolt energy by utilizing the blowback effect available from the residual powder gas pressure. In order to facilitate extraction and to make the best use of blowback, it is important to avoid binding or excessive friction between the cartridge case and chamber wall after unlocking occurs. With lubricated ammunition, friction and binding do not present a problem, but with unlubricated ammunition, the cartridge case will always tend to seize in the chamber. This binding occurs because the peak chamber pressures and the heat of the explosion expand the case tightly against the chamber, and since unlocking takes place while there is still an appreciable residual pressure, the case does not have a chance to contract sufficiently to permit it to move freely under blowback. This difficulty can be avoided by employing an operational feature known as "initial extraction". When this feature is incorporated in the unlocking mechanism, the bolt is unlocked in two stages. In the first stage, the bolt is not unlocked completely but is cammed powerfully back through just a sufficient distance to cause the taper of the cartridge case to break free of the chamber wall. Immediately thereafter, the bolt is unlocked completely and blowback can occur without difficulty.

The utilization of blowback is limited by the fact that the cartridge case can not be permitted to move too far out of the chamber while the residual powder gas pressure is still high enough to cause rupture of the case near the base. The actual limit on the amount by which the cartridge case can be permitted to move as it is related to the chamber pressure will of course depend on the specific cartridge case under consideration. A good way to estimate the limit for a given cartridge case is to consider what pressure could be withstood by the case when the case has moved just far enough to the rear to expose the thin walls near the base. (See fig. 3–9.) For an ordinary 20-mm cartridge case, this occurs when the case has moved approximately 0.250 inch to the rear. When the case has reached this position, it is reasonable to assume that the internal pressure should not be in excess of 750 pounds per square inch, in order to be sure that the case

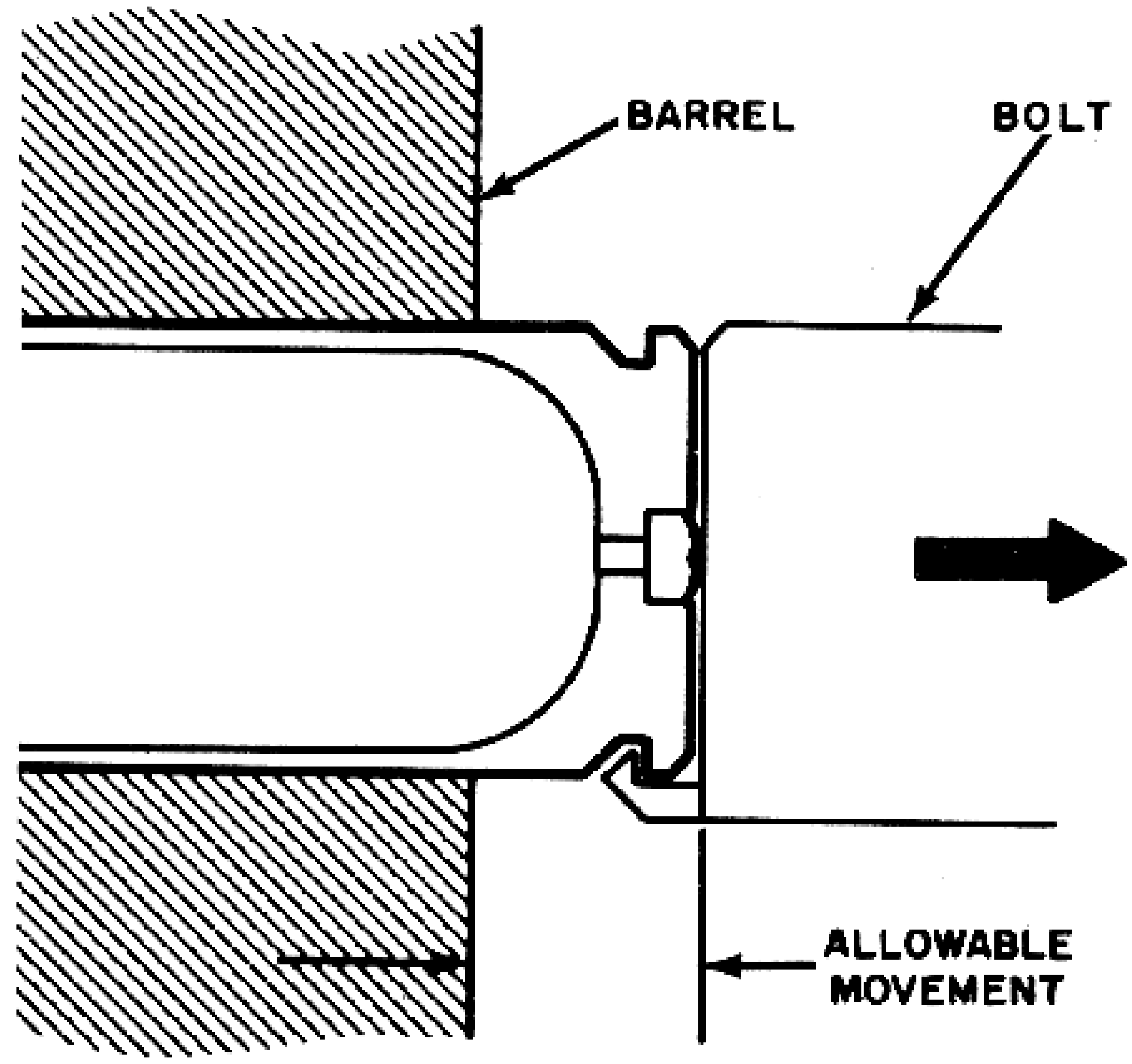


Figure 3–9. Limit of Cartridge Case Movement Rearward Before Residual Pressure Reaches Safe Distance.

will not be ruptured. Fig. 3–10, which is a graph showing the residual pressure variation with time for the assumed gun and cartridge, indicates that the pressure does not fall to 750 pounds per square inch until 0.005 second after ignition of the propellant charge. (Of course, in any practical application, the actual limiting values for a cartridge case should be determined by experiment.)

Having a bolt with a given weight, the bolt movement can be limited as required only by selecting the proper instant for unlocking. If the bolt is unlocked too soon, it will receive too great an impulse from blowback and its average velocity will be so great that the allowable movement will be exceeded before the pressure drops to the safe limit. If unlocking is delayed too long, the impulse imparted to the bolt will be unnecessarily small and the full benefit of blowback will not be realized. The ideal unlocking time for a given bolt weight is that which will permit the bolt to move the full allowable distance and no more by the time that the pressure has dropped to the desired level. After the pressure becomes less than this value, there is no further danger of case rupture and the movement of the case need not be limited. In fact, from this point on, there is no reason for limiting the bolt velocity except to avoid excessive violence of action and exorbitant breakage of parts which would occur

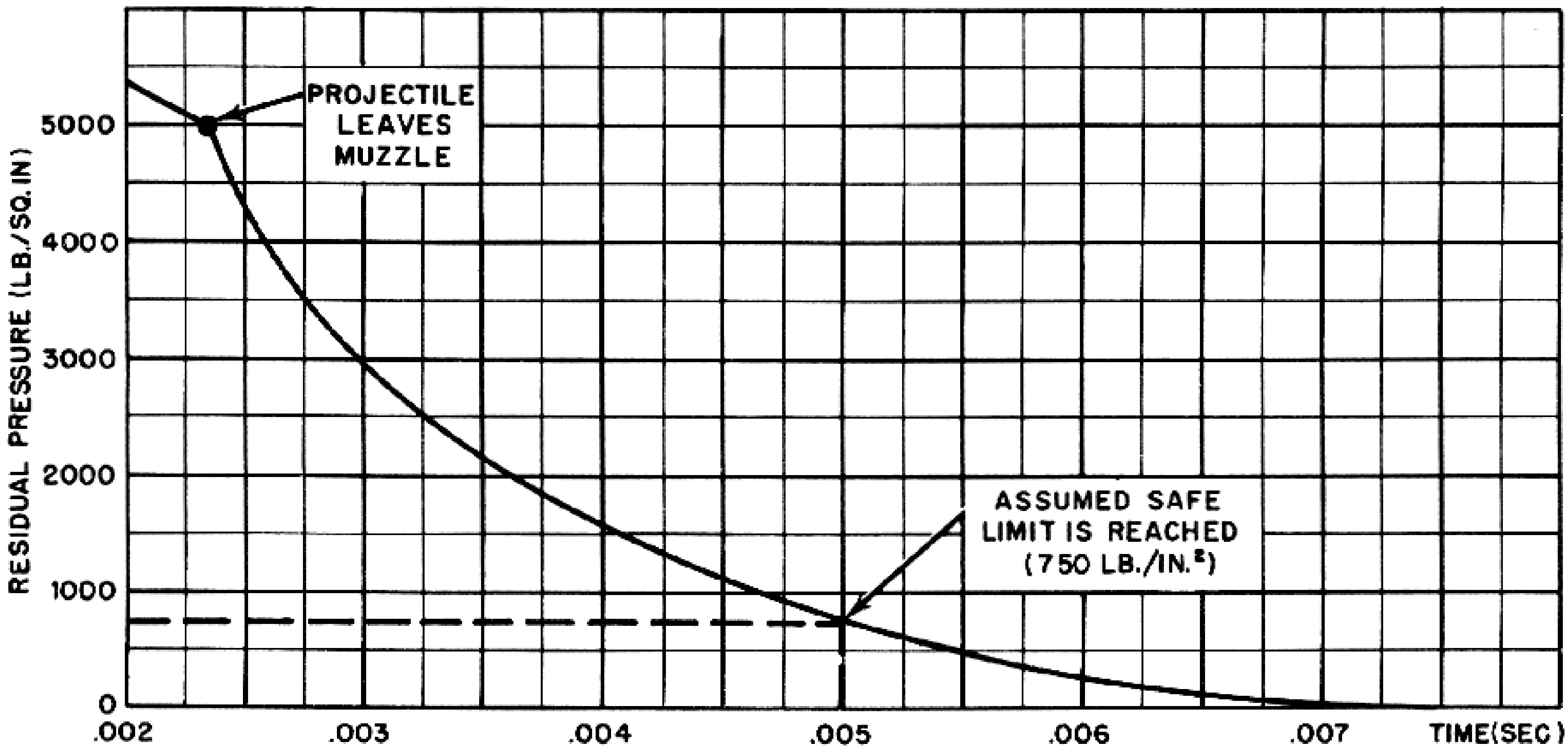


Figure 3–10. Graph of Residual Pressure Versus Time for a Typical 20 mm Gun.

during the reversal of the bolt motion at the end of the recoil stroke.

Since the object of utilizing blowback is to impart velocity to the bolt, it is of interest to determine what conditions lead to the attainment of high blowback velocities. The problem involved in determining these conditions is how to obtain the high velocity and yet not exceed the allowable bolt movement (0.250 inch for the assumed conditions). If the time in which this movement is accomplished is long, the average velocity of the movement will necessarily be low. However, if the time for the movement is made very short, the average velocity may be very large. For example, suppose the bolt is unlocked 0.002 second before the safe pressure is reached. The bolt can now travel the 0.250 inch in 0.002 second. That is to say, its average velocity for this interval must be limited to:

$$V_{av}=\frac{D}{t}=\frac{.250}{12}\times\frac{1}{.002}=10.4\left(\frac{\text{ft.}}{\text{sec.}}\right)$$

Now, assume that the bolt is unlocked only 0.001 second before the safe pressure is reached. It can then travel the 0.250 inch at an average velocity of:

$$V_{av}=\frac{D}{t}=\frac{.250}{12}\times\frac{1}{.002}=20.8\left(\frac{\text{ft.}}{\text{sec.}}\right)$$

The preceding examples indicate that, by shortening the time for which blowback operates before the safe pressure is reached, increased bolt velocity can be achieved without exceeding the allowance bolt movement.

Of course, it should be realized that shortening the time of blowback action reduces the blowback impulse available for producing the velocity. Therefore, in order to gain an increase in allowable average velocity by reducing the time of action, it is necessary to reduce the bolt weight to make up for the reduction in the impulse. To illustrate this point, if the velocity of 10.4 feet per second cited in the first of the preceding examples was obtained with an 8-pound bolt, it would be necessary (with the same cartridge and gun) to reduce the bolt weight by a factor of at least 4 to obtain the velocity of the second example, even if it is assumed that the average blowback pressure is the same for both examples. Actually, since the residual pressure decreases with time, the average pressure for the second example would be considerably less than for the first and therefore a further reduction in bolt weight would be required. The actual weight reduction factor would be more nearly in the neighborhood of 6, giving a bolt weight of only 1.3 pounds. (This would probably be much too light for a practical 20-mm gun.)

Thus it appears that a substantial gain in average bolt velocity can be achieved by reducing the time of the blowback action, but this can be done only if the bolt weight is reduced. Although it is not practical to attempt to reduce bolt weight by an excessive amount, it is important to realize that efficient utilization of blowback in a gas-operated gun can be of great advantage in attaining the high bolt velocity necessary for a high rate of fire. However, this advantage can be gained only through precise timing of unlocking in combination with careful attention to minimizing bolt weight.

Having analyzed the factors to be taken into account in determining the time for unlocking, the next point to consider is the timing of the transfer of energy from the gas piston to the bolt. In establishing the timing for this transfer, it is desirable to keep in mind the requirements for effective utilization of the available blowback action. As previously pointed out, it is possible to choose the time of unlocking so that the maximum obtainable impulse is imparted by the residual pressure, this impulse being limited only by the requirement that the bolt movement must not exceed a definite distance (0.250 inch in the example) before the residual pressure has reached a safe limit (750 pounds per square inch at 0.005 second for the assumed conditions). Now, assuming that the time of unlocking is selected so as to take full advantage of this maximum impulse, it can be seen that permitting the piston to act on the bolt before the safe pressure is reached will impart an additional bolt velocity which will cause the allowable movement to be exceeded while the pressure is still dangerously high. The only way to correct this difficulty would be to delay further the time of unlocking in order to reduce the blowback impulse. However, this would mean that full advantage is not being taken of the available blowback impulse and the energy thus lost must be obtained from the piston. From the standpoint of energy alone, this is perhaps not of critical importance because the gas actuating device can be designed to produce almost any desired amount of energy. Nevertheless, it is important to realize that blowback impulse is, in a manner of speaking, "free of charge", while obtaining additional energy from the piston can be accomplished only by paying the full price in terms of increased difficulty in the design of the entire gas mechanism.

From the foregoing, it is apparent that the timing of the piston action should be arranged so that unlocking and initial extraction occur at the correct instant to permit the maximum use of the available blowback action. Then, after a sufficient delay to allow the chamber pressure to fall to the safe operating limit, the piston should start to transfer energy to the bolt. Timing the piston action in this manner will result in the most efficient use of available energy and in the least strain on the operating parts of the gas actuating device. The actual timing of the piston action is controlled by the distance the piston travels in performing its functions. Fig. 3–11 illustrates schematically the basic principles involved in this timing. As soon as the projectile passes the gas port, pressure builds up rapidly in the gas cylinder and drives the piston to the rear. The free piston travel from point A to point B is proportioned so as to allow sufficient time for the projectile to leave the muzzle and for the residual pressure to decrease to the point at which blowback should start. As indicated schematically in the figure, when the piston strikes the locking lever at point B, the bolt is first cammed powerfully back to provide initial extraction and then it is completely unlocked. After unlocking occurs, the free piston travel from point B to point C allows enough time for the blowback action to progress until the residual pressure reaches the safe limit. At this point, the piston strikes the bolt and the resulting impact causes the bolt to be driven rapidly to the rear.

Since the timing of the entire piston action related to unlocking is based on piston travel, it is evident that any factor that affects the manner in which the piston velocity varies with respect to time will have a direct effect on the timing. As has been explained previously, the piston velocity is influenced by various factors such as the conditions of barrel pressure, gas port location, orifice size, piston area, piston mass, and others. To obtain correct timing, it is essential for all of these factors to be controlled closely in the design and to be kept constant during the life of the gun by careful maintenance.

As a matter of practical interest, it should be noted that the problem of obtaining satisfactory timing in a gas-operated gun is often greatly complicated by the fact that the timing is critically dependent on such a large number of factors. Also, since the piston energy is controlled by the same factors which affect the timing, considerable difficulty can be encountered in attempts to improve the performance of a gas-operated weapon merely by making

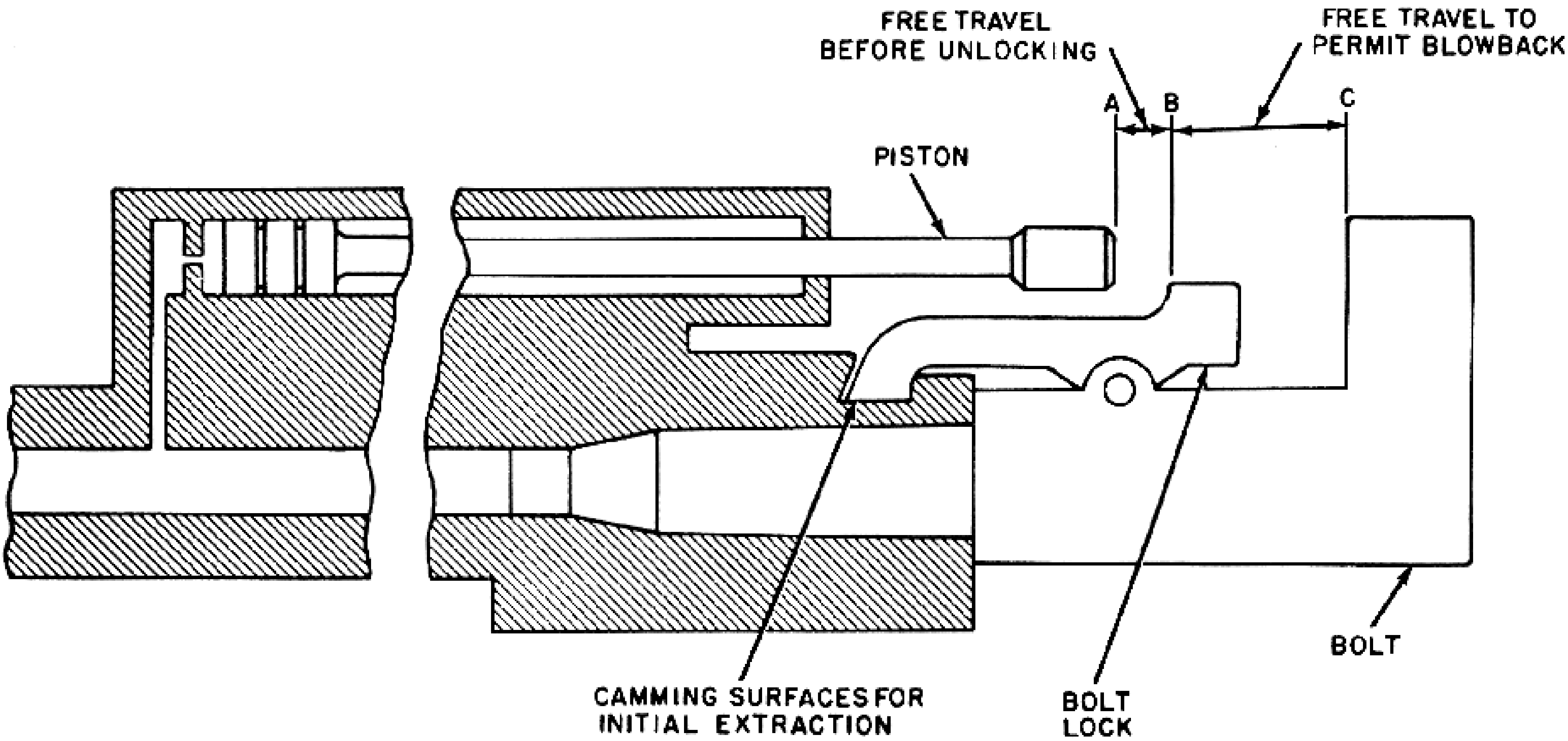


Figure 3–11. Principle of Timing Piston Action.

minor experimental changes to the gas orifice or other individual parts. It will usually be found that to accomplish any real improvement, a fairly extensive redesign of the entire gun will be required.

The analysis up to this point has been concerned with the basic factors affecting the amount of piston energy obtainable and the timing of the piston travel. The next subject for consideration is related to the conditions under which the piston transfers recoil energy to the bolt in order to speed the bolt rearward. There are a number of things which affect bolt velocity. First, since the entire gun is permitted to recoil for the purpose of reducing the forces on the gun mounting, the bolt is unlocked while all of the recoiling parts are in motion. Although it is sometimes desirable to think of the subsequent bolt velocity and piston velocity as being measured relative to the barrel parts, it is always well to remember that the absolute velocity of the barrel parts changes with time.

The recoil velocity attained before unlocking is dependent on the total mass of the recoiling parts and on the magnitude of the impulse imparted to these parts by the propellant explosion up to the time of unlocking. (The retardation of the barrel spring will have such a small effect up to the time of unlocking that the action of this spring can be ignored for the present.) The magnitude of the impulse imparted by the propellant explosion is determined by the interior ballistics properties of the particular cartridge-and-barrel combination employed. Generally speaking, the more powerful the cartridge and the longer the barrel, the greater will be the impulse. The recoil velocity produced by the impulse is inversely proportional to the weight of the recoiling parts; that is, the lighter the recoiling parts, the higher will be their velocity. Thus, with a powerful cartridge, long barrel, and light recoiling parts, the recoil velocity and recoil energy will be correspondingly high.

In this connection, it is important to realize that the velocity and energy of the recoiling parts play an important part in the design of a gas-operated gun. The tendency in the design of modern automatic cannon is toward higher powered cartridges, greater rates of fire, and reduced weight. All of these factors result in greater recoil energies and aggravate the problems involved in controlling the gun motions. In a gas-operated gun, the recoil energy imparted to the gun itself is not used and especially heavy buffers must be provided to dissipate and control this excess energy. Although it is true that by proper timing of the cycle of operation it is possible to make some advantageous use of the recoil velocity inherited by the bolt, this advantage is more than offset by the difficulties resulting from the excess energy in the other recoiling parts. Ideally, it would be desirable for a gas-operated gun not to recoil at all or at least to recoil with a low velocity in order to minimize the problem of energy dissipation. In such a case, entire dependence for the production of bolt velocity could be placed on the piston and blowback. Unfortunately, the requirements of modern gun design as stated above, make a high recoil energy unavoidable, and the designer of the gas-operated gun is required to make the best of the situation. (From the standpoint of efficient design, it is somewhat paradoxical that, when the gas system is employed, a considerable amount of energy is accumulated, this energy is then discarded without being used, and finally energy for operating the gun mechanism is obtained from another source.)

After unlocking occurs and just before the piston strikes the bolt, the gun itself, the gas piston, and the bolt are all moving to the rear. The piston is moving at much higher velocity than the gun because of the action of the gas pressure on the relatively light piston mass. The bolt is also moving at a higher velocity than the gun because of the effect of blowback. When the piston strikes the bolt, the impact causes the piston velocity to decrease. The factors involved in this action can be seen clearly by considering the fundamental mathematical relationships affecting the conditions of impact. These relationships are expressed as follows:

$$M_1V_1+M_2V_2=M_1V'_1+M_2V'_2 \qquad (3\text{–}3)$$

$$V'_2-V'_1=e(V_1-V_2) \qquad (3\text{–}4)$$

Equation 3–3 is based on the assumption that the spring forces, friction, or other forces acting during the impact are negligible when compared to the impact forces. Therefore the net impulse received during the period of impact is zero and the total momentum of the system remains the same. M_1 and M_2 are the masses of the piston and bolt, V_1 and V_2 their velocities before impact, and V'_1 and V'_2 their velocities after impact. Equation 3–4 states that the relative velocity of separation of two bodies after impact is directly proportional to their relative velocity of approach before impact. The constant of proportionality is the coefficient of restitution, e, and the value of this constant depends on the materials (approximately 0.55 for steel).

Solving equation 3–4 for V'_1 gives:

$$V'_1=V'_2-e(V_1-V_2)$$

Substituting the result in equation 3–3 gives:

$$M_1V_1+M_2V_2=M_1[V'_2-e(V_1-V_2)]+M_2V'_2$$

Solving for V'_2:

$$V=\frac{M_1V_1+M_2V_2+e\,M_1(V_1-V_2)}{M_1+M_2} \qquad (3\text{–}5)$$

This equation may be rewritten in the following form:

$$V=\frac{V_1(1+e)}{1+\frac{M_2}{M_1}}+\frac{V_2}{1+\frac{M_1}{M_2}}-\frac{eV_2}{1+\frac{M_2}{M_1}} \qquad (3\text{–}6)$$

Now if V_2 is zero or is very small when compared with V_1, this equation reduces to:

$$V'_2=\frac{V_1(1+e)}{1+\frac{M_2}{M_1}} \qquad (3\text{–}7)$$

Examination of equation 3–7 alone might lead to the erroneous conclusion that the piston mass M_1 should be heavier than the bolt mass M_2 in order to produce a high bolt velocity V'_2, or even to the conclusion that the final bolt velocity depends only on the ratio between the masses. However, it must be remembered that the piston velocity V_1 imparted by the gas pressure will be inversely proportional to the piston mass. This factor can be taken into account by setting V_1 equal to I/M_1, where I is the impulse of the powder gases on the piston. It is best to make this substitution in the complete equation 3–6 giving:

$$V'_2=\frac{I(1+e)}{M_1+M_2}+\frac{V_2}{1+\frac{M_1}{M_2}}-\frac{eV_2}{1+\frac{M_2}{M_1}} \qquad (3\text{–}8)$$

Now it can be seen that to obtain a high bolt velocity starting with a given impulse on the piston, both the piston mass and the bolt mass should be held to a minimum and furthermore the last two terms of the equation show that it is actually better from the overall viewpoint to have the bolt heavier than the piston. This is the reverse of the conclusion which might have been drawn from equation 3–7 alone.

In order to illustrate the conditions involved in the transfer of energy, the following example is given:

Let $W_1=1.5$ (lb.) $V_1=80$ (ft./sec.)

$W_2=5.0$ (lb.) $V_2=20$ (ft./sec.)

$e=0.55$ (for steel)

$$V'_2-V'_1=e(V_1-V_2)=.55\ (80-20)=33.0$$

Therefore $V'_1=V'_2-33.0$

Now, $M_1V_1+M_2V_2=M_1V'_1+M_2V'_2$

or $W_1V_1+W_2V_2=W_1V'_1+W_2V'_2$

$$1.5\times80+5\times20=1.5V'_1+5V'_2=1.5(V'_2-33)+5V'_2$$

$$6.5V'_2=269.5$$

$$V'_2=41.4\ \text{(ft./sec.)}$$

$$V'_1=8.4\ \text{(ft./sec.)}$$

Thus, it appears that for the sample condition, the impact between the piston and the bolt causes the bolt velocity to increase from 33.0 feet per second to 41.4 feet per second and causes the piston velocity to decrease from 80 to 8.4 feet per second.

It is also desirable to consider the energy effects of the impact. The kinetic energy lost by the piston is equal to:

$$E=\frac{1}{2}M_1(V_1^2-V'^2_1)=\frac{1}{2}\times\frac{1.5}{32.2}(80^2-8.4^2)$$

$$=147.4\ \text{(ft. lb.)}$$

The kinetic energy gained by the bolt is equal to:

$$E=\frac{1}{2}M_2(V'^2_2-V_2^2)=\frac{1}{2}\times\frac{5}{32.2}(41.4^2-20^2)$$

$$=102.0\ \text{(ft. lb.)}$$

It should be noted that the loss in piston energy is greater than the gain in bolt energy by 45.4 foot-pounds. This amount of energy is the impact loss and is dissipated in the form of heat. The final piston energy is equal to:

$$E=\frac{1}{2}M_1V'^2_1=\frac{1}{2}\times\frac{1.5}{32.2}8.4^2$$

$$=1.64\ \text{ft. lb.}$$

This remaining energy is also lost because it is not used for accomplishing any useful work. The initial kinetic energy of the piston is equal to:

$$E=\frac{1}{2}M_1V_1^2=\frac{1}{2}\times\frac{1.5}{32.2}\times80^2=149.1$$

Since 122.4 foot-pounds are transferred to the bolt, the efficiency of the piston action is:

$$\frac{102.0}{149.1}\times100=68.4\ \text{per cent}$$

The preceding analysis is primarily concerned with demonstrating the relationships among the various factors affecting the transfer of energy from the piston to the bolt. For the purpose of this demonstration it was assumed that the initial velocities and masses of the piston and bolt were known values. However, an actual design problem usually must be approached from a different point of view. Ordinarily the weight of the bolt will be known from a preliminary design layout, its initial velocity will be known from a motion study, and its velocity after impact will be selected on the basis of the rate of fire requirements. The problem is then to determine what piston weight and velocity are required to produce the desired final bolt velocity. These values can then be used to arrive at the design of the gas actuating mechanism. The procedure to be followed in this case is illustrated by the following example:

Let the following data be known:

Bolt weight, W_2	5 (lb.)
Initial bolt velocity, V_2	30 (ft./sec.)
Desired final bolt velocity, V'_2	60 (ft./sec.)
Coefficient of restitution, e	0.55

(3–9) $V'_2-V'_1=e(V_1-V_2)$

$$60-V'_1=.55V_1-.55\times30$$

(3–10) $V'_1=76.5-.55V_1$

(3–11) $W_1V_1+W_2V_2=W_1V'_1+W_2V'_2$

$$W_1V_1+5\times30=W_1(76.5-.55V_1)+5\times60$$

Solving for V_1:

(3–12) $V_1=\frac{96.7}{W_1}+49.3$

Thus, by substituting the known values and solving equations 3–9 and 3–11 simultaneously, an equation is obtained which expresses the necessary relationship between the initial piston velocity V_1 and the piston weight W_1. This equation can be satisfied by an infinite number of pairs of values for W_1 and V_1 and the problem is to select the particular pair of values which best suits the practical requirements of the gas mechanism design. To aid in making the selection it is advisable to tabulate the

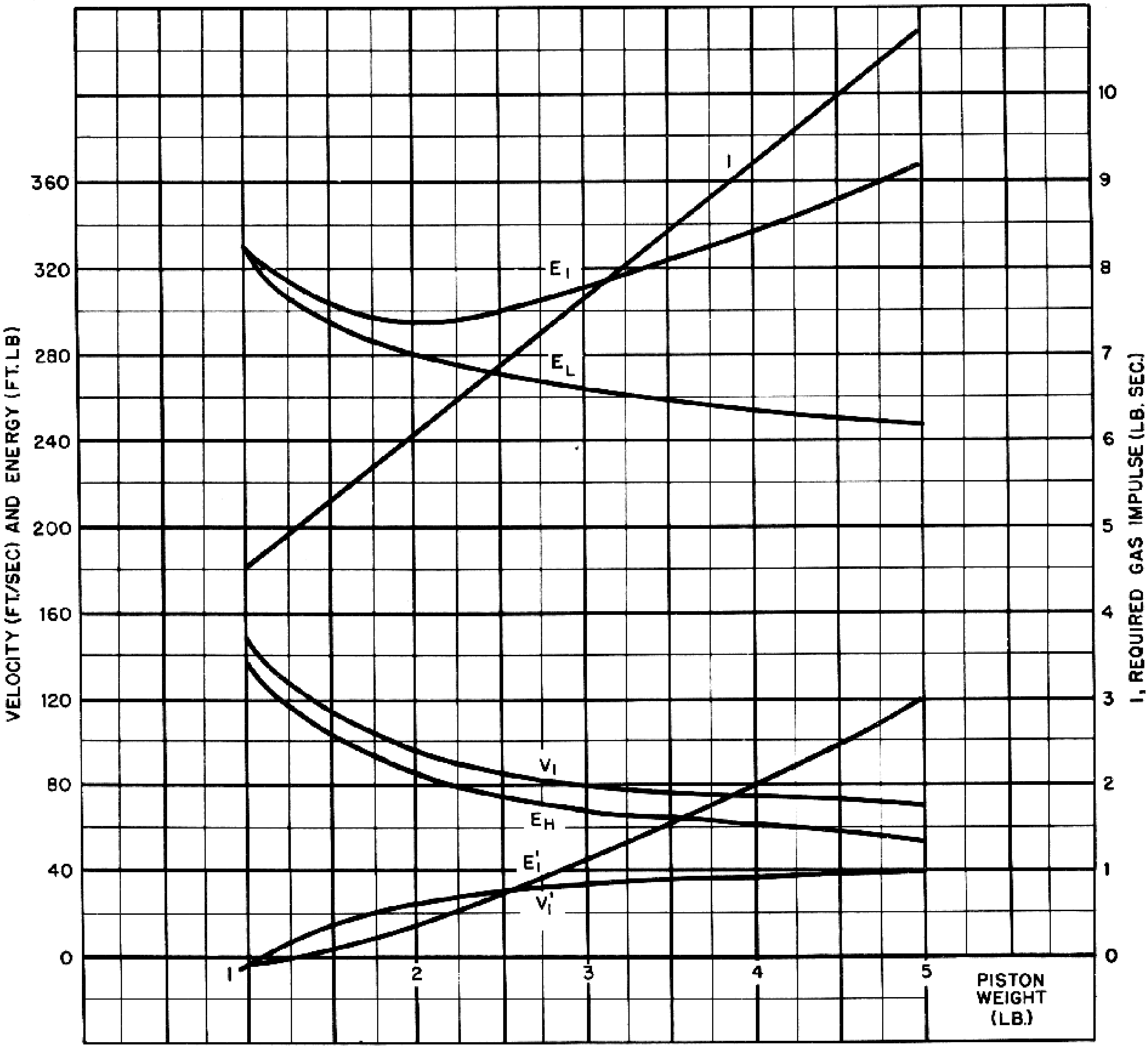


Figure 3–12. Graph of Factors Related to Selection of Piston Weight and Velocity.

corresponding values of W_1 and V_1 along with other related values which influence the design. This has been done in Table 3–1 and the results are shown graphically in figs. 3–12 and 3–13. The other values in the table and graph were found using the following formulas:

Velocity of piston after impact:

$$V'_1 = 76.5 - .55V_1 \text{ (ft./sec.)}$$

Energy lost by piston in impact:

$$E_L = \frac{W_1}{2g}(V_1^2 - V'^2_1) \text{ (ft./lb.)}$$

Initial piston energy:

$$E'_1 = \frac{W_1}{2g} V'^2_1 \text{ (ft. lb.)}$$

Final piston energy:

$$E'_1 = \frac{W_1}{2g} V'^2_1 \text{ (ft. lb.)}$$

Impact loss to heat:

$$E_H = E_L - E_G \text{ (}E_G\text{ is energy gained by bolt)}$$

Required gas impulse:

$$I = M_1V_1 \text{ (lb. sec.)}$$

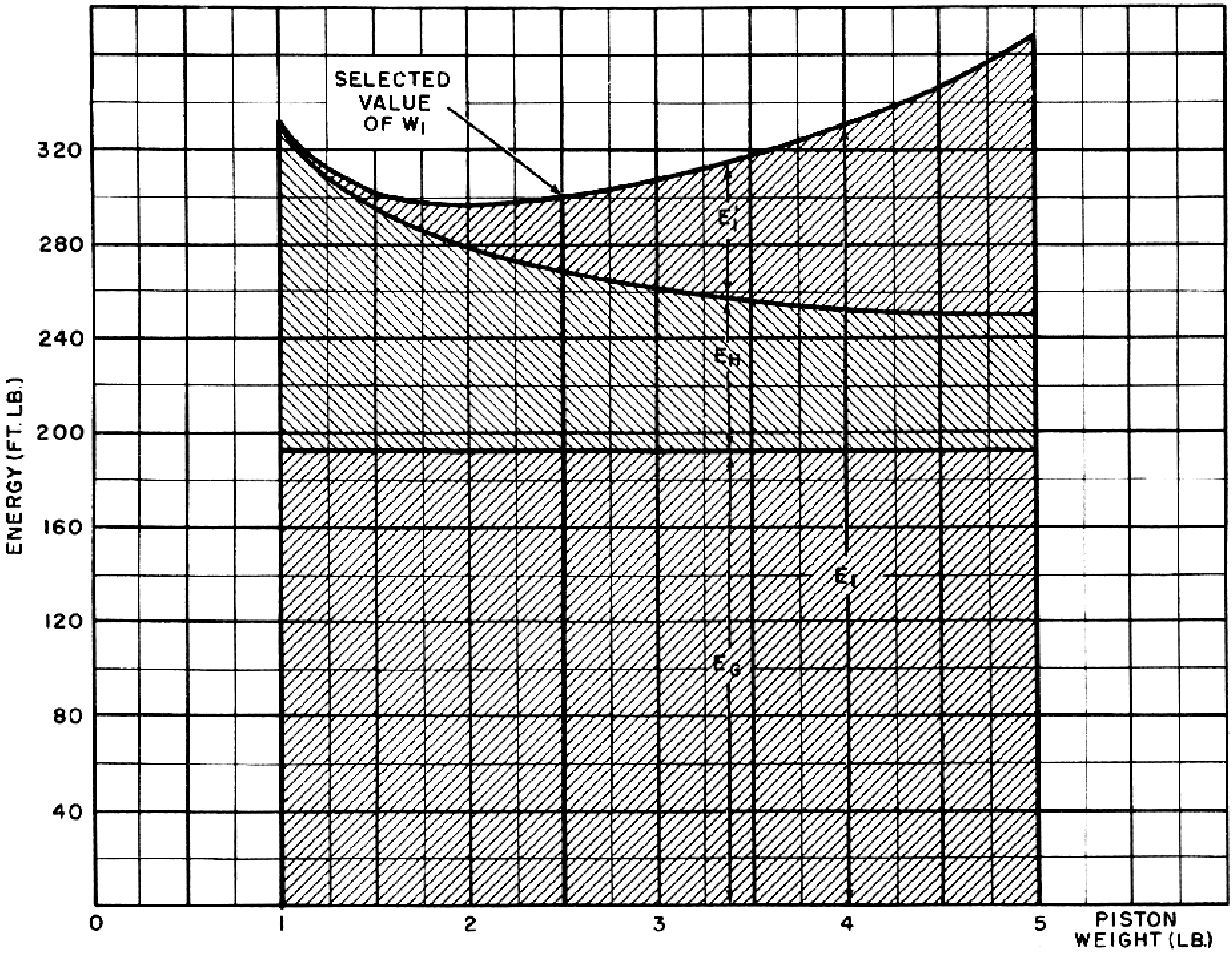


Figure 3–13. Distribution of Piston Energy for Various Weights.

The energy gained by the bolt is the same for all entries and is computed as follows:

$$E_G = \frac{W_2}{2g}(V_2'^2 - V_2^2) = \frac{5}{64.4}(60^2 - 30^2) = 194 \text{ (ft. lb.)}$$

The three items of major interest in Table 3–1 and figs. 3–12 and 3–13 are the energy E_L lost by the piston in the impact, the energy E'_1 remaining in the piston after impact, and the impulse I which must be obtained from the powder gases. The value of E_L is of prime importance because it is this value which indicates the severity of the impact. For the sample conditions, the impact must necessarily be heavy because 194 foot-pounds of energy must be imparted to the bolt, but the total energy involved in the impact must be greater than this value to allow for the impact loss to heat. Note from fig. 3–9 that the value of E_L, which is the sum of the energy transferred to the bolt E_G and the impact loss E_H, increases rather slowly as the bolt weight decreases, but finally begins to increase rapidly when W_1 is less than approximately 1.5 pounds. This would seem to indicate that the piston should be made quite heavy. However, note that, as the piston weight increases, the energy E'_1 remaining in the piston after impact becomes quite large. It is also important to note that the required gas impulse increases rapidly with increase in piston weight. Both of these factors tend to indicate the desirability of choosing a light piston. To make the best of the conflicting requirements, it seems reasonable to choose a piston weight of approximately 2.5 pounds. With this choice, E_L is 270 foot-pounds, only 20 foot-pounds more than for the 5-pound piston. The required gas impulse is only 6.8 pound-

Table 3-1. Values Related to Selection of Piston Weight

W_1	V_1	V_1	E_1	E_1	E_1	E_H	I
1.0	146.0	−3.7	332	332	−0.2	138	4.53
1.5	113.8	14.0	297	302	4.6	103	5.29
2.0	97.6	22.8	280	296	16.15	86	6.06
3.0	81.6	31.6	264	310	46.5	70	7.60
4.0	73.5	36.1	254	335	81.0	60	9.13
5.0	68.7	39.0	249	367	118.1	55	10.68

seconds instead of 10.7 pound-seconds as would be required for the 5-pound piston. This value of 6.8 pound-seconds should be possible of attainment with relative ease, while a value as high as 10.7 pound-seconds might present difficulties. Also note that the piston velocity V'_1 and piston energy E'_1 remaining after impact are reasonable values, as are the heat loss E_H and initial piston velocity V_1.

Having analyzed the factors which are involved in imparting velocity to the bolt, it remains only to consider the motions of the gun mechanism during the completion of the automatic cycle of operation. After the piston has acted on the bolt, the bolt moves to the rear at high velocity, travelling of its own momentum. There is a slight blowback which still acts on the bolt after the piston impact, and this action produces a small increase in the velocity of the bolt motion. The bolt must continue its rearward motion until the opening between it and the barrel is great enough to permit feeding a fresh cartridge. The motion of the bolt must then be reversed to load the fresh cartridge into the chamber and lock the breech. This action of the bolt in a gas-operated gun is similar in some ways to the corresponding action in guns employing other systems of operation and, although the action has been explained previously in this publication, the explanation will be repeated here to avoid the inconvenience of cross-referencing. In some guns, the reversal of the bolt motion is accomplished entirely through the use of a relatively powerful driving spring which is compressed as the bolt moves in recoil. The buffer and spring absorb the kinetic energy of the bolt over the full recoil travel, finally stopping the rearward motion of the bolt when all of the kinetic energy has been absorbed. The spring is designed so that this occurs when the opening is sufficient to permit feeding. The compressed spring then drives the bolt forward to complete the operating cycle. This type of design has a serious drawback from the standpoint of speed of operation. Since the bolt is gradually slowed down by the spring, its velocity varies from maximum at the beginning of recoil to zero at the end of recoil. (See fig. 3–14, a graph showing how the bolt velocity varies with time under these conditions.) The fact that the bolt velocity varies from maximum to zero in the manner illustrated means that its average velocity will only be slightly greater than one-half its maximum velocity. In other words, if this type of action were used in a gas-operated gun, in spite of all the pains taken to achieve a high initial bolt velocity, the overall travel of the bolt would be accomplished at a much lower average velocity.

To overcome this disadvantage, the bolt driving spring can be made relatively very light so that it offers a low retardation and will permit the bolt to move its entire recoil distance with little loss in velocity. In this case, the function of the driving spring is merely to provide a positive force which is just sufficient to insure that the bolt will close. Stopping the bolt at the end of its travel and reversing its motion can be accomplished by causing the bolt to rebound from a so-called "backplate buffer". This device is in effect an extremely stiff spring which absorbs all of the kinetic energy of the bolt over a very short distance and then delivers energy back to the bolt to propel it forward. The reversing action produced by the backplate is so abrupt that the effect may be classified as an elastic impact.

In order to obtain a high rate of fire, it is also important for the bolt return to be accomplished at high velocity. If there were no energy losses involved in the reversing action, the forward velocity

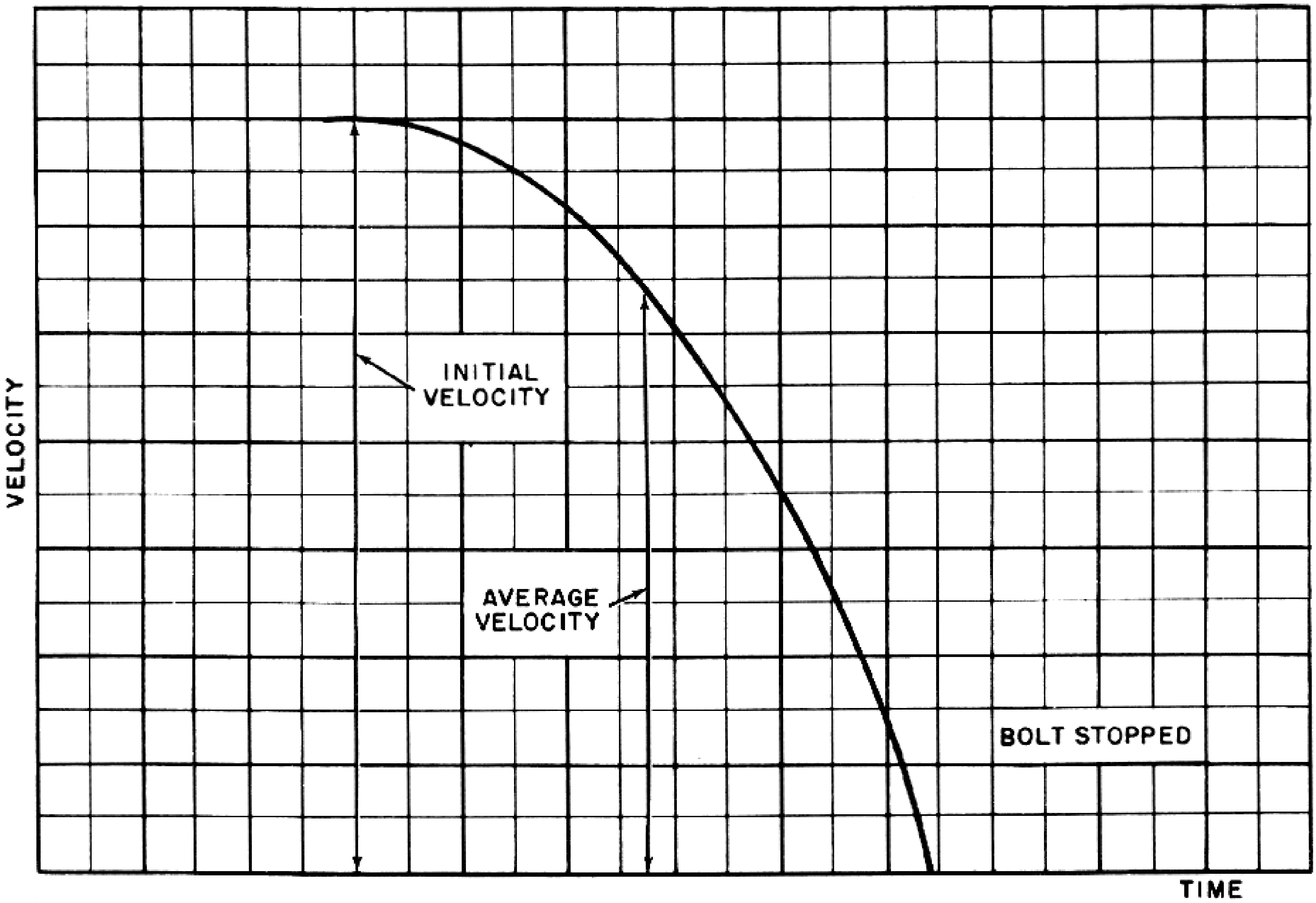


Figure 3–14. Variation of Bolt Velocity With Time When Driving Spring Absorbs All of Bolt Energy.

of the bolt after leaving the backplate would be equal to the velocity at which it strikes the backplate. This would be the ideal condition. However, in actual practice the coefficient of restitution for the bolt and backplate is usually considerably less than unity and the best that can be expected is a coefficient in the neighborhood of 0.60 or 0.70; that is, the velocity after impact will be 60 or 70 per cent of the velocity before impact. This represents satisfactory performance, but if the coefficient of restitution is too low as the result of poor backplate design, the return of the bolt will be sluggish and the rate of fire will be affected adversely. In this connection, it should be emphasized that the purpose of the backplate buffer is to reverse the motion of the bolt with as little loss of energy as possible. In many instances, the term "buffer" is used to refer to a device which has the primary purpose of dissipating impact energy rather than of conserving energy to produce an efficient rebound action. For this reason it might be better to refer to the backplate buffer as a "bolt deflector" or "rebound plate".

The conditions under which the bolt rebounds from the backplate in a gas-operated gun are extremely important and must be considered carefully in the design. In dealing with these conditions, it is essential to make proper allowances for the fact that the entire gun moves in recoil and to time correctly the motions of the various parts. The necessity for careful timing arises principally from the fact that the backplate buffer is mounted on the gun and accordingly moves with the gun in recoil. Since the position of the backplate is not fixed, it is possible to have several different conditions of relative motion and impact, depending on the particular timing used in the design.

The timing involved in this instance is primarily dependent on the motion of the gun in its cradle and is therefore mainly controlled by the action of the barrel return spring and the recoil buffer. If the spring and buffer stop the recoil motion of the gun and start to return the gun to battery before the bolt strikes the backplate, the velocity with which the bolt strikes will be the sum of the bolt velocity measured with respect to the cradle and the forward velocity possessed by the gun at the instant of impact. It also should be realized that motion of the gun in the cradle affects the distance through which the bolt must move with respect to the cradle in order to establish the bolt opening required to permit feeding.

The opposite situation is encountered when the barrel spring and buffer do not stop the recoil motion of the gun until after the bolt strikes the backplate. In this case, the gun is still moving back at the instant of contact and the impact velocity is the difference between the velocity of the bolt measured with respect to the cradle and the rearward velocity possessed by the gun at the instant of impact. Here again, proper allowance must be made for the fact that the motion of the gun in the cradle affects the distance through which the bolt must move with respect to the cradle.

The velocities and movements involved in the preceding timing arrangements would not cause any particular difficulty if the conditions of motion remained the same from shot to shot. However, under practical conditions, some variation in the recoil motion is unavoidable and therefore the relative velocity with which the bolt strikes the backplate will not remain constant and the position of the parts at the instant of impact will also vary. In a high-rate-of-fire gun, each cycle of operation has some effect on the following cycle and under the conditions of timing described above there is a strong tendency for any variation to produce even greater variations. This will cause the gun to quickly "fall out of step", with the associated symptoms of stuttering and extremely erratic action. With the gun operating in this manner, the parts can be subjected to abnormally heavy shocks and excessive parts breakage is certain to result.

A way to avoid malfunctions resulting from variations in the gun recoil movement would be to set up the timing so that the bolt strikes the backplate just at the same instant the recoil motion of the gun is reversed. If this could be arranged, the impact would occur while the gun is not moving and is at a definite position, with the result that the variations described in the preceding paragraph could have no effect. Unfortunately, when an ordinary ring spring buffer is used, it happens that this timing arrangement causes an even more critical condition to exist. With a ring spring type buffer, the velocity of the gun is reduced rapidly to zero and then the action of the compressed buffer immediately drives the gun forward, although with reduced velocity because of the fact that the buffer absorbs a considerable portion of the recoil kinetic energy. Fig. 3–15 is a graphical representation of how the gun velocity varies with respect to time during the action of the buffer. Note that on either side of the instant at which the velocity is zero, the velocity is changing quite rapidly. From this curve, it is evident that even a very slight variation in the instant that the bolt strikes the backplate can have a very great effect on the relative velocity of impact. It appears, then, that if the timing is such that the bolt strikes the backplate during the action of a ring spring buffer, the tendency toward erratic performances is especially pronounced.

The difficulty described above can be avoided by modifying the characteristics of the buffer. The major cause of the trouble is that the ring spring buffer has the steep time-velocity characteristic shown by fig. 3–15. If the buffer is designed to act over a greater interval of time, some improvement will be gained because the change in velocity with respect to time will then not be so abrupt. However, the best results will be obtained if the time-velocity characteristic of the buffer is as shown in fig. 3–16. One way to obtain this type of action is with a hydraulic buffer designed so that its resistance is proportional to the gun velocity, thus producing a viscous damping effect. The slight step in the curve of fig. 3–10 immediately adjacent to the point of zero velocity, is due to the fact that the buffer action terminates in such a manner as to provide the effect of a fixed positive stop. Note that for a considerable interval on either side of the instant of zero velocity, the velocity is nearly zero and changes very slowly. Hence, even if the instant of bolt impact varies slightly over this interval, there will still be very little change in the relative impact velocity. The effect of using this type of buffer is to cause a hesitation which stops the gun and backplate at the same place for each shot and which maintains the gun velocity very close to zero for an adequate time interval. This effect is equivalent to providing the gun with a fixed receiver, thus permitting the conditions of the bolt impact to be kept under precise control.

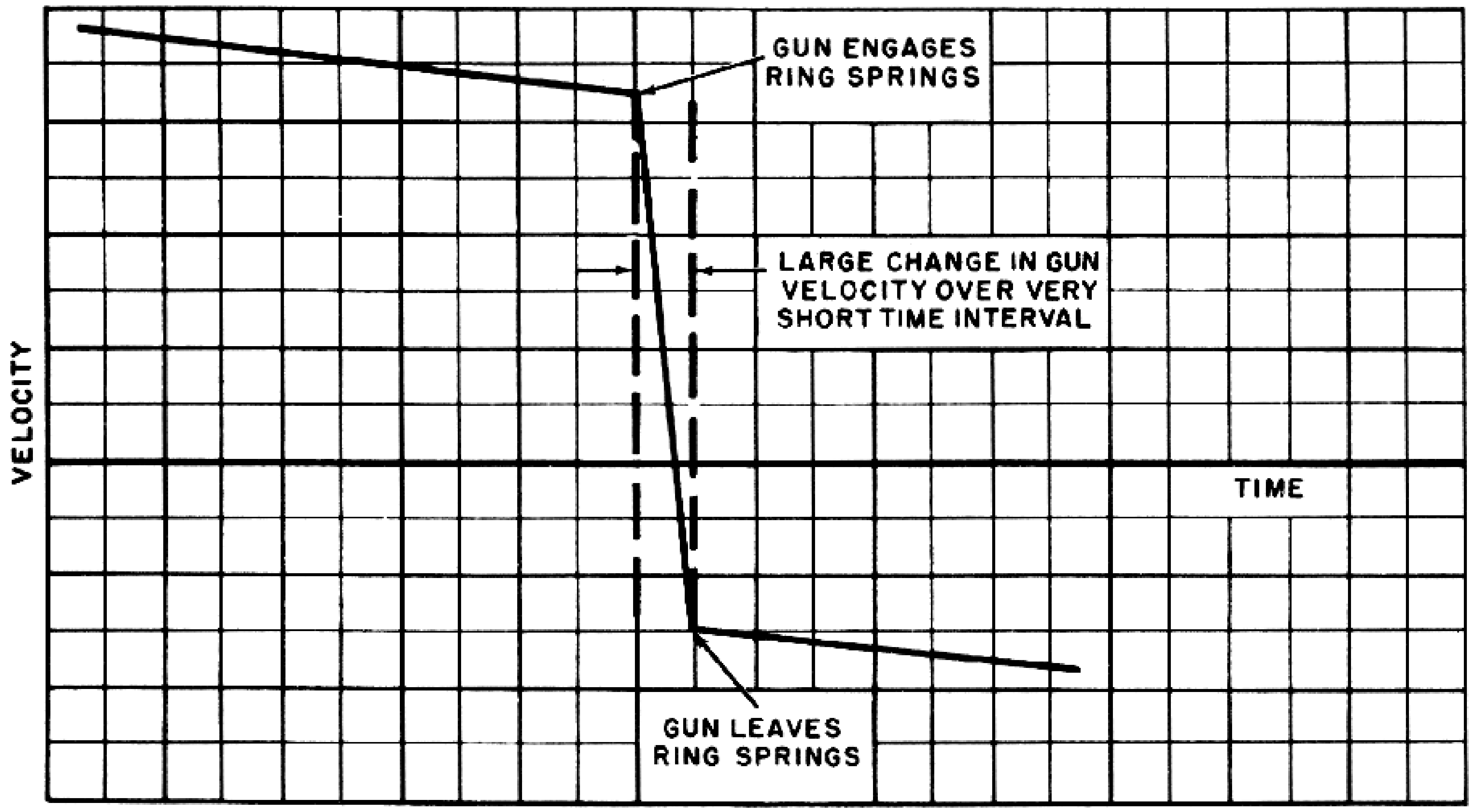


Figure 3–15. Time-Velocity Characteristic of Ring Spring Buffer.

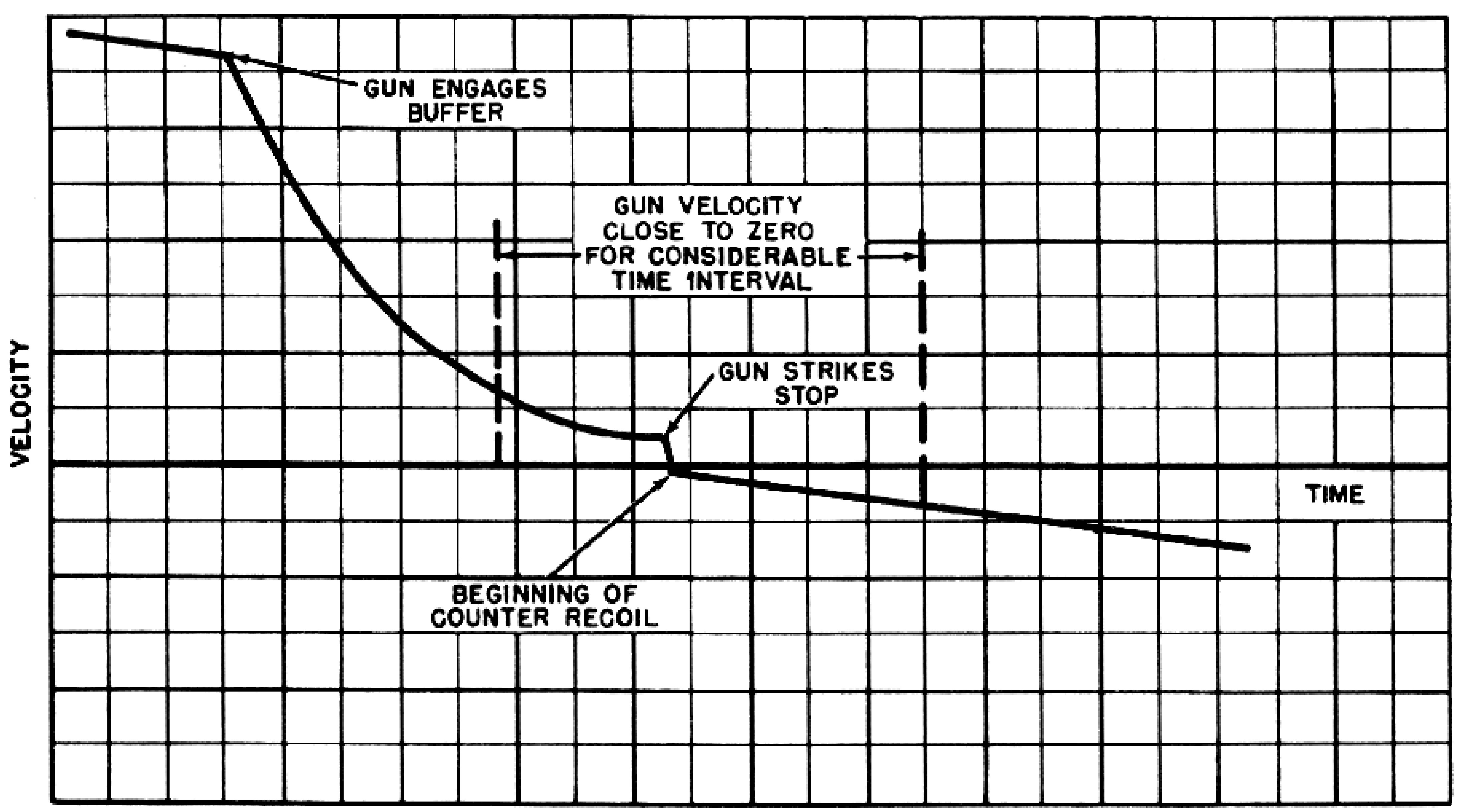


Figure 3–16. Desirable Time-Velocity Characteristic for Recoil Buffer.

The last point to consider in analyzing the action of a gas-operated gun is the forward motion of the gun parts. After the bolt rebounds from the backplate, both the gun itself and the bolt move toward the battery position, the gun being driven by the barrel spring and the bolt traveling of its own momentum assisted by the action of the bolt driving spring. During the return motion, both the gun and the bolt reach rather high velocities and consequently acquire a large amount of kinetic energy. Unless this energy is properly handled and dissipated, the return of the gun and bolt can result in very damaging shocks and can produce extremely violent oscillations which will interfere with smooth operation at high rates of fire.

To minimize the shock produced when the bolt strikes the barrel, it is desirable to arrange the design so that the bolt will lock to the barrel before the gun has completed its forward movement. With this arrangement, the relative velocity of impact is lower than it would be if the gun were stationary and also the gun is free to yield to the impact.

Now, with the bolt locked to the barrel and with the entire gun still moving forward, the remaining problem is how to handle the kinetic energy contained in the gun as it reaches the battery position. Since the gun will possess a very large amount of kinetic energy, it would not be feasible to stop the forward motion by means of a metal-to-metal impact against a part of the cradle. To avoid severe shock and a violent rebound, it is necessary to provide a buffer action to absorb and dispose of the excess energy in the counter-recoiling gun. This action can be obtained through the use of a heavy-duty buffer which is designed to dissipate practically all of the energy it absorbs.

A very effective method of stopping the forward motion of the gun is to fire the chambered round just before the gun completes its counter-recoil travel. When this is done, the recoil forces generated by the explosion of the propellant charge first stop the gun and then propel it to the rear in recoil. The action of the explosion produces a rapid but very smooth reversal of motion and provides an excellent means of disposing of the excess counter-recoil energy without applying any shock to the gun mounting. Another important advantage of utilizing the propellant explosion in this manner in a gas-operated gun is that it greatly decreases the intensity of recoil. This is true because a fairly large portion of the explosive impulse is expended in stopping the forward motion of the gun and therefore the amount of impulse remaining to cause recoil is reduced. Of course, even if the explosion is employed to provide the counter-recoil buffer action, it is still necessary in guns of large caliber to include a physical buffer to prevent damage to the gun in the event a round fails to fire. Since the presence of the physical buffer is necessary, it may be desirable to time the firing so that this buffer assists in the reversing action.

Mathematical Analysis of Gas Operation

Most of the problems encountered in the design of gas-operated automatic gun can be handled in a straightforward manner by the same general analytical methods used for the other systems of operation described in this publication. These methods lend themselves readily to the analysis of the recoil forces, blowback effect, energy transfers, and spring data and can also be applied directly in developing the theoretical time-travel and time-velocity diagrams. However, there is one problem for which no satisfactory method of analysis is available. This problem concerns the design considerations related to the flow of gases and to the build-up of pressure against the piston or other actuating member. If it were possible, it would be highly desirable to be able to compute exactly what size and shape of orifice should be used, or to know in advance how the configuration of the passage leading from the barrel to the gas cylinder will affect the variation of the cylinder pressure with respect to time. Unfortunately, accurate solutions to these problems and to problems of a similar nature can not be obtained analytically because of the complexities involved in predicting the flow of the turbulent and high velocity gases produced by the propellant explosion.

Although the fact that the problems described in the preceding paragraph can not be solved by mathematical analysis causes a real difficulty for the designer of a gas-operated gun, this difficulty is by no means insurmountable. By making the necessary allowances in the analysis and by the judicious use of available empirical data, it is possible to produce a preliminary design which is safe and yet is arranged to permit convenient modification on the basis of experimental firing. It must be emphasized that this process, when properly carried out, does not amount to "fumbling in the dark" or to making haphazard changes. In the design analysis, the impulse required of the gas actuating device and the required timing for this impulse are carefully determined so as to produce the desired operating characteristics. The object of the experimental firing is then to adjust the factors which affect the impulse and the timing of the impulse so that the required values will be obtained.

The following pages describe a systematic approach to the design analysis of a gas-operated gun. The characteristics chosen for the gun to be used as an example do not represent any existing design, but have been selected to illustrate the principles described in the analysis of gas operation. It is assumed that the gun will be cradle-mounted and will employ a conventional gas piston which transfers energy to the bolt by direct impact. The desired rate of fire will be taken as approximately 1200 rounds per minute. To illustrate the design procedures involved when the propellant explosion is utilized to provide a counter-recoil buffer action, it will be assumed that the gun will be fired just before reaching the battery position. The assumption of these characteristics and of other specific properties of the gun will of course have some influence on the details of the analysis and as a result, the particular methods employed may not be directly applicable in their entirety to other gas-operated gun mechanisms having a different arrangement. Nevertheless, gas-operated guns all function according to the same basic principles and the gun selected as an example should serve to illustrate the approach to a typical design.

The methods which will be used in the analysis follow the same general lines employed throughout this publication with the necessary modifications to adapt the procedure to the gas system of operation. Primary attention will be given only to the factors controlling the motions of the principal operating parts and to the major forces effecting these parts. Here, as in the other parts of this publication, no attempt will be made to cover the conventional methods of machine design by means of which the results of the analysis are applied in arriving at the particular physical form of the mechanisms. Also, no detailed computations are made to cover the effects of such factors as friction or the incidental forces imposed on the actuating device by the auxiliary mechanisms such as the feeder, firing device or locking device. These effects will have only a relatively slight influence on the motions of the main operating parts and, in any case, they can be properly taken into account in the advanced stages of a design when the form of the gun mechanism becomes fairly well established. At this point, the results of the preliminary analysis can easily be modified as desired.

In the design of a gas-operated gun, the weights of the recoiling parts will have a considerable influence on performance characteristics and therefore it is necessary to have certain weight data before the analysis can be started. The weights of the barrel and its associated parts and the weight of the bolt are determined largely by the particular configuration selected by the designer and by the requirements for strength, rigidity, and durability. For this reason, the first step in the design process should be to design the barrel to withstand the forces produced by the selected cartridge and then make a preliminary layout of the entire mechanism. In making this layout, experience and good judgment will aid in arriving at a mechanism of practical proportions and will permit the design to be brought to the point where it is feasible to obtain a fair estimate of what weights will be involved and of what distance the parts will be required to travel. On the basis of these data, it will be possible to perform a preliminary design analysis from which a good approximation of the operating forces can be obtained. Then, if necessary, these forces can be taken into consideration in making adjustments to the design to insure that all parts will have adequate strength. A knowledge of the operating force will also assist in refining the design to eliminate excess weight, particularly in such parts as the bolt and piston where weight has a great influence on the performance of the gun.

The following analysis is based on the assumption that a particular cartridge with known characteristics is to be used and that the desired muzzle velocity and barrel length have been predetermined. It is also assumed that all necessary interior ballistics data are known and that graphs showing the time variation of chamber pressure, projectile velocity, and projectile bore travel are available (figs. 3–17, 3–18, and 3–19).

NOTE: For some design problems, all or part of this information may not be available. Analytical methods by which to approximate the required data and graphs for use in pre-

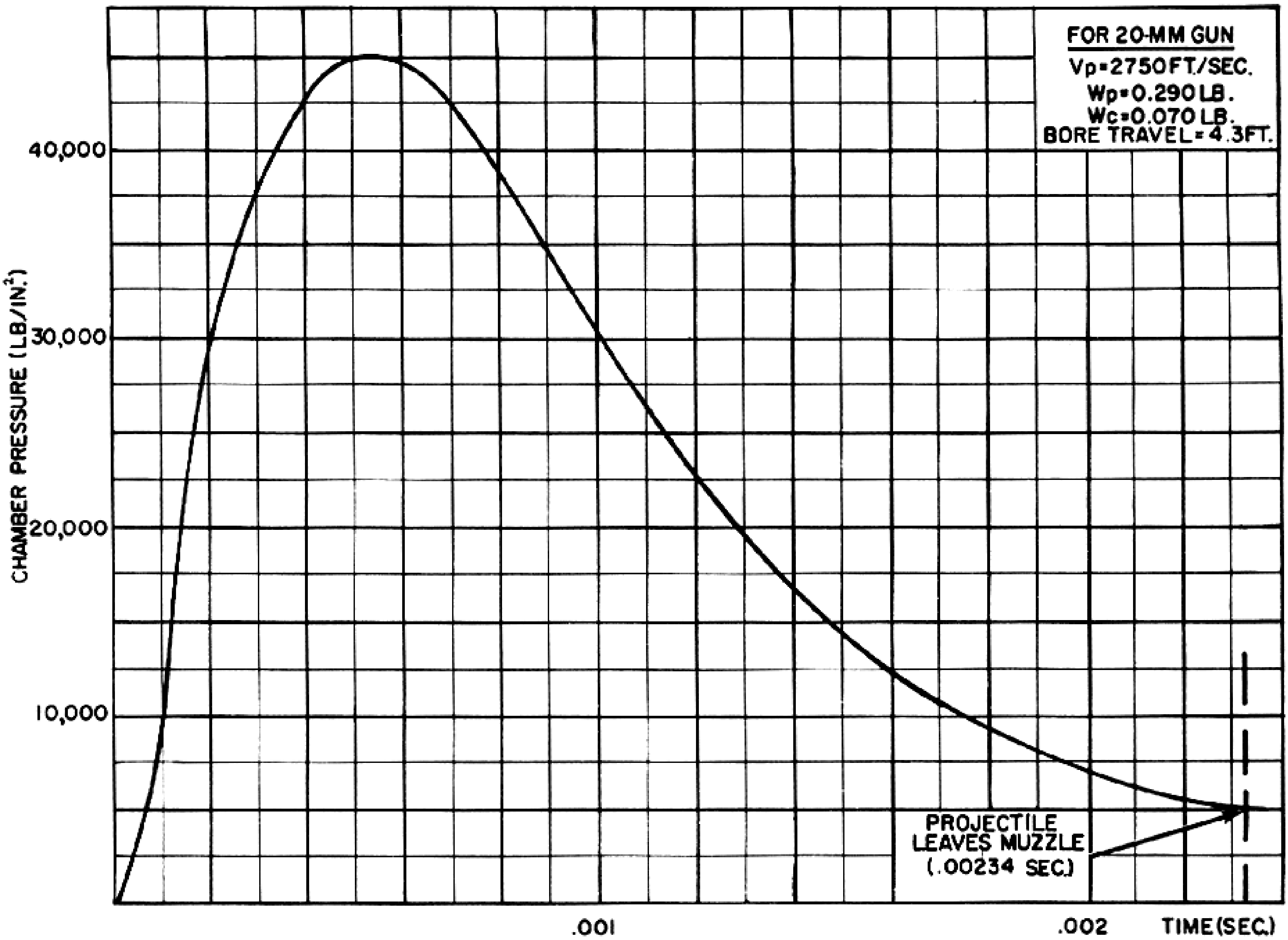


Figure 3–17. Graph of Chamber Pressure Versus Time (20 mm Gun).

liminary studies may be determined by conventional interior ballistics computations.

As the analysis progresses, its applications will be illustrated by means of sample calculations. Although these calculations and the related graphs are for a specific 20-mm cartridge and barrel and are based on certain assumed weights and other characteristics, the general approach described is applicable to gas operated guns of any caliber. The calculations cover the following important points:

1. Determination of the conditions of free recoil.
2. Determination of the correct time for unlocking.
3. Computation of data required for design of the gas actuating device.
4. Determination of data required for timing the operation of the piston.
5. Selection of characteristics of barrel springs and bolt driving spring and determination of data for backplate buffer and buffers associated with barrel spring.
6. Development of graphs show how the velocity and travel of the gun, piston, and bolt vary with respect to time.

In the course of describing these calculations, the following fundamental formulas will be developed and explained.

a. Momentum and velocity relations for time projectile is in bore
b. Formula for determining velocity of free recoil
c. Expression for duration of residual pressure
d. Formulas for determining spring retardations.

(Before proceeding, it should be mentioned that the action of a gas-operated gun up to the time the piston strikes the bolt is very similar from the analytical point of view to the operation of a short-

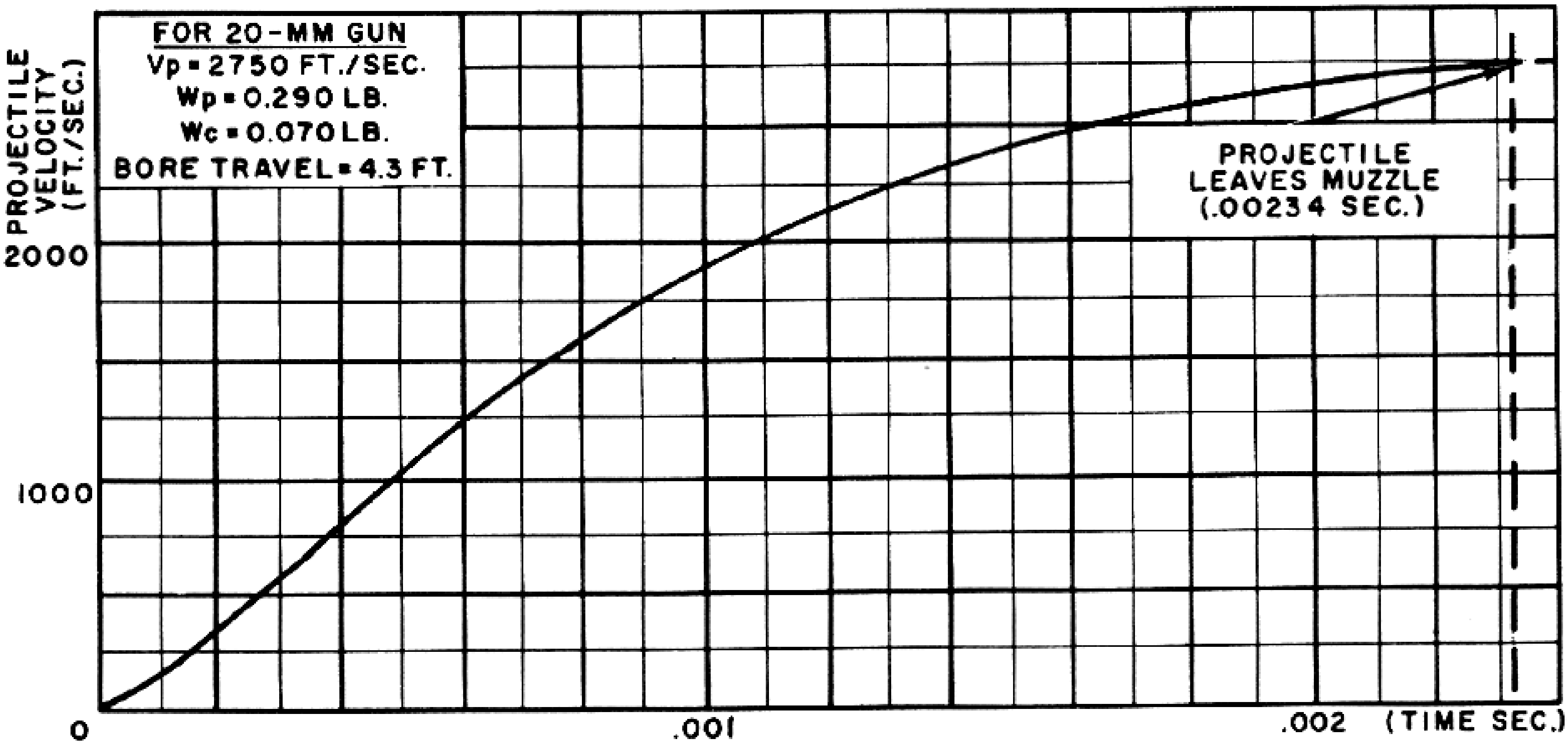


Figure 3–18. Graph of Projectile Velocity Versus Time (20 mm Gun).

recoil gun up to the time the accelerator begins its action. There are certain differences, however, which result from the influence of the gas actuating device. Since these differences make its impractical to refer simply to the applicable portion of the short-recoil analysis, a complete analysis of the entire operating cycle for gas operation will be given here. Because of the close similarity of the two systems at some points in the cycle, a certain amount of repetition of the material covered under short recoil is unavoidable.)

1. *Conditions of free recoil*

Before considering the actual motions of the recoiling parts under the restraint of the barrel spring and bolt driving spring, and before analyzing the effect of firing while the gun is still moving forward, it is necessary in the following method to determine first how the recoiling parts would move under the conditions of free recoil. (For determining the free recoil motion, it is assumed that the gun is fired while stationary and is mounted so that it can move to the rear without friction or any other restraint.) Under these conditions, the impulse of the recoil force will impart to the gun a rearward momentum equal to the forward momentum of the projectile and powder gases. Until the instant the projectile passes the gas port, this momentum relation is expressed by the equation:

(3–13) $$M_r V_{r_f} = M_p V_p + M_c V_c$$

Since the powder gases will be thoroughly mixed by the turbulence created in the propellant explosion, it is reasonable to assume that the center of mass of the gases moves forward at one-half the velocity of the projectile. Actually, this is not quite accurate because the presence of the enlargement at the chamber and the fact that the rifling does not extend the full length of the space occupied by the gases creates a condition in which the volume of the space is not uniformly distributed along its length. Nevertheless, the assumption is close enough for present purposes. Therefore, equation 3–13 may be rewritten as:

(3–14) $$M_r v_{r_f} = M_p v_p + M_c \frac{v_p}{2} = \left(M_p + \frac{M_c}{2}\right) v_p$$

NOTE: It should be pointed out here that the momentum equality expressed by equation 3–14 is not affected by the internal frictional forces opposing the motion of the projectile and powder gases or by the force incident to engraving the rifling band and to imparting the rotational velocity to the projectile. Although all of these forces retard the forward motion of the projectile and powder gases, they produce equal and opposite reactions on the barrel which result in a corre-

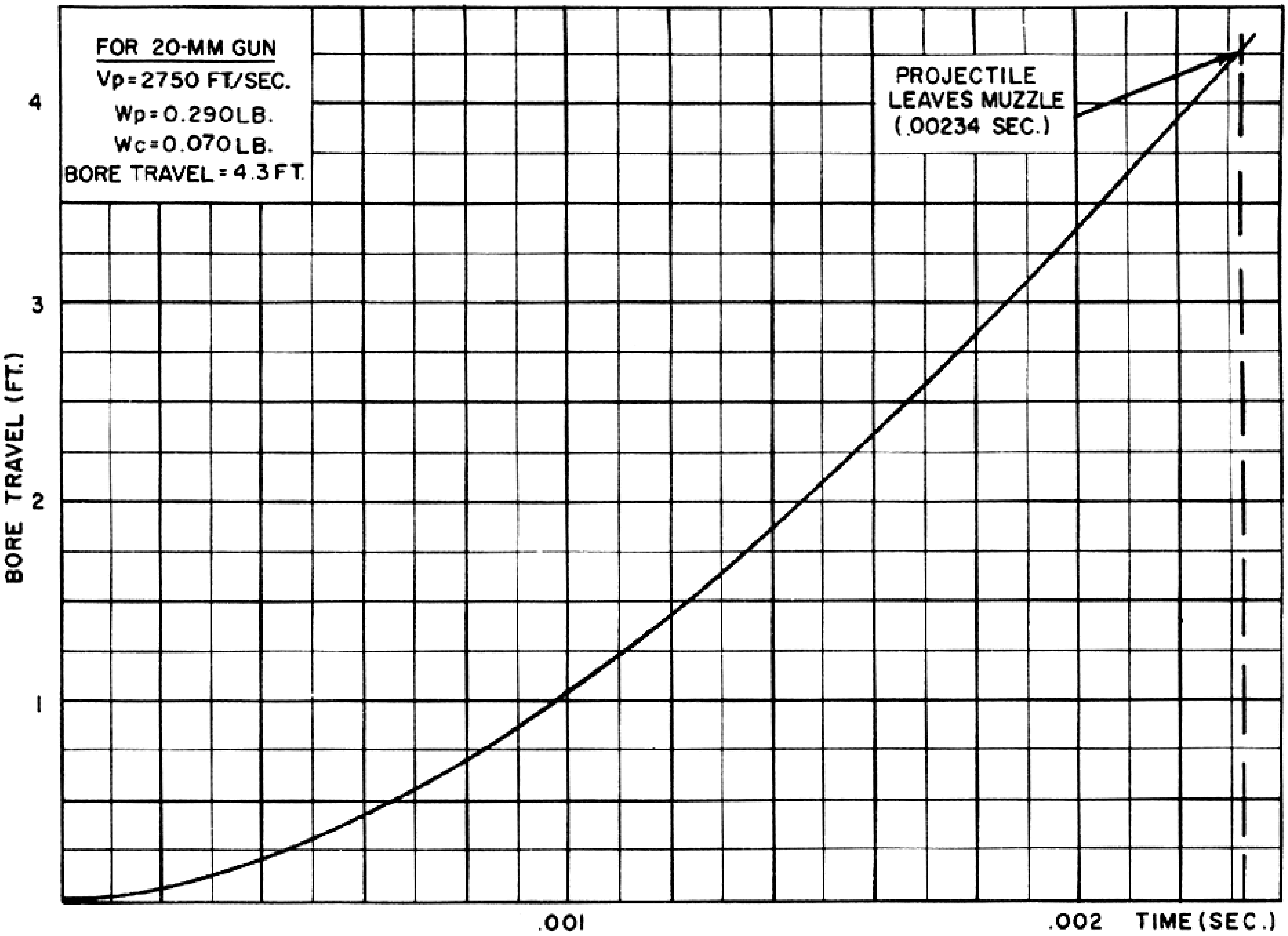


Figure 3–19. Graph of Projectile Bore Travel Versus Time (20 mm Gun).

sponding retardation of the rearward movement of the gun. In other words, the internal resistances merely decrease the effective impulse producing motion but they do not cause any inequality in the forward and rearward momentums.

Solving equation 3–14 for v_{r_f} gives the velocity of free recoil for the time before the projectile passes the port as:

$$v_{r_f}=\frac{M_p+\frac{M_c}{2}}{M_r}\,v_p=\frac{W_p+\frac{W_c}{2}}{W_r}\,v_p \tag{3–15}$$

Equation 3–15 can be used to plot a curve showing the free recoil velocity versus time for the period before the projectile passes the gas port. The weights of the projectile and powder charge are both known and it is assumed that the weight of the recoiling parts has been estimated from a preliminary design layout. Also, the velocity of the projectile is known from the available ballistic data (fig. 3–18). Therefore, the ordinate of the free recoil velocity curve, t, can be found by multiplying the corresponding ordinate of the projectile velocity curve by the factor:

$$\frac{W_p+\frac{W_c}{2}}{W_r}$$

Assuming that in the 20-mm gun to be used as an example the estimated weight of the recoiling parts is 60 pounds and the weights of the projectile and powder charge are as shown in fig. 3–15, the value of the multiplying factor is:

$$\frac{W_p+\frac{W_c}{2}}{W_r}=\frac{.29+\frac{.070}{2}}{60}=.00542$$

Therefore, before the projectile passes the gas port, the free velocity of the recoiling parts is:

$$(3\text{–}16)\qquad v_{r_f}=.00542\ v_p\left(\frac{\text{ft.}}{\text{sec.}}\right)$$

If it were not for the presence of the gas port, this same equation would apply until the instant that the projectile leaves the muzzle. However, after the projectile passes the gas port, the pressure in the gas cylinder rapidly rises and starts to drive the piston to the rear. This pressure acts both rearward on the piston and forward on the front projection of the cylinder bore. Since the piston at this time does not exert any force on the gun (except perhaps through a relatively weak piston return spring), the rearward pressure on the piston does not have any effect on the recoiling gun mass. On the other hand, forward pressure on the front cylinder face is transmitted directly to the gun and acts to oppose the recoil motion. In other words, after the projectile passes the gas port, the pressure in the gas cylinder produces a retarding impulse on the gun which is equal to the impulse imparted to the gas piston.

The actual magnitude of the retarding impulse and the manner in which it develops with respect to time will depend on the operational characteristics of the gas cylinder and on the location of the gas port. At this point in the design, these characteristics are not yet established, so it will be necessary to make a reasonable estimate which can be corrected later if necessary. Experience with weapons of this caliber indicates that the impulse which must be applied to the piston will vary with time approximately as shown in fig. 3–8. Assuming for the present that this curve is applicable to the gun of the example, the free recoil curve for the interval before the projectile leaves the muzzle can be drawn as follows:

Using equation 3–16, a curve is plotted for the interval from t=0 to t=.00234 second as shown in fig. 3–20. This curve is shown dotted after t=.0016 second, at which time the assumed curve of fig. 3–8 indicates that the projectile passes the gas port. For the interval from t=.0016 to t=.00234 second, the changes in recoil velocity produced by the piston impulse are now computed, dividing the ordinates of the curve in fig. 3–8 by the mass of the recoiling parts (assuming that the weight of the piston is negligible when compared to the entire weight of the recoiling parts). That is:

$$\Delta V_{r_f}=\frac{I}{M_r}=\frac{I_g}{W_r}=\frac{32.2I}{60}=.520I$$

This calculation is performed for selected ordinates in the interval and the values obtained are subtracted from the corresponding ordinates of the curve plotted from equation 3–16. The resulting curve is shown in fig. 3–20 and is also shown in fig. 3–21. (In fig. 3–21, the time axis is compressed to show how the velocity varies after the projectile leaves the muzzle.)

The manner in which the free recoil velocity varies after the projectile leaves the muzzle can not be determined from equation 3–16 because the projectile

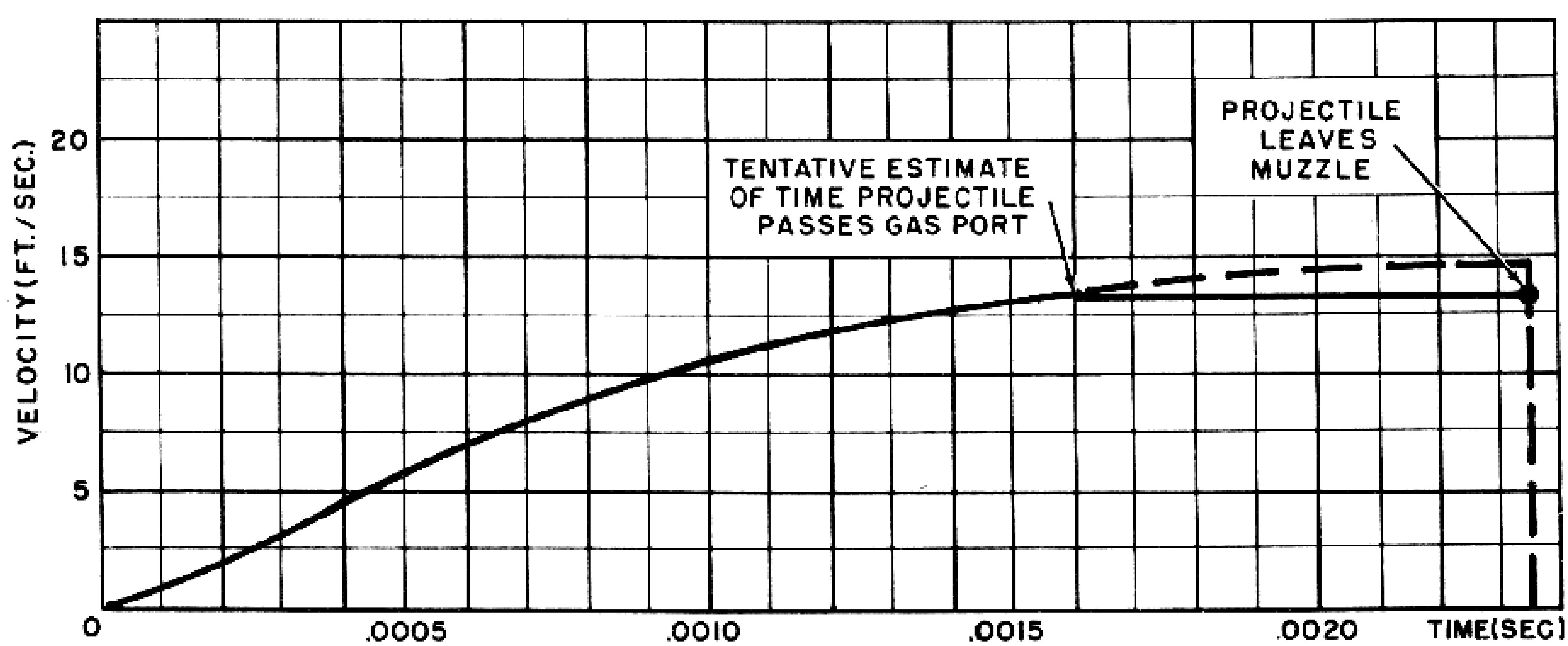


Figure 3 20. Free Recoil Velocity While Projectile Is in Bore.

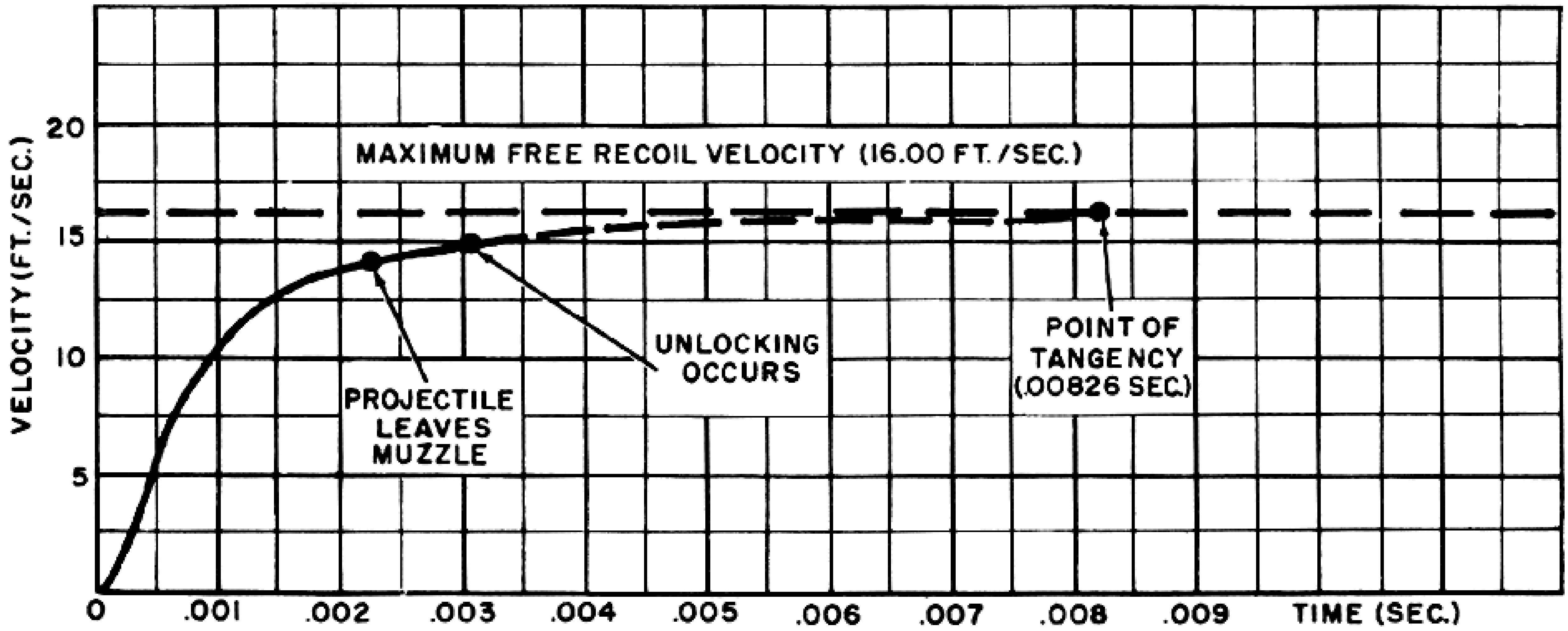


Figure 3–21. Free Recoil Velocity Before Unlocking.

and a portion of the powder gases then are no longer part of the recoiling system. Since the effect of the residual pressure can not be expressed in simple terms, a special method is used to extend the curve obtained by using equation 3–16 and fig. 3–8. This method is based on the fact that the results of experimental firings of various guns show that the maximum velocity of free recoil may be closely approximated as:

$$V_{r_f}=\frac{W_pV_p+4700\ W_c}{W_r} \tag{3–17}$$

This relationship is equivalent to saying that the maximum momentum imparted to the recoiling parts is equal to the sum of the muzzle momentum of the projectile and the momentum of the powder gases, assuming that the powder gases leave the gun at an average velocity of 4700 feet per second.

Although equation 3–17 gives a good approximation of the maximum free recoil velocity for most ordinary guns, it does not take into consideration the retarding effect of the total impulse produced by the particular gas mechanism assumed for this design. It is therefore necessary to subtract the velocity change produced by this impulse from the right side of the equation as follows:

$$V_{r_f}=\frac{W_pV_p+4700\ W_c}{W_r}-\frac{I}{M_r} \tag{3–18}$$

$$=\frac{W_pV_p+4700\ W_c-I_g}{W_r}$$

where it is assumed that the piston mass is negligible when compared with the total weight of the recoiling parts. The assumed curve of fig. 3–8 shows that the total piston impulse is equal to 5.13 pound seconds. Evaluating equation 3–18 for the gun of the example gives:

$$V_{r_f}=\frac{.29\times2750\times4700\times.070-5.13\times32.2}{60}$$

$$=16.00\left(\frac{\text{ft.}}{\text{sec.}}\right)$$

A line representing this value of the maximum velocity of free recoil is drawn on the velocity graph (fig. 3–21) and the curve previously drawn from equation 3–16 and fig. 3–8 is extrapolated until it becomes tangent to the line. The point at which the curve becomes tangent represents the time at which the residual pressure becomes zero and therefore imparts no further velocity to the recoiling parts. Although an error in locating the exact point of tangency will not have any serious effect on the accuracy of the results, it may be of some assistance in drawing the curve to determine this point by using Vallier's formula for approximating the duration of the residual pressure:

$$T_{res}=\frac{M_c}{AP}\,(9400-V_p) \tag{3–19}$$

For the sample cartridge and barrel:

$$T_{res}=\frac{.070}{32.2\times\frac{\pi}{4}\left(.790\right)^2\times5000}$$

$$(9400-2750)=.00592\ (\text{sec.})$$

To obtain the total time of action of the powder gases, this value is added to the time at which the projectile leaves the muzzle:

$$T_{res} = .00234 + .00592 = .00826 \text{ (sec.)}$$

Extending the original curve until it is tangent to the maximum free recoil velocity line at this point gives the complete free recoil velocity curve shown in fig. 3–21. Actually only a portion of the curve shown in the figure applies to the recoil conditions in a gas-operated gun because unlocking occurs before the residual pressure has become zero. It also must be remembered that the curve obtained by the preceding method must be checked after the actual piston impulse curve is obtained.

2. *Effect of blowback before piston strikes bolt and computation of unlocking time*

The next point for consideration is the effect on the bolt velocity of the blowback action which occurs between the time that the bolt is unlocked and the time that the piston strikes the bolt to speed it rearward. As pointed out in the analysis of gas operation, the ideal condition for this portion of the blowback action is that the bolt should move 0.250 inch with respect to the barrel by the time that the residual pressure has dropped to the safe limit of 750 pounds per square inch. (These figures are based on assumed safe values for a typical 20-mm cartridge and should be checked experimentally for any specific cartridge.)

For purposes of determining the blowback effect, it is only necessary to consider the velocity of the bolt with respect to the gun. For this determination, it is necessary to know the bolt weight. It will be assumed here that the bolt weight, as estimated from the preliminary design layout, is equal to 5 pounds. After the bolt is unlocked, the residual pressure continues to act on the bolt, but since the bolt is now free of the gun, the recoil force exerted on the gun by the residual pressure is reduced to a negligible value. (The gases expanding at the muzzle do exert some force on the muzzle face of the barrel, but in the absence of a gas trap, such as exists when a muzzle booster is used, the impulse applied to the muzzle face represents a very small portion of the total impulse resulting from the residual pressure.)

Fig. 3–10, which is a graph of the residual pressure versus time for the sample gun, shows that the residual pressure reaches 750 pounds per square inch at 0.005 second. The problem is to decide how long before this point the bolt should be unlocked so that its motion with respect to the barrel will be 0.250 inch at 0.005 second. This problem can be solved using the data in fig. 3–22. This curve is plotted by the same method used for the curve in fig. 3–21 except that the effect of the piston impulse is not included. In other words, this curve represents the free recoil velocity that would be imparted if there were no gas cylinder. If the ordinates of the velocity curve in fig. 3–22 are multiplied by the mass of the recoiling parts, the resulting curve (fig. 3–23) will show the im-

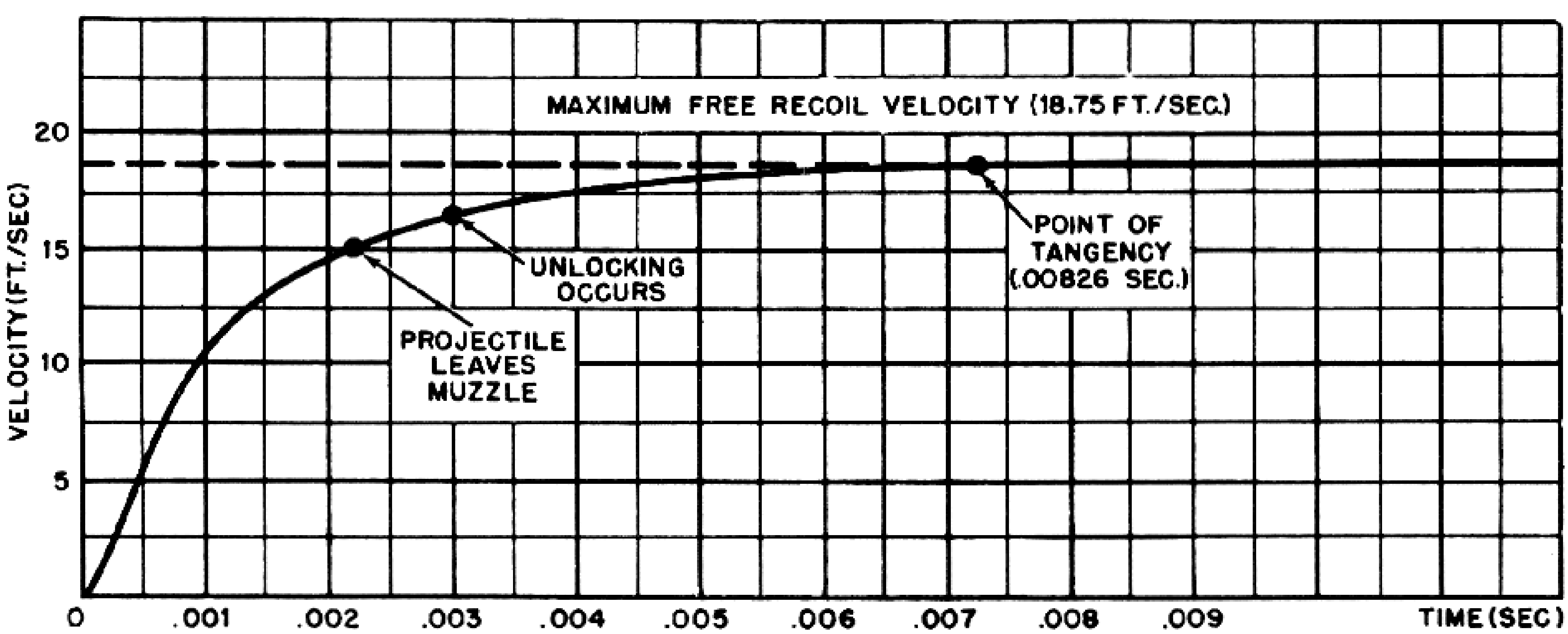


Figure 3–22. Free Recoil Velocity (With No Gas Cylinder).

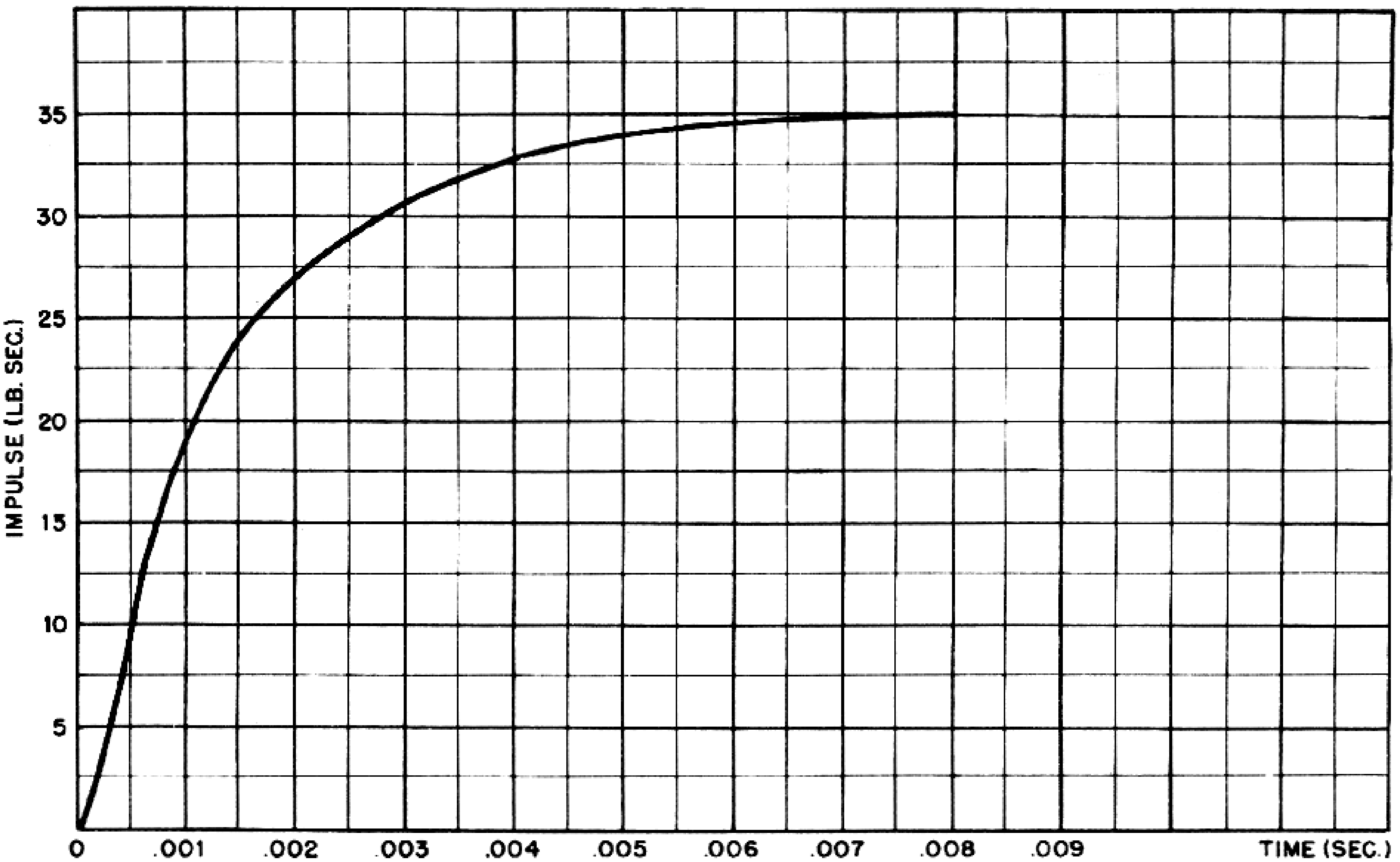


Figure 3–23. Impulse of Chamber Pressure.

pulse imparted up to any instant by the action of the chamber pressure. (That this is true may be seen by recalling the basic relation, I=MV.) The reason for using the special curve of fig. 3–19 to determine the impulse is that only the chamber pressure acts on the bolt. Since the piston impulse is applied only to the gun, it should not enter into the calculations for the blowback action.

Now, after unlocking occurs, the impulse shown by fig. 3–23 will be applied almost entirely in changing the velocity of the bolt. Therefore it is possible to divide each ordinate of the impulse curve by the bolt mass to obtain the new curve shown in fig. 3–24. (Only a portion of the vertical scale is shown in order to produce the significant portion of the curve in a large size.) The actual velocity values shown by this curve are meaningless but between any two values of time the curve does show what *change* in bolt velocity would be produced by the impulse.

Having the curve of fig. 3–24, it is only necessary to determine where to place the zero velocity axis so that the area between this axis and the curve up to 0.005 second is equal to 0.250 inch or 0.0208 foot. (Since this is a velocity-time graph, areas under the curve represent displacement.) The zero axis can be located quite simply by drawing a line along the 0.005-second ordinate and measuring the area between the line and the curve, taking the elements of area as shown in the figure and working downward until the area is 0.0208 foot. The abscissa of the point where the line bounding the lower limit of this curve intersects the curve is the required time of unlocking (0.00307 second). Ordinates measured above this line are equal to the free recoil velocity with respect to the barrel imparted to the bolt by blowback. The curve shows that the gain in free bolt velocity between the time of unlocking and 0.005 second is 18.2 feet per second.

It should be noted that although this computation neglects the effect of the bolt driving spring on the 0.250-inch travel, the resulting error is extremely small and entirely insignificant.

The data shown in fig. 3–24 are used later in the computations for completing the bolt motion curves up to 0.005 second. The manner in which the data

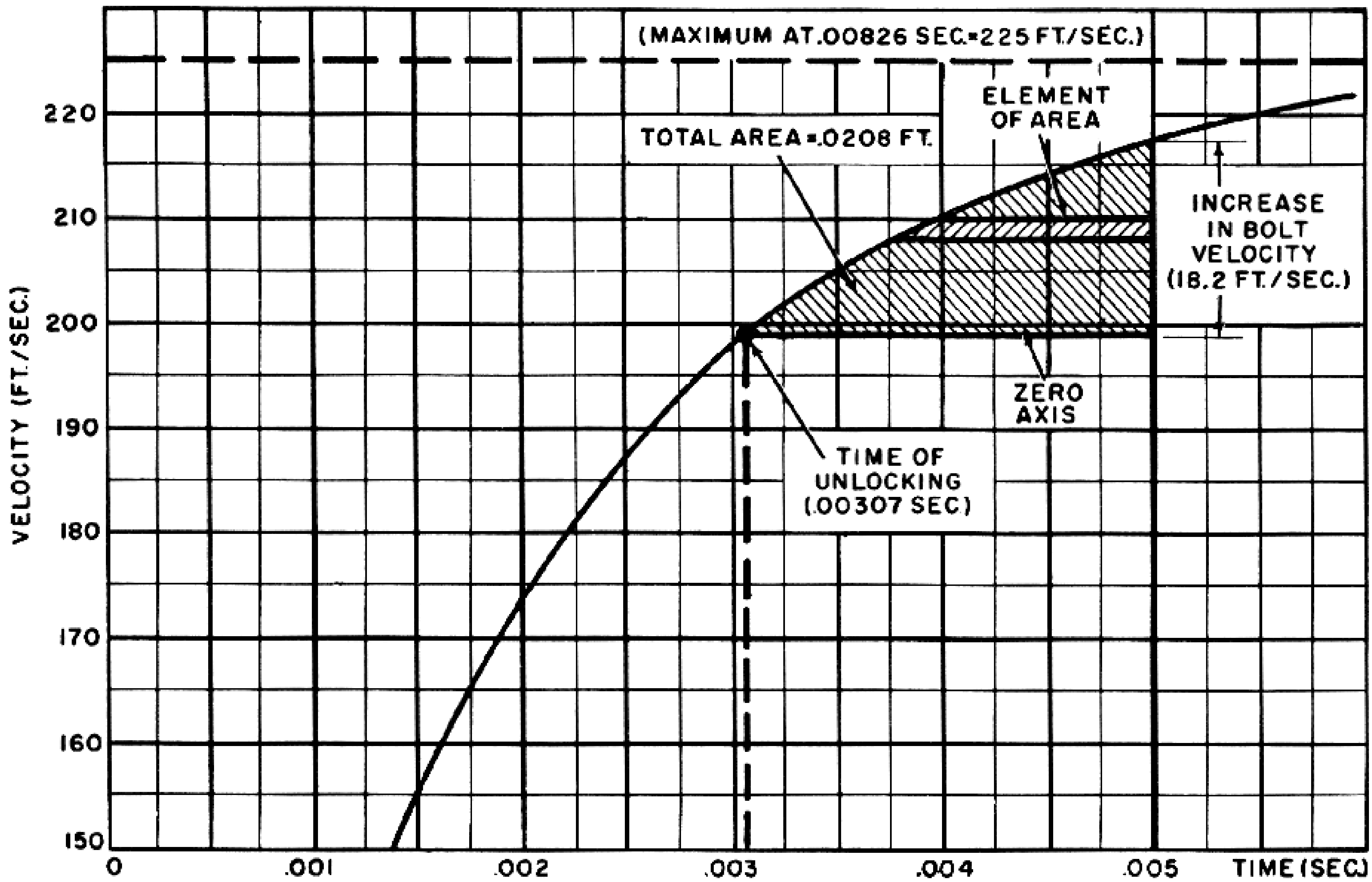


Figure 3–24. Changes in Bolt Velocity Imparted by Blowback and Determination of Time for Unlocking.

are used is explained later in connection with plotting the theoretical time-travel and time-velocity curves for the interval before the piston strikes the bolt.

3. *Selection of barrel spring characteristics and determination of counter-recoil velocity*

Having determined the free recoil condition, the effect of blowback, and the unlocking time, the next step in the analysis is to select the characteristics of the barrel spring and to determine the counter-recoil velocity possessed by the gun at the instant it is fired just before reaching the battery position (advanced primer ignition).

In order to make use of advanced primer ignition it is necessary to select the barrel spring characteristics carefully to insure proper timing of the counter-recoil motion of the gun. If the spring is too strong, the gun will reach the firing position too early and will be stopped by the mechanical buffer before the bolt can return, with the result that the advanced primer ignition effect will be lost. If the spring is too weak, the barrel will return too slowly, thus reducing the rate of fire. Within reasonable limits, however, the choice of the spring characteristics is not absolutely critical because the timing can be modified slightly by adjusting the length of the recoil movement.

The required spring characteristics are determined as follows: A reasonable recoil travel for the gun is approximately 1.5 inches or 0.125 foot. Allowing for the fact that the gun is fired a short distance before it reaches battery, the counter-recoil travel before firing will be taken as 0.100 foot. At a rate of fire of 1200 rounds per minute, the time available for the gun to move through this distance in counter-recoil is somewhat more than half the cycle time or approximately 0.030 second. Therefore the average velocity of counter-recoil must be:

$$V_{av}=\frac{D}{t}=\frac{.100}{.030}=3.33\left(\frac{\text{ft.}}{\text{sec.}}\right)$$

Under the action of the spring, the counter-recoil velocity will not change at exactly a constant rate and hence the average velocity of counter-recoil will be slightly greater than half the maximum velocity (say 60 per cent):

$$V_{max}=\frac{V_{av}}{.60}=\frac{3.33}{.60}=5.54\left(\frac{\text{ft.}}{\text{sec.}}\right)$$

This means that the final kinetic energy of the gun is:

$$KE=\frac{1}{2}MV^2=\frac{1}{2}\times\frac{55}{32.2}\times 5.54^2=26.2 \text{ (ft. lb.)}$$

Practically all of this energy must be supplied by the expansion of the barrel spring. To produce this amount of energy by expanding over a distance of 0.100 foot, the spring must exert an average force of:

$$F_{av}=\frac{KE}{d}=\frac{26.2}{.100}=262 \text{ (lb.)}$$

Actually, if the spring losses were taken into account, the average force required to compress the spring would be slightly higher than this value. For purposes of this analysis, the effect of the losses will be taken into account by adding 30 pounds (approximately 10 per cent) and it will be assumed that 292 pounds is the average force for compression of the spring. To produce this average force, the initial compression may be taken as 200 pounds and the force at a 0.125-foot deflection as 384 pounds. This requires a spring constant of:

$$K=\frac{384-200}{.125}=1472\left(\frac{\text{lb.}}{\text{ft.}}\right), \text{ or } \frac{1472}{12}=122.5\left(\frac{\text{lb.}}{\text{in.}}\right)$$

In the preceding calculations used for arriving at the spring characteristics, it was determined that the velocity with which the gun reaches the firing position is 5.54 feet per second. However, when the bolt strikes the barrel and locks to it the resulting impact will cause this velocity to increase. Since no information is yet available concerning the actual velocities of the gun and bolt at the instant of impact, it will be estimated for the present that the velocity increase is one foot per second and therefore that the gun will reach the firing position with a velocity of 6.54 feet per second. When the cartridge in the chamber is fired, the impulse exerted by the propellant explosion must first cancel this velocity before the gun will start to move to the rear in recoil.

4. *Effect of using advanced primer ignition on free recoil before unlocking occurs*

The free recoil velocity curve given in fig. 3–21 shows the velocity which would be produced in the recoiling parts if the gun were not moving at the instant of firing. Another way of looking at this curve is that, starting with zero velocity, it shows the change in velocity produced by the impulse of the propellant explosion. This same *change* in velocity would be produced, regardless of what velocity the gun possesses at the instant of firing. Since it has been determined that the gun is moving at a forward (negative) velocity of 6.54 feet per second when it is fired, its velocity at any instant after firing can be determined by simply drawing the same curve, starting at a velocity of —6.54 feet per second instead of from zero velocity. This has been done to produce the curve shown in fig. 3–25. Note that the negative velocity of the gun decreases to zero at 0.00058 second indicating that at this instant the forward motion of the gun is halted. The gun is then driven to the rear (velocity positive).

It is important to point out that the final free recoil velocity attained at the instant of unlocking is now much less than the final velocity that would have been attained if the gun were not moving when fired. This effect of using advanced primer ignition is highly advantageous because the reduction in recoil velocity results in a greatly reduced energy in the recoiling parts, thus simplifying the design of the recoil mechanism and permitting a lower trunnion reaction.

5. *Theoretical time-travel and time-velocity curves before unlocking occurs*

Because of the complexities resulting from the multiplicity of actions during the recoil and counter-recoil movements in a gas-operated gun, it is not practical to attempt to derive analytically, expressions for the time to recoil and time to counter-recoil. Also, such derivations would be extremely complicated unless it is assumed that the initial kinetic energy is transferred instantaneously to the recoiling parts, ignoring the detailed effects which occur during the action of the powder gas pressures. However, in high-rate-of-fire guns employing the gas system of operation, the time of action of the powder gas pressures is extremely significant and must be given due consideration in plotting the bolt motion

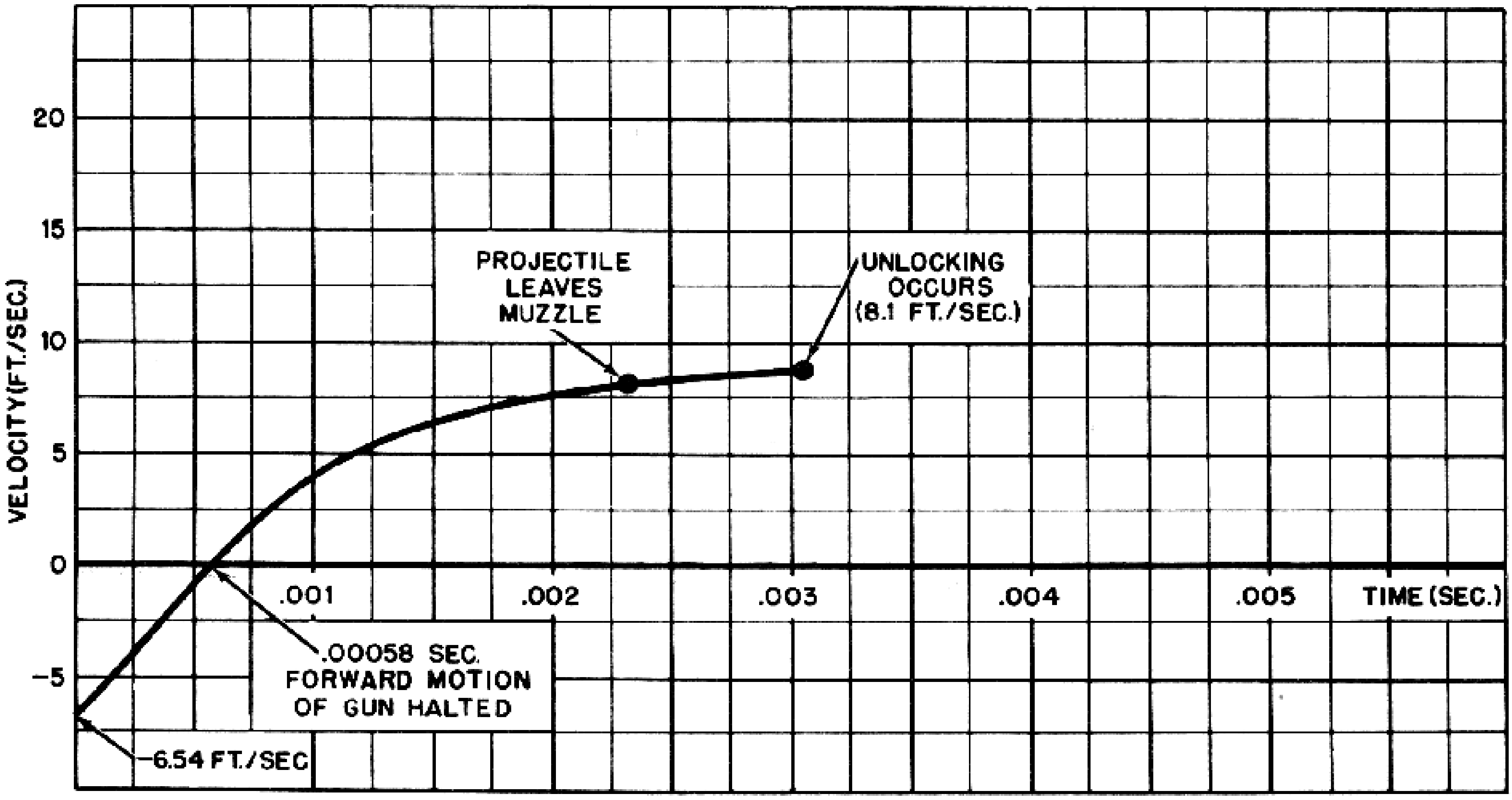


Figure 3–25. Free Recoil Velocity Before Unlocking (With Advanced Primer Ignition).

curves. A detailed analysis of this type is particularly important because most of the critical actions and high accelerations occur during the progress of the propellant explosion and it is therefore highly desirable to determine what motion characteristics may be expected in the initial portion of the operating cycle.

Since the effects of the powder gases can not be expressed by simple equations, a special method is employed to account for these effects in plotting the bolt motion curves. The method consists essentially of first plotting a curve of free recoil velocity against time and then subtracting from each ordinate of this curve the velocity loss resulting from the retarding effects of the springs.

The curve showing the velocity of free recoil versus time for the time interval before unlocking was developed previously and is shown in fig. 3–25. This curve will be used to illustrate the following description of the method.

To determine the retarding effects of the springs, use is made of the law expressed by the equation:

(3–20) $$Fdt=Mdv$$

This law states that the change in the momentum of a mass is equal to the applied impulse (the product of the force and the time for which it is applied). Solving for dv gives:

$$dv=\frac{Fdt}{M}$$

To obtain the variation of the change in velocity with respect to time, this expression is integrated.

(3–21) $$v=\int_0^t \frac{Fdt}{M}=\frac{1}{M}\int_0^t Fdt$$

In accordance with equation 3–21, the retarding effect of a force on a given mass can be determined as follows:

1. Plot a curve showing the variation of the force with respect to time.
2. Measure the area under the curve between $t=0$ and some time t_1.
3. Divide the measured area by the mass. This gives the ordinate of the retardation curve for the time t_1.
4. Repeat steps 2 and 3 for other values of t and plot the retardation curve.

Applying this procedure using the mass of the recoiling parts and the resistance of the barrel spring produces a curve showing the loss in recoil velocity resulting from the action of the spring up to the time of unlocking. Since the free recoil velocity curve shows the gain in velocity resulting from the thrust of the powder gases, the difference between the curves will be the net recoil velocity, or in other words the velocity of retarded recoil.

The foregoing method would be very simple if the retarding force were constant or if the variation of this force with respect to time were known. However, when the force varies with recoil travel as it does with the type of spring assumed for purposes of this analysis, a difficulty is encountered. In order to plot a graph showing the variation of the retarding force with respect to time, it is necessary to have a curve showing the variation of the recoil travel wtih respect to time, and the latter curve is one of those which yet remain to be determined.

This difficulty can be overcome by employing a process of successive approximation. While the powder gas pressures are acting, the loss in velocity resulting from the retarding effect of the spring will be relatively small and will be almost entirely due to the constant effect of the initial compression. The varying force due to the spring constant during this interval of time will almost certainly be negligible but, if necessary, it can be approximated very closely.

The procedure for plotting the velocity and travel curves for the time before unlocking occurs is as follows:

1. Plot the curve of free recoil velocity versus time (fig. 3–26).
2. The loss in velocity due to the initial compression of the barrel spring is equal to:

$$\frac{F_{o_1}t}{M_r}$$

   Determine the velocity loss for various values of t, subtract each from the corresponding ordinate of the free recoil velocity curve and draw a curve through the resulting points. If the effect of the spring constant proves to be negligible, this curve is the retarded velocity curve.
3. Integrate under the curve drawn in step 2 to obtain the displacement curve.
4. Assume that the curve drawn in step 3 represents the actual time-travel curve and use this curve to determine the retardation due to the spring constant. Ordinarily, it will be found that this retardation is so small that it will not have any effect worthy of consideration for the interval before unlocking.
5. In the event that the retardation determined in step 4 is sufficient to affect the velocity, use it to modify the curve drawn in step 2 and then integrate under the new curve to obtain a corrected displacement curve.
6. Steps 4 and 5 can be repeated as often as is necessary until no significant change occurs in the displacement curve. Actually, this process of successive approximation should never be necessary and satisfactory result should be obtained in the first three steps or at least in the first five steps.

Fig. 3–26 shows the curves obtained for the gun of the example for the interval before unlocking. The total loss in velocity due to the initial compression of the barrel spring during this interval (0.00058 to 0.00307 second) is:

$$v=\frac{F_{o_1}t}{M_r}=\frac{200\times.00249\times32.2}{60}$$
$$=.268\left(\frac{\text{ft.}}{\text{sec.}}\right)$$

The loss due to the effect of the spring constant as determined by the method of step 4 is only about 0.013 foot per second. The final curves shown in fig. 3–26 are the result of performing step 3. Since the velocity loss due to the effect of the spring constant is so small, step 5 need not be taken. The curves show that the velocity at the instant of unlocking is 7.9 feet per second and that at this instant the gun has travelled 0.01492 foot in recoil (0.179 inch).

6. *Theoretical time-travel and time-velocity curves after unlocking and selection of bolt driving spring characteristics*

After unlocking occurs, the gun and bolt are essentially independent of each other, except for the relatively small interaction between them through the bolt driving spring. Since the bolt is unlocked, the gun itself is no longer affected appreciably by the pressure of the powder gases and therefore its free recoil characteristic is to continue moving at the same velocity it had at the instant of unlocking. This is indicated in fig. 3–27 by the fact that the free gun velocity curve after unlocking is a horizontal line. The free bolt velocity curve of fig. 3–27 is obtained from the data shown in fig. 3–24 by adding to the ordinates of the free gun velocity curve, the

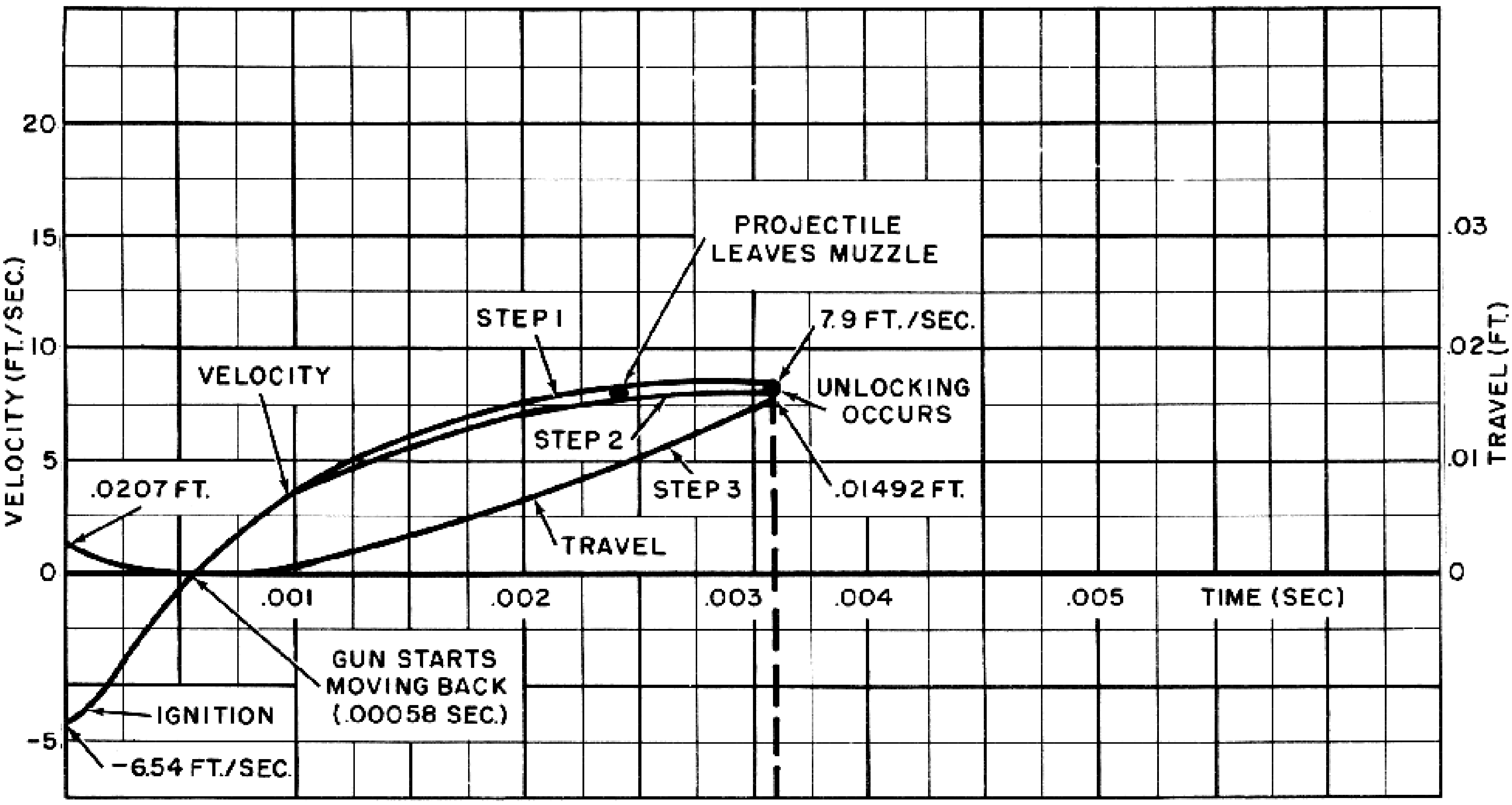


Figure 3–26. Development of Time-Travel and Time-Velocity Curves for Period Before Unlocking.

corresponding ordinates of the curve in fig. 3–24, measuring these ordinates above the zero axis.

Before proceeding, it is necessary to select the characteristics of the bolt driving spring. Since the only purpose of the bolt driving spring is to assist the return of the bolt to the battery position, and since this spring is not required to absorb all of the bolt recoil energy, the magnitude of the force exerted by the driving spring is not critical in the design. For this reason, the characteristics of the spring may be selected more or less arbitrarily. In order to permit a high rate of fire, the spring should be made relatively light so that it will not offer a high retardation to the recoil movement of the five-pound bolt, but on the other hand, the spring should be heavy enough to provide adequate force for assisting the closing of the bolt. Taking both of these requirements into consideration, it appears reasonable that an initial compression of 25 pounds and a spring constant of 10 pounds per inch should produce the desired action. If it is assumed that the bolt must open 10 inches to permit feeding, the maximum force exerted by the spring will be 125 pounds. This is a reasonable value and is not high enough to cause excessive difficulty in charging the weapon.

In the analysis of the motions after unlocking. two factors must be taken into consideration. First at the instant of unlocking, the barrel spring has been compressed 0.01492 foot (fig. 3–26). This means that from the time of unlocking on, the initial compression of the spring must be increased by the effect of its spring constant for this deflection. That is:

$$F_{o_1}=200+.01492\times 122.5\times 12=200+22=222(\text{lb.})$$

Second, it should be realized that after the bolt is unlocked, the force of the bolt driving spring exerts a rearward thrust on the gun. Although this force is relatively small at first, it should be taken into account by subtracting the initial compression of the driving spring from that of the barrel spring and subtracting the effect of the spring constant of the driving spring from that of the barrel spring. It should also be remembered that the movement which must be considered in determining the force produced by the bolt driving spring is the relative travel between the bolt and gun.

Except for the differences noted in the preceding paragraph, the retarding effects of the barrel spring and bolt driving spring are determined by the same

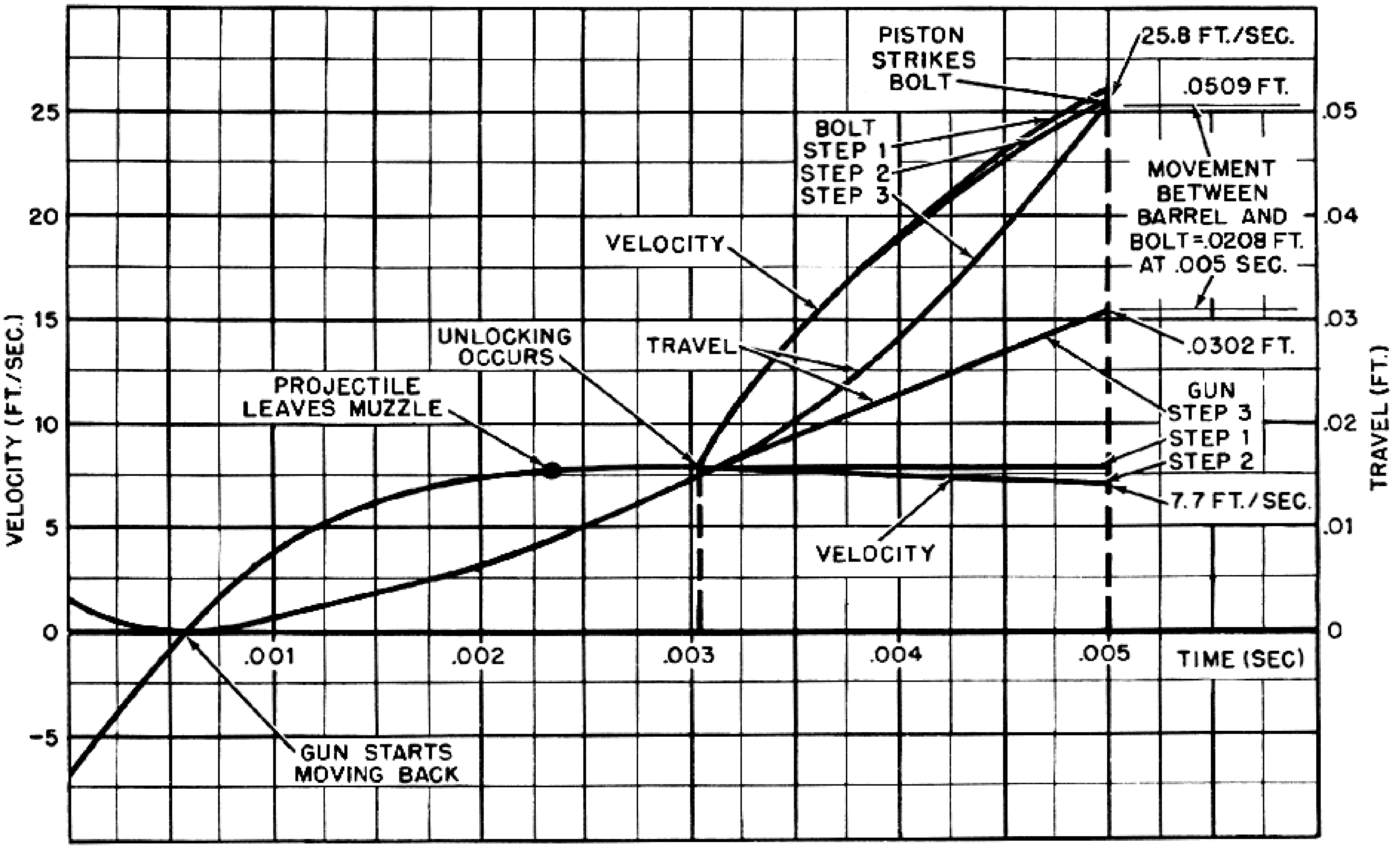


Figure 3–27. Development of Time-Travel and Time-Velocity Curves for Period Between Unlocking and Impact of Piston on Bolt.

general method as used before unlocking. The total loss in gun velocity due to the corrected initial compression of the barrel spring during the interval between unlocking at 0.00307 second and the impact of the piston on the bolt at 0.005 second (an interval of .005—.00307=0.00193 second) is:

$$V=\frac{F_o}{M_1}t=\frac{(222-25)\times32.2\times.00193}{55}=.223\left(\frac{\text{ft.}}{\text{sec.}}\right)$$

The loss due to the combined effects of the spring constants as determined by the methods of step 4 modified to account for the difference described in the preceding paragraph is only about 0.0446 foot per second. The final gun motion curves shown in fig. 3–27 are the result of performing steps 2 and 3. Since the velocity loss due to the effect of the spring constants is so small, it is not necessary to take step 5.

The retarding effect of the bolt driving spring is found as follows: Step 2 is performed to determine the bolt velocity loss due to the effect of the initial compression. The total loss between the instant of unlocking and the instant the piston strikes the bolt is:

$$V=\frac{F_{o_2}}{M_2}t=\frac{25\times32.2\times.00193}{5}=.310\left(\frac{\text{ft.}}{\text{lb.}}\right)$$

Next step 3 is performed and then the relative movement between the gun and bolt is determined by subtracting the gun travel curve from the bolt travel curve. The relative movement curve can now be used to perform step 4. The loss found in this way is only about 0.012 foot per second. Since the velocity loss due to the effect of the spring constant is so small, it is not necessary to take step 5.

The final curves shown in fig. 3–27 indicate that at the instant the piston strikes the bolt, the bolt velocity is 25.8 feet per second and the velocity of the gun is 7.7 feet per second. The bolt has moved 0.0507 foot to the rear and the gun has moved 0.0302 foot. The relative movement is 0.0207 foot, or very close to the allowable movement of 0.0208 foot (0.250 inch).

7. Impact of piston on bolt

When the cycle of operation has progressed for 0.005 second, as described up to this point, the residual pressure has decreased to the assumed safe operating limit of 750 pounds per square inch and it is now possible to increase the velocity of the bolt without danger of rupture of the cartridge case. It should be noted that, at 0.005 second, the residual powder gas pressure has not yet reached zero and therefore some blowback action will occur during and after the impact of the piston.

The first point to consider is what bolt velocity is desired after impact in order to obtain the required rate of fire. For the specified rate of fire of 1200 rounds per minute, the time available for the bolt to complete its rearward travel is about 0.022 second (slightly less than half the cycle time). The required bolt travel with respect to the gun to provide an opening sufficient for feeding will be taken as 10 inches (0.833 foot). Since the gun recoils 1.5 inches or 0.125 foot, the total bolt travel is $.833+.125=.958$ foot. At 0.005 second the bolt has already moved 0.0507 foot and therefore the remaining travel of 0.907 foot must be accomplished in 0.017 second. This means that the bolt must move this distance at an average velocity of:

$$V_{av}=\frac{D}{t}=\frac{.907}{.017}=53.3\left(\frac{\text{ft.}}{\text{sec.}}\right)$$

The effect of the bolt driving spring on the bolt velocity can be estimated as follows: The initial compression of the spring at the instant of piston impact is equal to:

$$F_o{}'_2=F_{o2}+DK_2=25+.0207\times10\times12$$
$$=25+2.48=27.5\text{ (lb.)}$$

The force exerted by the spring at a 10-inch deflection is

$$F=25+10\times10=125\text{ (lb.)}$$

Therefore, the average force of the spring (taken with respect to time) over the 0.018 second required for completion of the bolt travel may be estimated roughly as:

$$\frac{125+27.5}{2}=81.2\text{ (lb.)}$$

(This estimate is not exact because the velocity of the movement will not be constant over the interval, but it is close enough for present purposes.) The velocity loss caused by the action of the driving spring can now be estimated by using the formula:

$$V=\frac{F_{av}xt}{M}=\frac{81.2\times.0170\times32.2}{5}=8.89\left(\frac{\text{ft.}}{\text{sec.}}\right)$$

It will be recalled that there will still be some blowback action after the bolt impact. As shown in fig. 3–24, the action of blowback after 0.005 second will increase the bolt velocity by approximately 7.5 feet per second. Therefore, the net loss of bolt velocity after impact will be the difference between the loss produced by the spring and the gain produced by the remaining blowback action or $8.89-7.5=1.4$ feet per second. Since the loss is approximately 1.4 feet per second and the desired average velocity is 53.3 feet per second, the velocity after the piston impact should be $53.3+1.4/2=54$ feet per second. To allow for the time of action of the backplate, this velocity will be taken as 55 feet per second.

The following data are now available for determining the conditions of piston impact:

Bolt weight, $W_2=5$ (lb.)

Initial bolt velocity, $V_2=25.8$ (ft./sec.)

Desired final bolt velocity $V'_2=55$ (ft./sec.)

Since the parts will be of steel, the coefficient of restitution, e, will be taken as 0.55. Using these data, computations are made by the same methods described in the analysis of gas operation. The equation expressing the relationship between the piston velocity V_1 and the piston weight W_1 is found as follows:

$$V'_2-V'_1=e(V_1-V_2)$$
$$55-V'_1=.55(V_1-25.8)$$
$$V'_1=69.2-.55V_1$$
$$W_1V_1+W_2V_2=W_1V'_1+W_2V'_2$$
$$W_1V_1+5\times25.8=W_1(69.2-.55V_1)+5\times55$$
$$V_1=\frac{94.2}{W_1}+44.6$$

Various values of V_1 and W_1 which satisfy this equation are listed in Table 3–2 and are also shown graphically in figs. 3–28 and 3–29. The other values shown in the table and graphs were found using the following formulas:

Velocity of piston after impact:

$$V'_1=69.2-.55V_1\text{ (ft./sec.)}$$

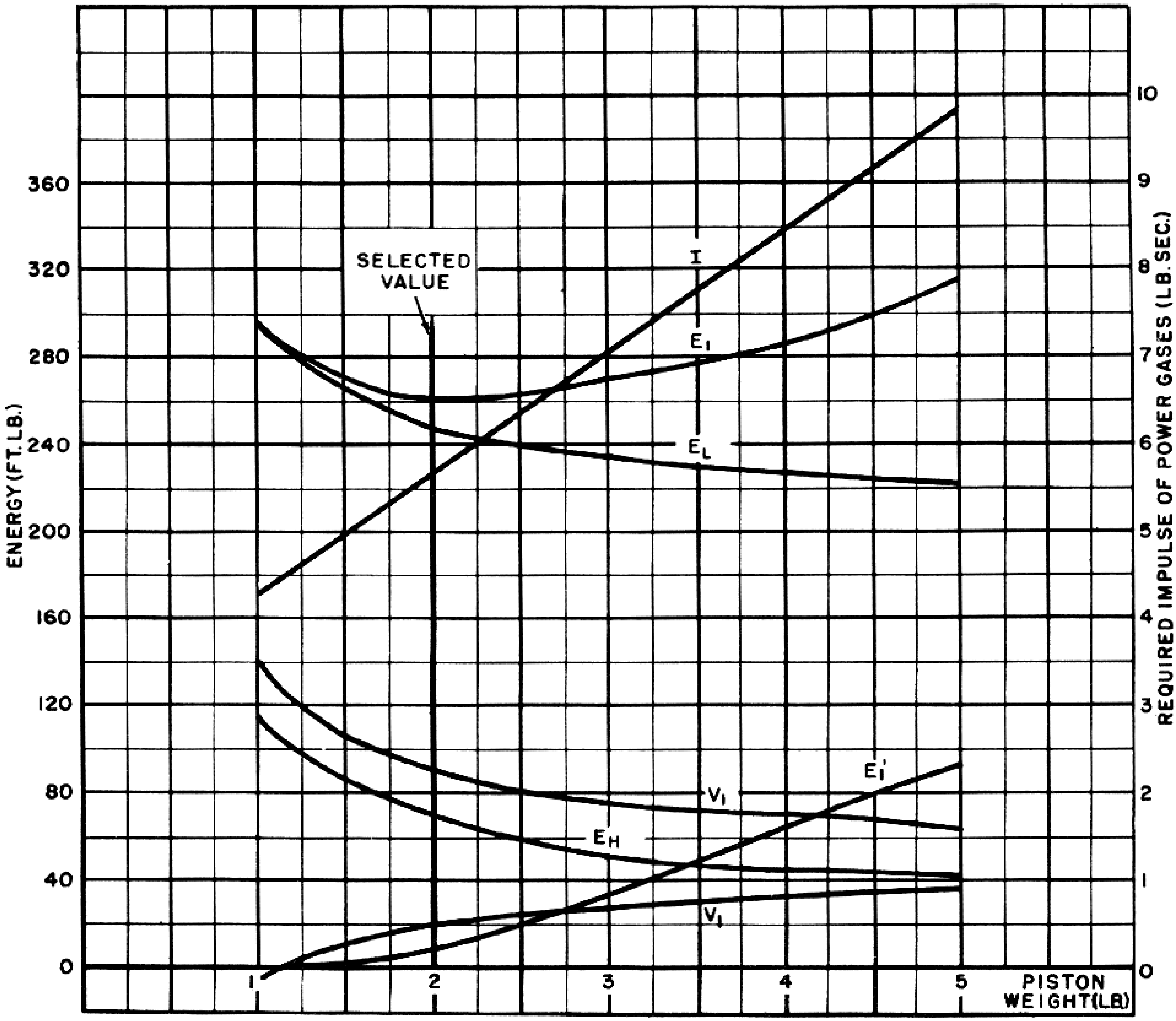


Figure 3–28. Factors Related to Selection of Piston Weight and Velocity in Gun of Example.

Energy lost by piston in impact:

$$E_L = \frac{W_1}{2g}(V_1^2 - V'^2_1) \quad \text{(ft. lb.)}$$

Initial piston energy:

$$E_1 = \frac{W_1}{2g} V_1^2 \quad \text{(ft. lb.)}$$

Final piston energy:

$$E'_1 = \frac{W_1}{2g} V'^2_1 \quad \text{(ft. lb)}$$

Impact loss (to heat):

$$E_H = E_L - E_G \quad \text{(ft. lb.)}$$

Required impulse:

$$I = M_1 V_1 \quad \text{(lb./sec.)}$$

The energy gained by the bolt is the same for all entries and is computed as follows:

$$E_G = \frac{W_2}{2g}(V'^2_1 - V_1^2) = \frac{5}{64.4}(55^2 - 25.2^2) = 182 \quad \text{(ft. lb.)}$$

Table 3–2. Values Related to Selection of Piston Weight

W_1	V_1	V'_1	E_L	E_1	E'_1	E_H	I
1.0	138.8	−7.1	298	299	0.76	116	4.31
1.5	107.4	10.1	267	269	2.37	85	5.00
2.0	91.7	18.2	251	261	10.3	69	5.70
2.5	82.3	23.9	241	263	22.1	59	6.38
3.0	76.0	27.4	234	269	35.0	52	7.07
4.0	68.1	31.7	226	289	62.4	44	8.45
5.0	63.4	34.3	221	312	91.3	39	9.85

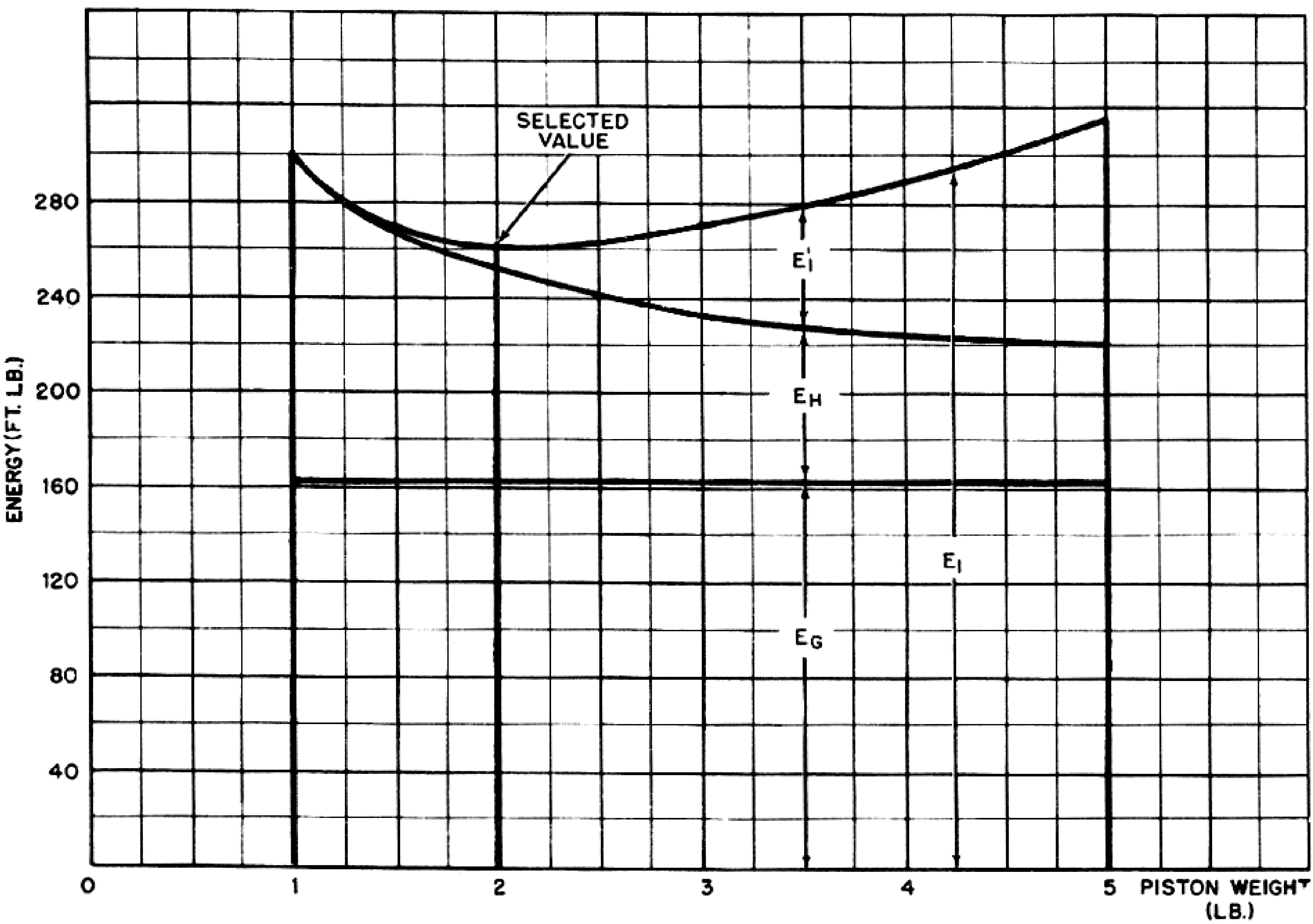


Figure 3–29. Distribution of Piston Energy for Various Piston Weights in Gun of Example.

Consideration of the values in Table 3–2 and of the graphs of figs. 3–28 and 3–29 indicate that a piston weight of 2.0 pounds is a reasonable choice. This choice is based on the same factors explained previously in the analysis of gas operation.

8. *Design of gas mechanism and analysis of piston motion*

Having determined the desired piston weight (2.0 pounds) and velocity (91.7 feet per second), the gas mechanism must be designed to produce this velocity. The design process consists essentially of determining the location of the gas port, selecting the orifice size, and establishing the piston area so that the impulse applied to the piston by the gas pressure will be of the correct value to produce the desired velocity. In the design, due allowance should be made for friction losses and for losses in piston energy resulting from operation of the unlocking device, but these losses will be neglected for purposes of this analysis.

As pointed out at the beginning of this mathematical analysis, the factors controlling the flow of the powder gases through the gas port and orifice into the gas cylinder can not be handled in a simple manner by direct computation. However, it is possible to analyze the piston motion and determine the necessary impulse on the basis of a conservative assumption of how the pressure will rise in the gas cylinder in the presence of an orifice with a reasonable throttling action. When the gun is actually developed, the actual orifice size required to produce the necessary impulse can be determined by experimental firings; starting first with a very small orifice and gradually increasing its size until the desired action is obtained.

As a starting point for the theoretical design, let the distance of the gas port be set so that the projectile will pass the port after a bore travel of 2.5 feet. As shown in fig. 3–19, this will occur at 0.00166 second. At this instant, the gun has acquired a recoil velocity of 6.4 feet per second (fig. 3–26). Since the piston moves in recoil with the gun, the piston has this initial velocity at the time the powder gas pressure starts to act on it. Fig. 3–30 shows a portion of the variation of the barrel pressure with respect to time and also shows a reasonable assumption of how the throttling effect of the orifice will affect the rise of pressure in the cylinder. The design must be arranged so that the pressure, acting between 0.00166 second and 0.005 second, will increase the piston velocity from its initial value of 6.4 feet per second to a final value of 91.7 feet per second.

The impulse of the gas cylinder pressure on a piston of unit area (one square inch) can be found by integrating under the pressure curve between limits of 0.00166 second and 0.005 second. This impulse is approximately 6.0 pound seconds. Now to increase the velocity of the piston (weight 2 pounds) from 6.4 to 91.7 feet per second requires an impulse of:

$$I = M(V'_1 - V_1) = \frac{2}{32.2}(91.7 - 6.4) = 5.3 \quad \text{(lb./sec.)}$$

This will require a piston area of:

$$A = \frac{5.3}{6.0} \times 1 = .884 \text{ (sq. in.)}$$

The piston diameter to produce this area is:

$$D = \sqrt{\frac{4A}{\pi}} = \sqrt{\frac{4 \times .884}{\pi}} = 1.06 \text{ (in.)}$$

This piston diameter is of reasonable size (only slightly larger than the gun bore diameter of 0.79 inch). It should also be noted that the impulse produced by the gas cylinder (5.3 pound-seconds) is sufficiently close to the impulse assumed tentatively in paragraph 1 (5.13 pound-seconds) that it will not be necessary to revise fig. 3–21.

On the basis of the pressure curve of fig. 3–30, it is now possible to determine the piston motion. Since the gun velocity changes during the interval between the start of the piston movement and the impact of the piston on the bolt, it is advisable to consider the absolute movement of the piston (with respect to the cradle). Multiplying each ordinate of the gas cylinder pressure curve by the area of the piston (0.884 square inch) would give the force on the piston at any instant. Dividing by the piston mass and integrating under the curve will give the change in piston velocity produced by the pressure. That is:

$$\Delta V = \int_{t_1}^{t_2} \frac{PA}{M}\, dt$$

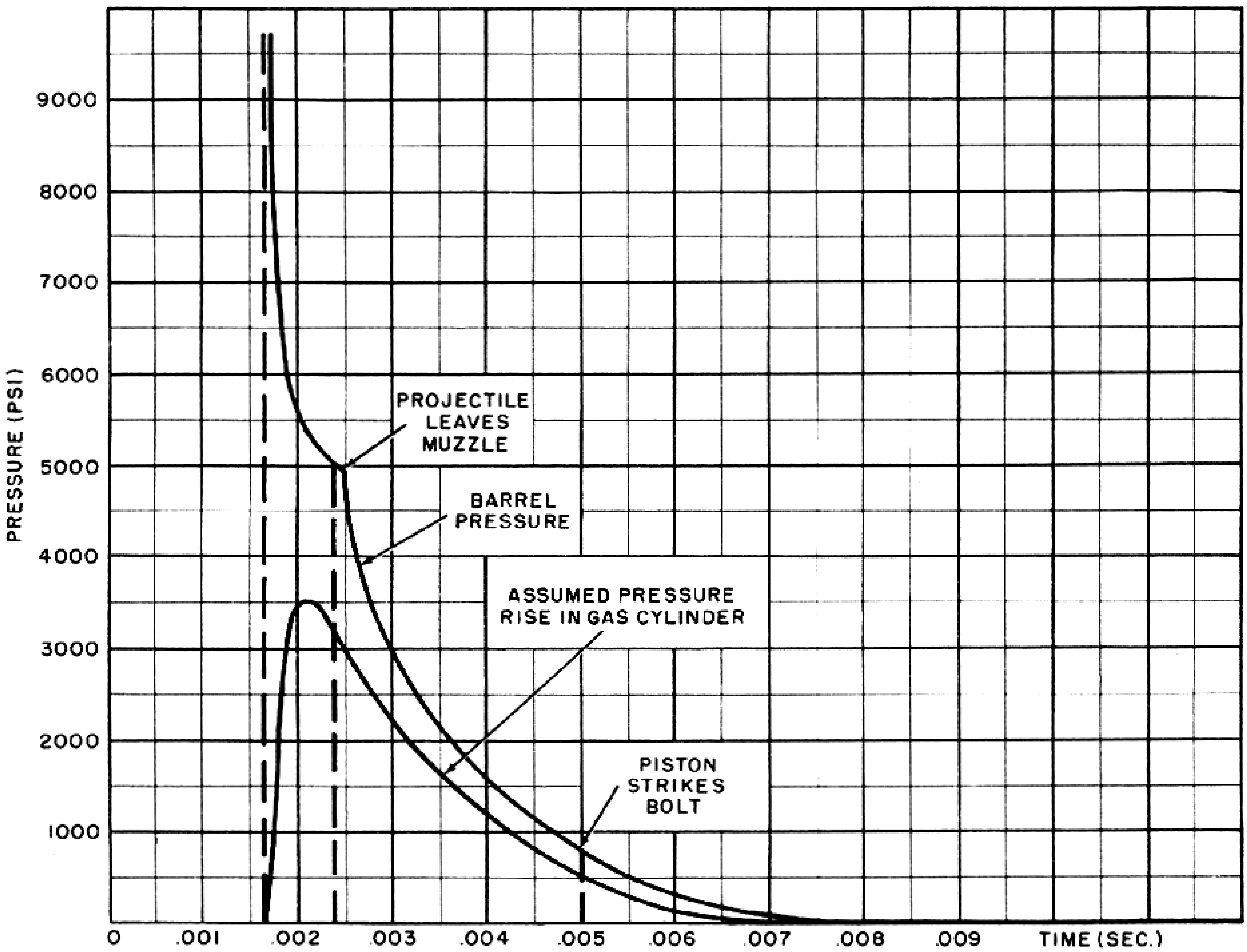


Figure 3–30. Assumed Pressure Rise in Gas Cylinder.

The velocity curve shown in fig. 3–31 is the result of performing this operation and adding the velocity changes so obtained to the initial velocity of 6.4 feet per second. The piston travel curve was obtained by integrating under the velocity curve. For convenient reference, the piston travel and bolt travel curves (obtained from fig. 3–27) are both drawn on the field of fig. 3–31. Comparing the relative movements shows that the free travel of the piston before actuating the unlocking device must be 0.036 foot or 0.432 inch (distance AB in fig. 3–11). The piston must then have an additional free travel of 0.132 foot or 1.504 inches before it strikes the bolt (distance BC in fig. 3–11). This free travel permits sufficient time for blowback to occur while the residual pressure is decreasing to a safe operating limit.

9. *Theoretical time-travel and time-velocity curves after piston impact*

In order to determine the theoretical time-travel and time-velocity curves after the impact of the piston, it is necessary to consider the gun motion and bolt motion simultaneously. As shown in fig. 3–27, the velocity of the gun at 0.005 second is 7.7 feet per second and from this instant on the free recoil velocity may be represented as a horizontal line. (See line designated as step 1 in fig. 3–32.) At 0.005 second the travel of the gun is 0.0302 foot and at this displacement the force of the barrel spring is:

$$F_{o_1}+K_1D=200+122.5\times 12\times .0302=244.5 \text{ (lb.)}$$

For purposes of determining the gun motion from 0.005 second on, this force of 244.5 pounds can be

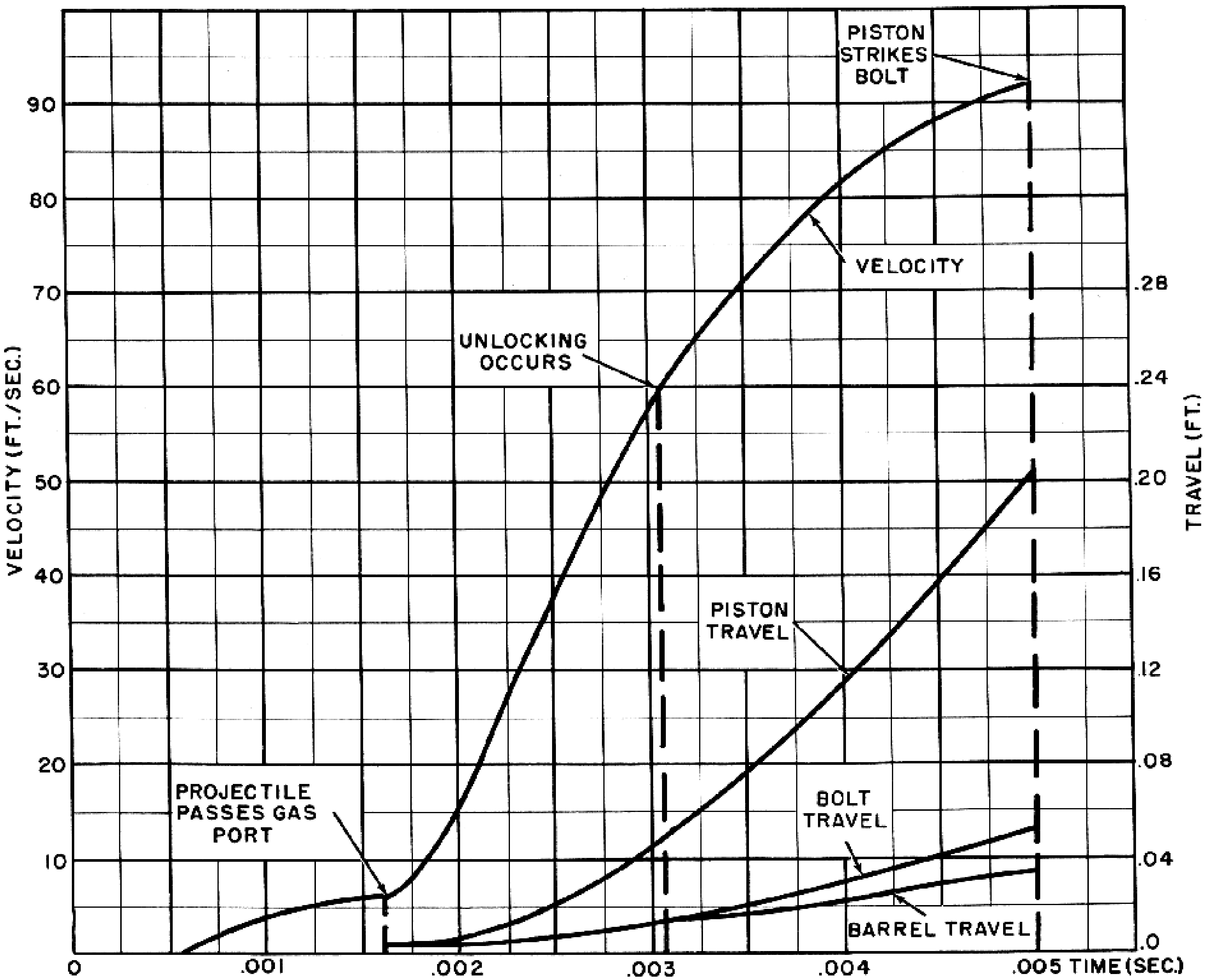


Figure 3–31. Time-Travel and Time-Velocity Curves for Piston Before Impact With Bolt.

considered to be the initial compression of the spring. However, since the bolt is free of the gun, the force of the bolt spring acts rearward on the gun and must be subtracted from the barrel spring force. At the instant of impact the bolt opening is 0.0208 foot. At this deflection, the force of the driving spring is:

$$F_{02}+K_2D=25+10\times 12\times .0208=27.5$$

Subtracting this force from the corrected initial compression of the barrel spring gives an effective initial compression of 217 pounds. The retarding effect of this force on the gun can be computed by the same methods used for developing the motion curves before piston impact. The velocity loss due to the initial compression will be:

$$V=\frac{F_o}{M}\,t=\frac{21.7\times 32.2}{55}\,t=127\,t$$

That is, the effect of the initial compression causes the gun recoil velocity to decrease at the rate of 127 feet per second. This loss is shown in fig. 3–32 by the curve designated as step 2 for the gun.

When the piston strikes the bolt, the bolt velocity will be increased from 25.8 feet per second to 55 feet per second. This action will occur practically instantaneously as shown in fig. 3–32 by the vertical line at 0.005 second. After the impact occurs, the

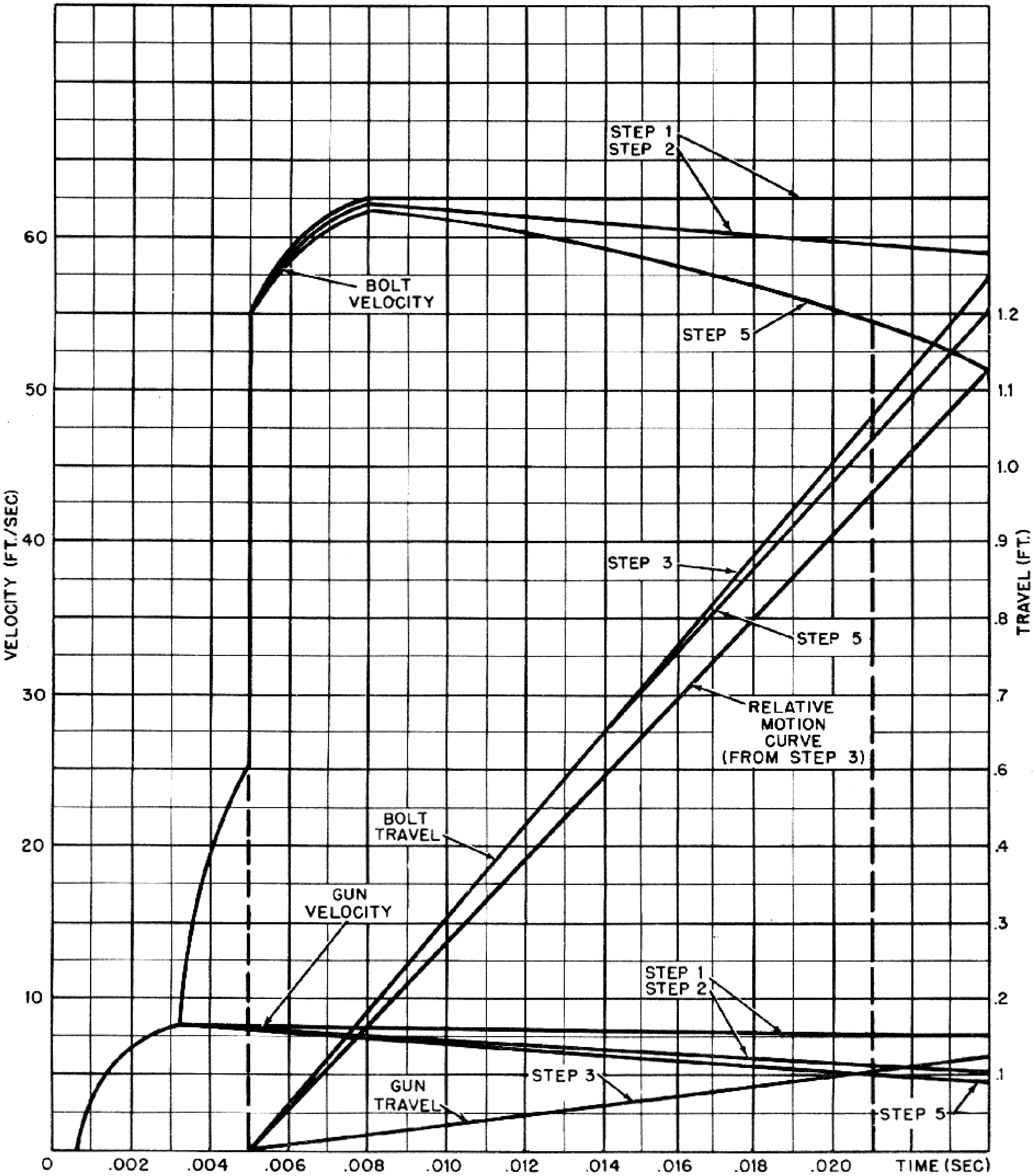


Figure 3–32. Effect of Bolt Driving Spring and Barrel Spring Up to Instant Bolt Strikes Backplate.

residual pressure still continues to act until 0.00826 second and imparts an additional free bolt velocity of 7.5 feet per second. (Cf. fig. 3–24.) This increase is shown by the curve designated as step 1 in fig. 3–33. Note that after the residual pressure has decreased to zero, the free recoil curve is a horizontal line, indicating that the bolt tends to continue moving of its own momentum at the maximum velocity of 62.5 feet per second.

At the instant of impact, the bolt has moved 0.0208 foot with respect to the gun and at this displacement, the force of the bolt driving spring is:

$$F_{o_2}+K_2D=25+10\times 12\times .0208-27.5 \text{ (lb.)}$$

For developing the bolt motion curves after the impact, this force of 27.5 pounds can be considered to be the initial compression of the spring and the retarding effect of the spring can be determined by methods similar to those used before the impact. The velocity loss due to the initial compression will be:

$$V-\frac{F_o}{M}t=\frac{27.5\times 32.2}{5}t=177\ t$$

That is, the effect of the initial compression causes the bolt velocity to decrease at the rate of 177 feet per second. This loss is shown in fig. 3–32 by the curve designated as step 2 for the bolt.

To determine the effect of the spring constants, allowance must be made for the time that the bolt is moving. The force exerted on the bolt and gun by the driving spring will therefore depend on the relative movement between the bolt and gun. The first step is to use the curves designated as step 2 to obtain a first approximation of the gun and bolt travels (curves designated as step 3 in fig. 3–32). The first approximation of the relative motion between the gun and bolt is obtained by subtracting the gun travel curve of step 3 from the bolt travel curve of step 3.

The effect of the springs on the gun is obtained by performing step 4 in a special way. First, the method of step 4 is applied using the spring constant for the barrel spring, the gun mass, and the barrel travel curve of step 3. This gives the loss in gun velocity due to the barrel spring. Second, the procedure is employed again using the spring constant for the bolt driving spring, the gun mass, and the relative travel curve. This gives the gain in gun velocity due to the

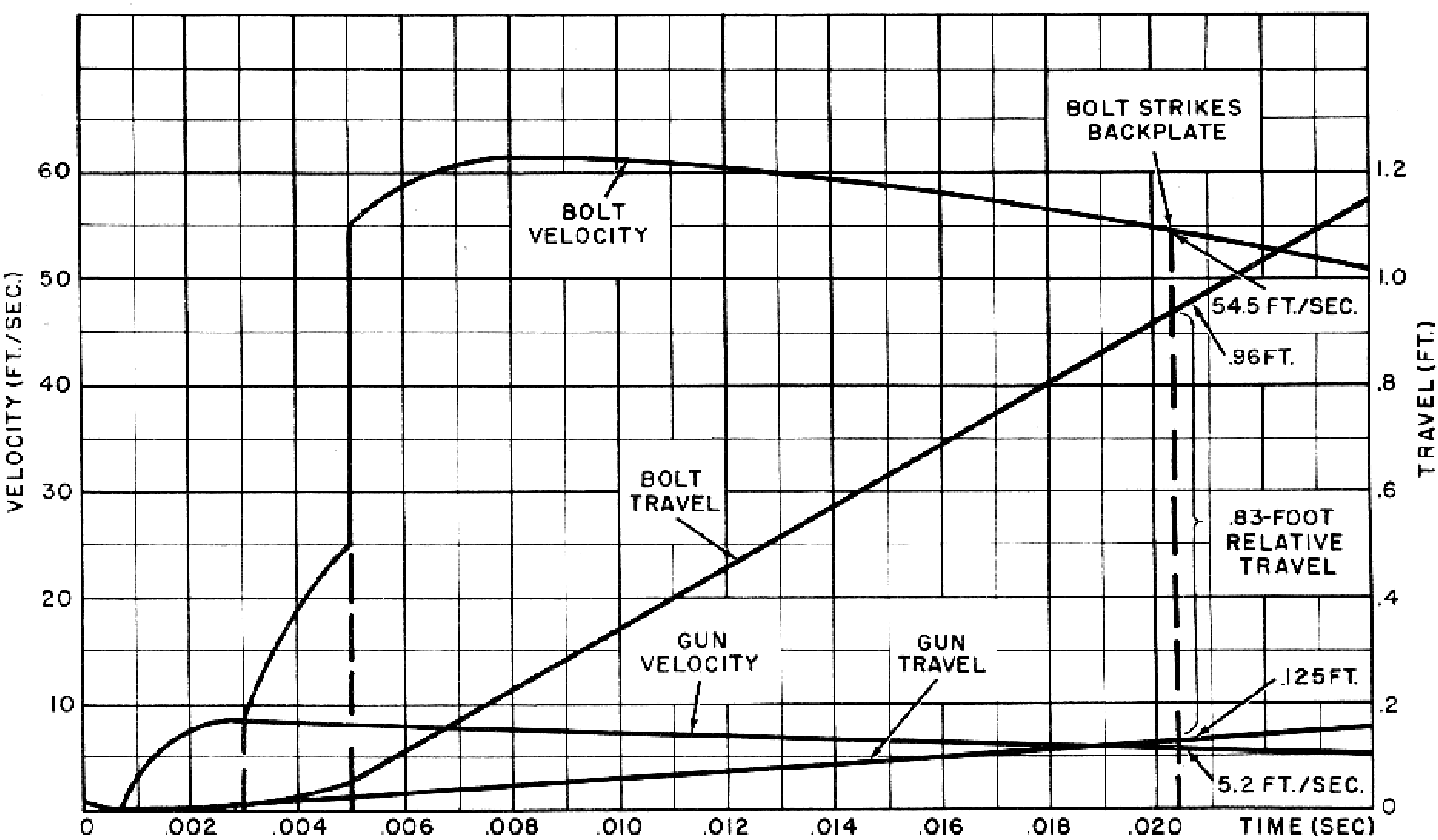


Figure 3–33. Time-Travel and Time-Velocity Curves for Gun and Bolt Up to Instant Bolt Strikes Backplate.

force of the bolt driving spring. The actual loss in gun velocity is obtained by subtracting the gain due to the bolt driving spring from the loss due to the barrel spring. This loss is subtracted from the gun velocity curve designated as step 3 to give the final velocity curve designated as step 5. Since the change in the velocity curve is so slight, it is not necessary to modify the gun travel curve and the curve designated as step 3 can be used as the final gun travel curve.

The effect of the spring constant of the bolt driving spring is obtained by using the relative travel curve in performing step 4 to obtain the bolt velocity curve indicated as step 5 in fig. 3–32. The final travel curve (also designated as step 5) is found by integrating under the velocity curve. Since the performance of step 6 produces a negligible change in the curves, the curves drawn in accordance with step 5 represent the effect of the driving spring on the bolt motion.

Fig. 3–33 shows the velocity curves for the bolt and gun and shows the travel curves obtained by adding the travels shown in fig. 3–32 to the bolt travel and gun travel at the instant of bolt impact (0.0509 for the bolt and 0.0305 for the gun). Having the final travel curves it is now possible to determine at what instant the bolt will reach the backplate. To strike the backplate, the bolt must move a distance of 10 inches (0.833 foot) with respect to the gun. Fig. 3–23 shows that this relative movement occurs at 0.021 second (which is close enough to the value of 0.022 second previously estimated). At the instant of contact, the recoil travel of the gun as shown in the figure is equal to 0.125 foot (which is equal to the 0.125-foot displacement estimated near the beginning of the analysis). Because of the good agreement obtained between the estimated and computed values, it will not be necessary to adjust any of the computations made up to this point in order to obtain the desired rate of fire and the required timing of the movements. Note that the velocity with which the bolt strikes the backplate is 54.5 feet per second and that the velocity of the gun at full recoil is 5.2 feet per second.

10. *Analysis of events at end of recoil*

The purpose of the backplate buffer is to reverse the bolt motion at the end of the recoil stroke with the minimum possible loss of time and energy. In the analysis of gas operation, it was pointed out that although the reversing action is accomplished almost instantaneously by causing the bolt to rebound from an extremely stiff elastic member, the impact is accompanied by a loss of energy with the result that the velocity of the bolt after impact will be at best approximately 60 per cent of its striking velocity.

Since the velocity of the bolt before striking the backplate is 54.5 feet per second, the momentum of the bolt is:

$$MV=\frac{5}{32.2}\times 54.5=8.45 \text{ (lb. sec.)}$$

Assuming that the coefficient of restitution of the backplate is 0.60, the velocity of the bolt after impact will be:

$$V=.60\times 54.5=32.7\left(\frac{\text{ft.}}{\text{sec.}}\right)$$

The momentum of the bolt will then be:

$$MV=\frac{5}{32.2}\times 32.7=5.09 \text{ (lb. sec.)}$$

Thus, in the reversing action of the backplate, the change in bolt momentum is equal to 8.45+5.09= 13.54 (lb. sec.). If the entire reversing action occurs in 0.001 second, the average force exerted on the backplate must be:

$$\frac{13.54}{.001}=13{,}540 \text{ (lb.)}$$

The striking energy of the bolt is:

$$KE=\frac{1}{2}MV^2=\frac{1}{2}\times\frac{5}{32.2}\times 54.5^2=230 \text{ (ft. lb.)}$$

If it is assumed for purposes of estimation that the backplate offers a constant resistance of 13,540 pounds, the deflection of the elastic member under the impact will be:

$$\frac{230}{13{,}540}=.0170 \text{ (ft.) or approximately } \tfrac{3}{16} \text{ (inch)}$$

The data derived above are used to complete the bolt motion curves for the 0.001-second interval assumed for the action of the backplate. The curves

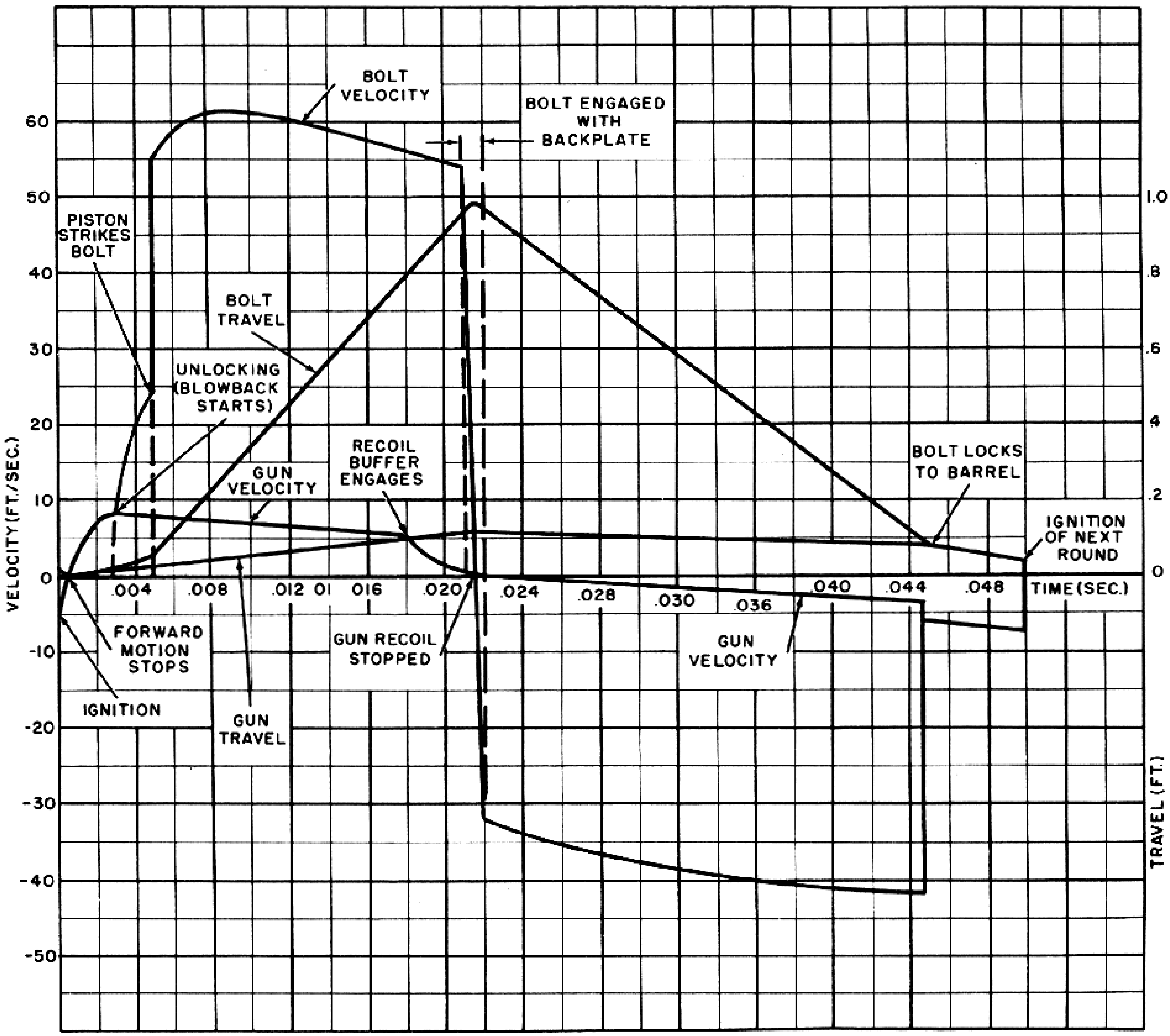


Figure 3–34. Complete Time-Travel and Time-Velocity Curves for Gas-Operated Gun.

are shown in fig. 3–34 which gives the theoretical time-travel and time-velocity curves for the complete cycle.

As explained in the analysis of gas operation, the gun motion must be controlled so that the gun recoil movement is halted just as the bolt strikes the backplate and proper buffer action must be provided so that the gun velocity will be kept low for a reasonable amount of time before and after the bolt impact. This arrangement is necessary in order to insure that slight variation in the instant at which impact occurs will not cause erratic rebound action. No attempt will be made here to design an actual buffer but it will be assumed that a hydraulic buffer is used to produce the velocity characteristic shown in fig. 3–34. Instead of permitting the gun to recoil the entire distance opposed only by the barrel spring as shown in fig. 3–33, the hydraulic buffer starts to act at 0.18 second and reduces the gun recoil velocity from 5.8 feet per second to zero at 0.0210 second. At this point a positive stop is engaged and therefore the impact of the bolt on the backplate does not impart any rearward velocity to the gun mass. (Note that for a considerable time interval on either side of the instant of bolt impact, the gun velocity is in the order of only one or two feet per second, which is very close to zero when compared to the bolt striking velocity of 54.5 feet per second.)

11. *Counter-recoil motions of bolt and gun*

While the bolt and gun are moving forward, the bolt motion is influenced by the force of the bolt driving spring, but the gun motion is influenced by both the force of the barrel spring and the force of the bolt driving spring. (Since the bolt is free, the force of its spring opposes the gun motion.) The counter-recoil motions are determined by essentially the same method previously employed for analyzing the effects of the springs.

The first step is to draw the free bolt velocity curve which is a horizontal line at minus 32.7 feet per second and the free gun velocity curve which is a horizontal line at zero feet per second (fig. 3–35). The subsequent procedure must be modified slightly because the springs are aiding the motions rather than retarding them. At the start of the counter-recoil movement the barrel spring is compressed 0.125 foot and hence, if the spring losses were ignored, the initial compression of the spring for purpose of computing the counter-recoil motion would be:

$$F_{o_1}+K_1D=200+122.5\times12\times.125=383 \text{ (lb.)}$$

However, if 10 per cent is allowed to account for the spring losses, the force exerted by the barrel spring at the start of counter-recoil will be 345 pounds. The bolt driving spring is compressed 0.833 feet and, ignoring spring losses, its force would be:

$$F_{o_2}+K_2D=25+(10\times12\times.833)=125 \text{ (lb.)}$$

Again allowing 10 per cent for the losses, the force exerted by the bolt driving spring at the start of counter-recoil will be 112.5 pounds.

Since the bolt is free of the gun, the force of the bolt spring must be subtracted from the barrel spring force to give the effective force acting on the gun as 345−112.5=232.5 pounds. The velocity gain due to this force would be:

$$V=\frac{F_o}{M}\,t=\frac{232.5\times32.2}{55}\,t=136\,t$$

The effect of this gain in velocity is shown in fig. 3–35 by the line designated as step 2 for the gun. The gain in bolt velocity due to the initial force of the bolt driving spring would be:

$$V=\frac{F_o}{M}\,t=\frac{112.5\times32.2}{5}=700\,t$$

The effect of this gain in velocity is shown in fig. 3–35 by the line designated as step 2 for the bolt.

The effect of the spring constants is determined by using the curves designated as step 2 to obtain a first approximation of the gun and bolt travels (curves designated as steps 3 in fig. 3–32). The first approximation of the relative motion between the gun and bolt is obtained by subtracting the gun travel curve of step 3 from the bolt travel curve of step 3. This relative motion curve is used during recoil to determine the effect on the gun of the spring constant for the bolt driving spring. Combining this effect with the effect of the barrel spring on the gun gives the gun velocity curve designated as step 5 in fig. 3–35. Since the change in the velocity curve is so slight, it is not necessary to modify the gun travel curve obtained in step 3.

NOTE: Since the gun is moving forward, the effects of the spring constants must be applied opposite to the way they were applied during recoil. (Here, the effect of the spring constant for the barrel spring must be subtracted from the curve obtained in step 2 and the effect of the bolt spring constant must be added.) The validity of this procedure can be demonstrated by examining the equation expressing the change in gun velocity due to the effect of the barrel spring alone.

$$\Delta V=\int_{t_1}^{t_2}\frac{F\,dt}{M}=\int_{t_1}^{t_2}\frac{F_o+K\,(D-d)}{M}\,dt$$

where: D is the total distance the spring is compressed at the start of the forward motion;

and, d is the forward movement of the gun from its rearmost position.

$$\Delta V=\frac{1}{M}\int_{t_1}^{t_2}(F_o+KD)\,dt-\frac{1}{M}\int_{t_1}^{t_2}(Kd)\,dt$$

$$=\frac{F_o+Kd}{M}\,t-\frac{K}{M}\int_{t_1}^{t_2}(d)\,dt$$

which is the equation defining the procedure described above for handling the effect of the barrel spring.

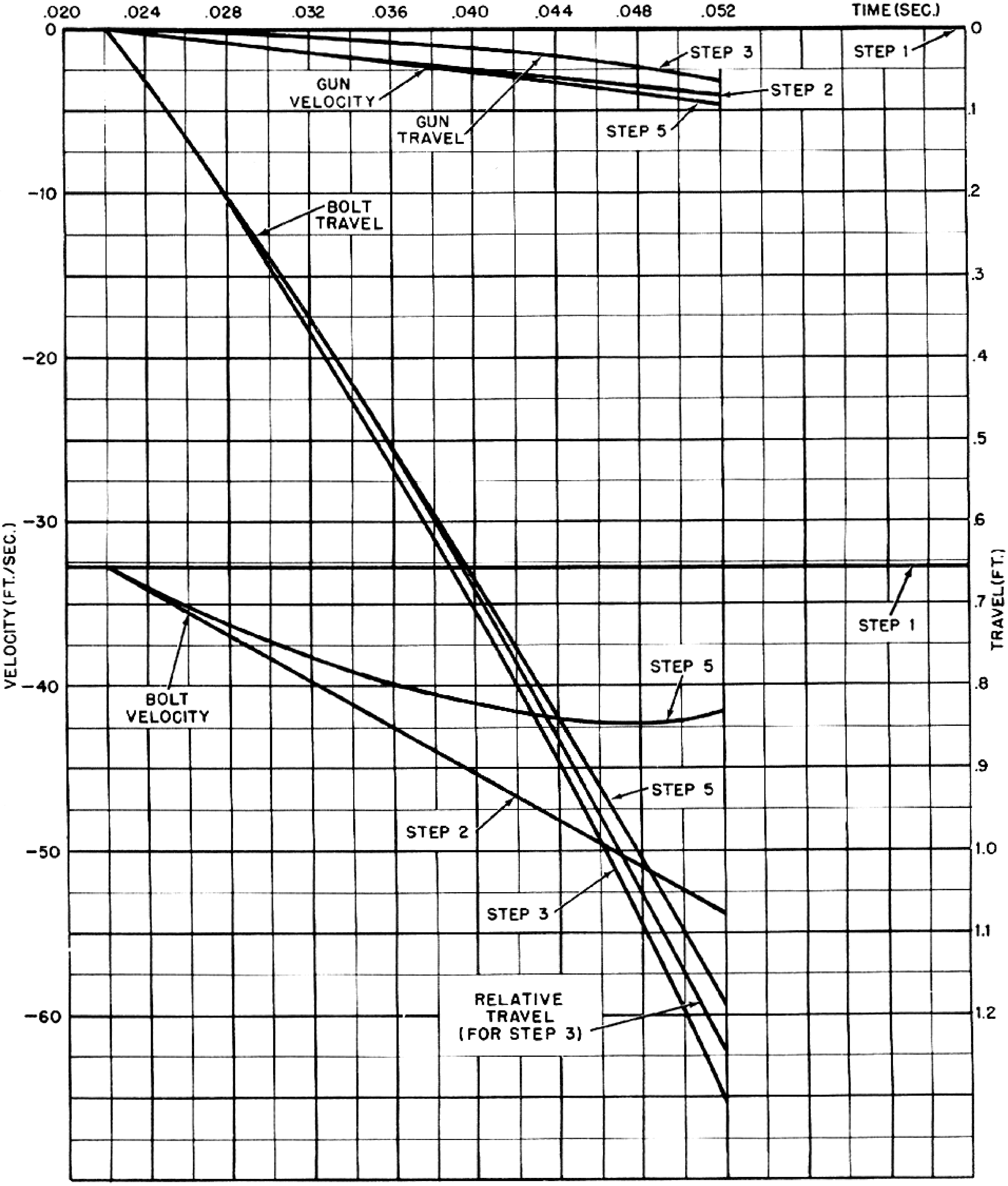


Figure 3–35. Effect of Bolt Driving Spring and Barrel Spring During Counter-Recoil.

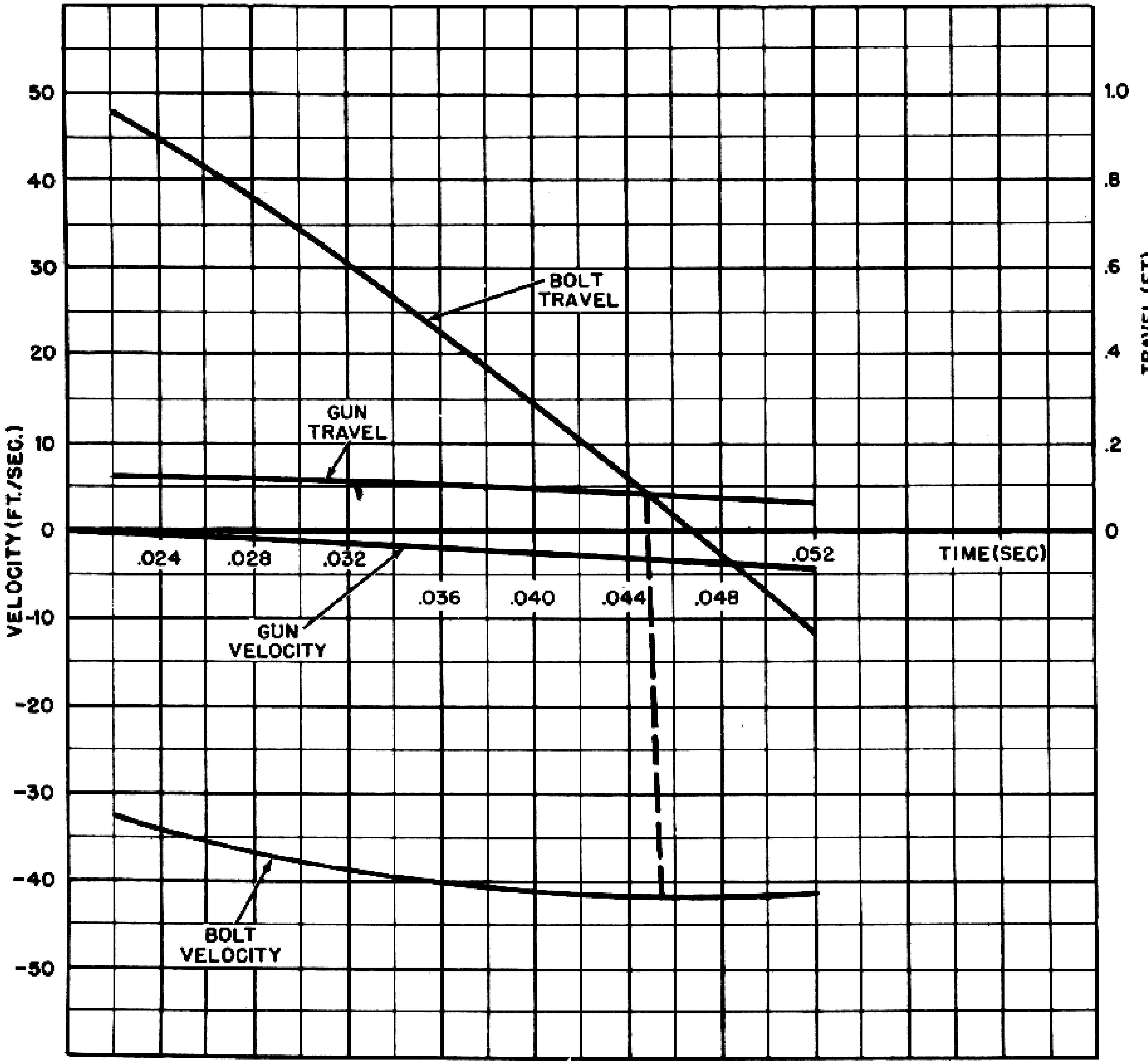


Figure 3–36. Extension of Time-Travel and Time-Velocity Curves for Interval Before Bolt Relocks to Barrel.

The effect on the bolt of the spring constant for the bolt driving spring is determined by using the relative motion curve and following the procedure described in the preceding note. The resulting velocity curve is designated as step 5 in fig. 3–35. Integrating under this curve gives the bolt travel curve designated as step 5.

Fig. 3–36 shows the travel and velocity curves obtained by using the data in fig. 3–35 to extend the curves previously constructed. Note that the bolt travel values obtained from fig. 3–35 are subtracted from 0.96 foot, which is the displacement at which the bolt leaves the backplate. Similarly, the gun travel values are subtracted from 0.125 foot. The travel curves show that the bolt meets the barrel at 0.448 second. At this instant the bolt is moving at 42 feet per second and the gun velocity is 3.5 feet per second. The displacement from the firing position at which the impact occurs is 0.085 foot.

12. *Gun motion after bolt locks to barrel*

When the bolt locks to the barrel, the gun velocity is 3.5 feet per second and the bolt velocity is 42 feet per second. Since the gun and bolt are locked, the parts will assume some common velocity which is determined by the fact that the momentum of the combined mass after impact will be the same as the total momentum before impact. That is:

$$M_rV_3=M_1V_1+M_2V_2$$

For the conditions of the example:

$$\frac{60}{32.2}V_3=\frac{55}{32.2}\times 3.5+\frac{5}{32.2}\times 42$$

$$V_3=6.7 \text{ (ft./sec.)}$$

In the construction of the curves showing the motions up to the time of unlocking (fig. 3–27) it was shown that the gun is fired during counter-recoil when it is still 0.0207 foot from its most forward position. As shown in fig. 3–34, the gun is 0.0805 foot from the firing position when the bolt locks to the barrel. Therefore the remaining travel to the firing position is .085—.0207=.0643 foot. Since the velocity of the gun is 6.7 feet per second at this instant, the time required for the gun to travel 0.0643 foot would be approximately 0.009 second. This time is actually too long for efficient operation, since the locking action can be completed and the effects of the shock of locking can settle out easily within 0.002 or 0.003 second. For this reason, the gun should be fired at least by 0.050 second as shown in fig. 3–34. However, at 0.050 second the gun will not have reached the 0.0207-foot displacement shown in fig. 3–27.

This situation arises because it was necessary at the outset of this analysis to estimate the required barrel spring characteristics before sufficient data were available to determine the timing accurately or to take into account such detailed factors as the effect of the impact of the returning bolt. The discrepancy resulting from the fact that the estimate was not exact is slight and for present purposes, the curves shown in fig. 3–34 show good enough agreement to be used for preliminary design purposes. In an actual design problem, better agreement could be attained by recomputing the curves for a slightly stronger barrel spring. Having the data shown in fig. 3–34, a better estimate can be made of the factors controlling the required strength of the spring.

The effect of the barrel spring after the locking occurs is determined as follows for completing the curves of fig. 3–34. The gun velocity at this instant has been shown to be 6.7 feet per second. As the gun moves forward, this velocity will be increased slightly by the force of the barrel spring. Since the time remaining until the gun is fired is so short, it will be sufficiently accurate to estimate the effect of the barrel spring force by assuming that the average force will be that which exists at a displacement of 0.04 foot. This force is:

$$F_{o_1}+K_1D=200+122.5\times 12\times .04=259 \text{ (lb.)}$$

The increase in velocity produced by this force will be:

$$V=\frac{F}{M}t=\frac{259\times 32.2}{60}t$$

$$=139\ t$$

This increase in velocity is indicated by sloping the velocity curve after locking occurs by an amount corresponding to a velocity increase of 139 feet per second. This curve shows that the average velocity for a considerable interval after locking can be taken as approximately 7.0 feet per second. Using this average velocity, the distance traveled by the gun from the instant of locking at 0.0448 second to the desired instant of firing at 0.050 second will be:

$$D=V_{av}\ t=7.0\ (.050-.0448)$$

$$=7.0\times .0052=.0364 \text{ (ft.)}$$

Thus, the position reached by the gun when it is fired at 0.050 second is 0.8050—.0364=.0441 foot from its most forward position. The velocity with which it reaches this position is approximately 7.3 feet per second. As previously explained, these values differ slightly from the original estimates but are close enough for present purposes. With the cycle time of 0.050 second, the rate of fire is 1200 rounds per minute as required.

In conclusion, it should be noted that the curves shown in fig. 3–34 represent the motions which occur after a burst is in progress. The conditions for the first shot in a weapon which uses advance primer ignition require special consideration. Since the action in this case is based on a forward velocity of the gun at the instant of firing, the charging mechanism must be arranged so that the effect of advanced primer ignition is obtained for the first shot. If this is not done, the first recoil will be excessively violent.

Chapter 4

ROTARY CHAMBER MECHANISMS

The preceding chapters of this publication are concerned with the operating and design principles of automatic weapons which employ a reciprocating bolt and derive the energy required for full automatic operation from blowback, long recoil, short recoil, or gas sources. There is another class of weapon, known as the revolver cannon, which is sufficiently different from the weapons described up to this point to merit individual and careful consideration. The principal difference between the revolver cannon and the reciprocating cannon does not lie in the source of operating energy because all machine guns of the full automatic type described in this publication use a portion of the energy released by the explosion of the propellant charge of each round to clear the weapon and to load and fire the next round in such a manner as to produce sustained or repetitive fire. Furthermore, the difference does not occur in the system whereby the energy is derived and applied since revolver cannons of the full automatic type obtain the power for their operation from recoil, gas, or even residual pressure in accordance with the same principles which are applicable to guns having a reciprocating bolt type of action. The real difference between the reciprocating cannon and the revolver cannon lies in the arrangement of the mechanical functions constituting the automatic cycle of operation and in the mechanisms associated with these functions.

Thus it appears that the classification of machine guns into the two groups, reciprocating weapons and rotary action weapons, represents a different type of classification than has been used in the preceding chapters of this publication. In these chapters, primary attention is given to the *systems* by means of which energy is derived from the explosive pressures developed in the combustion of the propellant charge and is applied to produce the mechanical motions necessary for sustained automatic fire. In treating each of these systems (blowback, long recoil, short recoil, and gas), the basic mechanical functions used to illustrate the application of the operating energy are the functions associated with reciprocating type actions. Actually, since these same systems are applied in a very similar manner to the actuation of rotary action weapons, it would have been entirely possible to cover the application of the recoil, gas, and blowback systems to rotary action mechanisms at the same time that their application to reciprocating mechanisms was described. However, the problems arising in the design of rotary action weapons are so special that it is practically mandatory to consider them separately.

HISTORICAL BACKGROUND OF THE REVOLVER

In order to provide a background for the description and analysis of the revolver cannon, a brief review of the history of this type of weapon will be given to clarify the factors which led to its adoption and which affect its relationship with the reciprocating type of machine gun.

Ever since the first recorded use of firearms early in the fourteenth century, there has been a need and a demand for multiple firing weapons. It is interesting to observe that many attempts to create such weapons were made almost immediately after the application of gun powder to the propelling of missiles and that multiple fire was originally achieved by the simple and rather obvious method of stacking a number of barrels side by side with an arrangement for firing the barrels simultaneously or in rapid succession. Although they were remarkable weapons in their day, the "orgues des bombardes", or battery guns, of the fourteenth century were extremely heavy and clumsily mounted and were only moderately successful because of the difficulties encountered in loading the barrels and in igniting the charges as desired.

During the fifteenth and sixteenth centuries, little progress was made in the field of multiple firing but during this time, attempts were made to place a number of barrels in a circular mounting rather than in the flat mounting previously used. This expedient made for a more compact and manageable weapon but still left much to be desired. Although the first guns employing circular mounting were in effect merely several independently functioning guns assembled as one unit, arrangements were soon developed to rotate the barrels about a common longitudinal axis so that each barrel could be brought successively into position to be fired by a single ignition device. During the sixteenth, seventeenth, and eighteenth centuries, many such arrangements were attempted using the match lock, wheel lock, and flintlock methods of ignition. Although none of these arrangements were successful enough to enjoy any wide acceptance, they did establish the basic idea of the revolver-type weapon. The upper drawing in fig. 4–1 shows the general appearance of a three-barrel weapon of the match lock era in which the barrels are revolved by hand. The second gun shown in fig. 4–1 is a seven-barrel rifle employing flintlock ignition. Each barrel was fired as it revolved into alignment with a fixed flintlock firing system.

At various times throughout the period described above, many inventors proposed a type of arrangement that was representative of a very important principle in weapon construction. In order to avoid the heavy and clumsy assembly that resulted from placing a number of complete gun barrels in a single circular mounting, it appears to be natural and convenient to use but one barrel and to provide the rear end of the weapon with a cylinder into which several chambers were bored. These chambers could be loaded separately and then the cylinder could be rotated so that each charge could be brought successively into alignment with the barrel and fired. This principle is the same as that

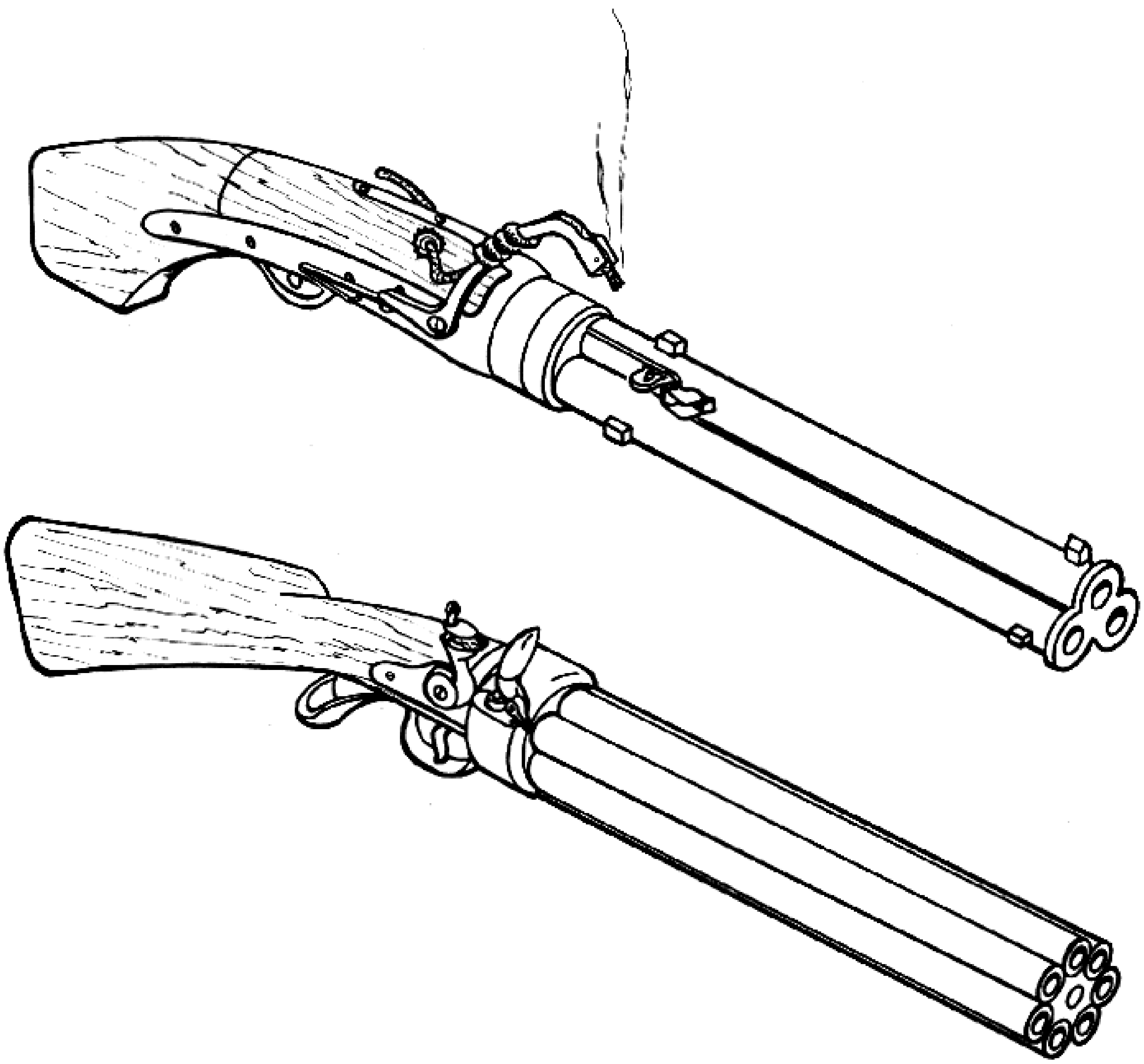


Figure 4–1. Matchlock Revolving Gun and Revolving Flintlock Rifle.

used in modern rotary action weapons. Its importance lies in the fact that it provides a rapid and convenient means for achieving repetitive firing and at the same time permits the construction of a weapon which need only be slightly more bulky than an ordinary single-shot arm.

In the course of the eighteenth century, there were a number of notable advances in the development of revolver weapons, particularly the introduction of mechanical means for rotating the cylinder and of a method for providing a gas-tight joint between the cylinder and barrel. An American inventor, Elisha Collier, was particularly active in promoting the rotating cylinder weapon and was responsible for many of the design improvements made in this field. One of his guns gained considerable favor and was even used in India by the English army. However the flintlock method of ignition then in use was not at all suited for use in repeating weapons. It was not until the early part of the nineteenth century, with the advent of percussion ignition, that any real progress was made toward achieving the development of practical and effective multifiring arms. The use of the percussion cap at last freed inventors of the limitations and almost hopeless complications imposed by the older methods of ignition. In 1830, Samuel Colt invented one of the first practical revolver mechanisms employing percussion ignition in conjunction with automatic revolution and locking of the cylinder by the act of cocking the hammer. This invention not only led to a long line of very popular and efficient firearms but it also initiated a veritable flood of inventions relating to the improvement of the revolver-type weapon. Indeed, the four or five decades following Colt's invention may be said to represent the "Golden Age" of the revolver. Soon after the beginning of this relatively brief period, in spite of the inconveniences attendant upon the use of the percussion cap and muzzle loading, the magnificent gun craftsmen and inventors of these times had produced almost every conceivable form of revolver mechanism. Each patent granted on a revolver mechanism or on an improvement in existing weapons was apparently the signal for a new flurry of inventions directed toward circumventing that patent or toward accomplishing still greater improvement. A study of the patents of this period forcibly demonstrates the ingenuity and vision which seemed to be so prevalent in the field of gun development. Even with percussion cap ignition, the revolver hand gun was developed and refined until it reached a high stage of compactness, ruggedness, and reliability. In addition to this steady process of refinement, many more radical ideas were advanced such as methods for sealing the gap between the cylinder and the barrel, arrangements for employing two or more cylinders in tandem so as to increase the number of shots which could be fired before reloading, and a host of other ideas for minimizing the disadvantages of the revolver weapon and overcoming its limitations.

Until the 1860's, the application of revolver principles was confined almost exclusively to hand guns, except for a short-lived adoption by the United States Army of the Colt Revolving Rifle, Model 1855, which did not prove successful under service conditions. However, during the Civil War, both the Union and Confederate forces became interested in multifiring weapons and particularly in adequate machine gun mechanisms capable of producing sustained fire. Beginning in 1861, various machine guns of several types were made available to the armies of both the South and the North but the full advantages of the machine gun in battle were not realized by the military experts of the day and the guns received only limited use, largely for fixed defensive installations.

Of the multifiring guns produced as a result of the stimulus of the Civil War, some were battery guns, some used the reciprocating principle, and some were based on the rotating mechanism principle. However, by far the most remarkable weapon to be conceived during this period was the machine gun invented by Richard Gatling. This was a hand-cranked multi-barreled rotary action weapon which was basically so sound in principle and so amenable to further improvement that it enjoyed world-wide fame and employment for the remainder of the nineteenth century. In fact, this gun was not declared obsolete by the United States Army until 1911.

The advent of the Gatling gun and the development of cartridge ammunition ushered in a new period in gun development. The machine gun had at last come into its own and inventors all over the world began a new wave of development to create competition for the Gatling gun. Many of the weapons produced at this time were of the rotary action type and many had reciprocating mechanisms, but in all the power for operation was supplied through a hand crank or lever turned by the operator. Although these guns were considered at the time to have reached a stage where no further improvement was possible, the era of the hand-operated machine gun came to an end with the invention of the first full automatic machine gun mechanism by Hiram Maxim in 1883. Of course, the full automatic gun did not immediately sweep the world market and instantly eliminated the hand-operated machine gun. Nevertheless, by 1888 most of the major powers of the world had ordered some of Maxim's guns for trial and long before the outbreak of World War I, the Maxim-type gun had been adopted as a first line weapon. The hand-operated machine gun was a thing of the past.

After Maxim's invention and successful development of his full automatic weapon, every significant new invention in the field of machine gun development was directed toward exploiting the principles of full automatic operation. The Maxim gun derived the energy for its operation from the recoil forces produced by the explosion of the propellant charge. The so-called Skoda machine gun patented in 1888 operated by the retarded blowback system and in 1890, John M. Browning produced a successful design for the first automatic gas-operated machine gun. These basic systems (recoil, blowback, and gas operation), all invented before the last ten years of the nineteenth century, have been used ever since to provide the power required for producing sustained fire.

It is particularly important to note that the first full automatic machine guns, whatever system was used to obtain operating energy, were all of the reciprocating type. The reciprocating mechanism was apparently well-adapted to the systems used for obtaining operating energy and, for the most part, the weapons produced even in the early days of full automatic operation were amazingly simple and efficient. According to reliable records of very exhaustive and demanding tests, the reciprocating machine gun could easily produce a rate of fire which was far in excess of that imposed by the military requirements of the years preceding World War II. At the same time, it was clear that the reciprocating principle could be applied to produce weapons which were reliable in performance, easy to maintain, and simple to manufacture. During the years following Maxim's invention, the gun industries of the world produced hundreds of new machine guns and thousands of patents related to the advancement of machine gun mechanisms. However, all of the successful designs adopted for military service were based on the reciprocating principle of operation and the rotary action-type mechanisms, so popular in the day of the manually-operated machine gun, were practically abandoned. The entire inventive effort in the field of machine guns was directed toward refining every detail, exploring every possible type of mechanism, and finding every conceivable combination and permutation of the principles relating to reciprocating actions.

Out of this maze of new weapons, new inventions, and re-invention of old inventions, there finally evolved a relatively small number of basic actions which had been proved by experience, both in test and in battle, to be sound enough and reliable enough to warrant their continued use. Once these actions were settled on, their development and refinement continued in an effort to eliminate "bugs" and to improve performance. Indeed, many of the weapons resulting from this intensive effort left little to be desired. They were powerful, efficient, relatively simple to maintain, and capable of mass production when needed. In a word, they were thoroughly practical and satisfactory weapons for the needs of their time, but again, as has happened so many times in the history of warfare, a new need developed.

From the latter days of World War I and particularly in the early stages of World War II, the rapid strides being made in the improvement of military aircraft confronted the gun industries of the world with an urgent and difficult problem. The new conditions of air combat made it imperative to have guns with greater muzzle velocity, larger caliber, and higher rates of fire. In response to this demand, the machine gun was advanced in tremendous strides until it reached calibers that formerly were considered in the domain of artillery and achieved rates of fire that were comparable with those formerly obtained with rifle caliber guns. In spite of these successes, the ever-increasing demands for even greater power and higher rates of fire continued and it became apparent at last that each succeeding improvement was accomplished with much greater difficulty than the last. In fact, it is generally conceded by many prominent gun designers and ordnance experts that, considering the state of modern metallurgy and technology, the conventional reciprocating gun may have either already reached or may be very close to the limit of its development potentialities. This does not mean that there is no room for further improvements affecting reliability, ease of maintenance, or simplicity in manufacture but merely that the basic physical and dynamic characteristics of the reciprocating mechanism probably do not lend themselves to permitting rates of fire to be increased very far beyond present-day values.

The design problems associated with the reciprocating mechanism were fully appreciated early in World War II and the German Luftwaffe had urgent need, late in 1942, for a high-rate-of-fire, high-muzzle-velocity 20-mm aircraft machine gun. In an attempt to avoid the difficulties experienced with the development of high-performance reciprocating-type guns, the Germans resorted to the rotary chamber mechanism principle and undertook the development of a 20-mm gas-operated rotary-action-type weapon. Under the pressure of the emergency Germany was facing, the development proceeded rapidly and by 1943 the first successful pilot model of the rotary action weapon was constructed. This was the first automatic rotary action cannon in which the cylinder is reloaded during firing. By the time Germany was overrun by the Allied forces, only a few prototypes of the weapon had been constructed. One of these guns was captured at the end of the war and was shipped to the United States. This captured weapon has since formed the basis for an extensive rotary chamber mechanism development program in this country. As a result of the renewed interest in the rotary action principle, this type of weapon once again enjoys equal footing with the reciprocating gun and many ordnance designers feel it holds great promise for future improvement.

It is interesting to note that the German program started in 1942 for the development of a rotary action machine cannon revived the use of principles which had been applied originally many years before but which had been neglected for a long time prior to World War II. One of the first recorded applications of the rotary chamber principle occurred as early as the year 1718 in a patent issued to James Puckle of England. Again, in the era of the American Civil War, a hand-operated machine cannon was developed which was similar in many striking ways to recently developed full automatic rotary action cannon. This was the DeBrame gun patented in 1862. One of the most amazing predecessors of the rotary action machine gun developed by the Germans is a weapon patented in the United States by an inventor named C. M. Clarke in 1905. This gun is a gas-operated, full automatic rotary chamber mechanism in which the mechanism is powered by an operating slide driven by a gas piston. It employs belt feeding, power ramming, and almost every other basic feature that distinguishes the modern family of rotary action weapons inspired by the German design. In fact, this gun is so representative of the rotating mechanism class that it is used later in this chapter to illustrate the basic functioning of these weapons. As to why this very advanced design lay dormant for almost 40 years before being rediscovered, it is probable that its inventor could not have chosen any worse time than 1905 for being inspired to conceive of this particular kind of machine gun. It was just at this time that the Maxim gun, Browning gun, and other reciprocating weapons were nearing the peak of a tremendous wave of popularity. The entire gun world was so preoccupied with the success of these new weapons that the Clarke gun simply failed to be noticed.

From the foregoing brief history of the place of the rotary action weapon in the development of guns, it is evident that there has been a definite pattern underlying the manner in which the rotary action principle has been utilized. The very first rudimentary attempts at achieving a multiple firing weapon quickly led to the basic and obvious device of grouping a number of individual barrels but this idea could not be advanced very far because of the lack of a suitable method for igniting the propellant charges in the barrels and because of the great bulk of the assemblies. As soon as an even slightly better method of ignition evolved, great improvements in the construction of multiple firing weapons occurred almost immediately as is witnessed by the fairly advanced revolving arms of the matchlock, wheel lock, and flintlock eras. However, these weapons, too, were not sufficiently effective and convenient to compensate for their relatively great unwieldiness and complexity and therefore never were extensively used to replace the simpler and more reliable single-shot weapons of the times. Again, in the early part of the nineteenth century, the invention of the percussion cap led quickly to a truly remarkable period of revolver development. The introduction of cartridge ammunition in the latter part of the same century produced even greater improvements in revolver mechanisms, and finally brought the sustained-fire weapon into the realm of practicality in the form of the Gatling gun. Although this weapon and other sustained-fire revolver arms of the period were very effective, they still were rather cumbersome and inconvenient and were soon abandoned after the full automatic reciprocating mechanism came into being. Now, with the new problems facing the gun designers of today, the rotary chamber mechanism principle is again being exploited.

Thus, it seems from the evidence of history that the rotary action principle has several times alternately risen to popularity because of its advantages and then fallen into disuse because of its shortcomings. The basic advantages of the rotary chamber mechanism are many. The very simplicity of the fundamental operating concept is in itself one of the rotary chamber mechanism's most important advantages. The mechanism is essentially rugged and durable and provides for very positive control in the handling of the ammunition. Unfortunately, these and the other advantages of the rotary chamber mechanism are accompanied by an almost equal number of disadvantages, some of which are relatively minor and some which are more serious. The following analysis will consider the rotary action principle from the general standpoint and then will cover the individual physical and operational characteristics of the mechanisms employing this principle in an attempt to throw some light on the basic problems encountered in the design of full automatic rotary chamber cannon.

PRINCIPLES OF MULTIPLE CHAMBER WEAPONS

The term "revolver" as applied with reference to firearms usually first calls to mind a type of mechanism which is best represented by the modern revolver hand gun. The fundamental elements of the mechanism are a single barrel and a cylinder which is bored with chambers for a number of cartridges. The cylinder is mounted so that it can be rotated to bring each chamber successively into alignment with the barrel. The revolver mechanism, of course, receives its name from the fact that the cylinder is rotated in order to achieve repetitive fire. However, in a larger sense, the true principles of the rotary action mechanism can be best understood and the properties of the mechanism can be more fully appreciated by reducing the concept to an even more elementary level. When all the nonessential factors are eliminated, the one remaining characteristic is that in the operation of the mechanism, each chamber is moved laterally with respect to the position at which it is fired. It is this lateral movement which holds the key to all of the characteristics peculiar to weapons of the multiple chamber type and also the key to the characteristics of rotary action guns which represent but one form of multiple chamber weapons.

Because the concept of the multiple chamber weapon forms the basis of all rotary action weapons, it is appropriate here to examine briefly the general nature of mechanisms which fall into the multiple chamber class. The most elementary form of the multiple chamber weapon is the battery gun or "orgue des bombarde" mentioned previously in this chapter. This gun, which consists merely of an assembly containing a number of individual complete barrels can hardly be considered as a mechanism since the only function required in its use is to obtain simultaneous or nearly simultaneous ignition of the propellant charges in all the barrels. A slightly more advanced type of weapon is exemplified by the conventional double-barrel shotgun, drillings, and other firearms which amount to nothing but two or more separate guns compactly assembled into a single stock. Although the elementary battery gun and firearms similar to the double-barrel shotgun are so simple in principle that no further discussion of them is called for here, consideration of the other forms of multiple chamber weapons brings to light a number of interesting and significant points.

One form of multiple chamber weapon, which was conceived very early in the history of firearms and has since reappeared at intervals with varying degrees of success, is the type of repeating weapon which employs a group of complete barrels. The salient feature of these weapons is that repetitive fire is achieved with the use of only one operating mechanism which serves a number of barrels. This means that for all intents and purposes, additional capacity can be built into the weapon merely by adding to the number of barrels without the necessity for greatly increasing the complexity of the operating mechanism or the bulk of the supporting structures. The particular form of a weapon in this class depends entirely on the manner in which the various parts are arranged in order to permit the barrels to be served by the operating mechanism. The fundamental arrangement may be such that the barrels remain fixed while the operating mechanism is moved from one barrel to the next, but the more commonly used method is for the barrels to move with respect to a fixed position of the operating mechanism. In some weapons, the barrels are placed parallel to each other in the same plane and the assembly slides laterally to move the barrels successively into the firing position. These so-called "harmonica" guns have not been used extensively because of the rather obvious disadvantages of such a mechanism for most applications. A much more suitable and practical arrangement is obtained by placing the barrels in a circular group so that the entire group can be rotated about an axis parallel to the bores. This type of mounting was employed in the revolving weapons of the matchlock and flintlock eras, in the popular "pepperbox" pocket pistols of the last century, and in the Gatling gun and other guns of similar construction. Even in recent years, this same principle of construction has been applied in the development of high-rate-of-fire machine guns. Although the multiple barrel principle is sound and its use eliminates many of the difficulties encountered with other forms of revolver cannon, weapons constructed on this principle suffer a severe handicap from the viewpoint of weight and bulk as well as other disadvantages which must be accounted for.

The remaining type of multiple chamber weapon is the important type in which the chambers are separate from the forward portion of the barrel. Weapons in this class usually have one fixed barrel (although there may be more than one barrel) and the chambers are moved successively into alignment

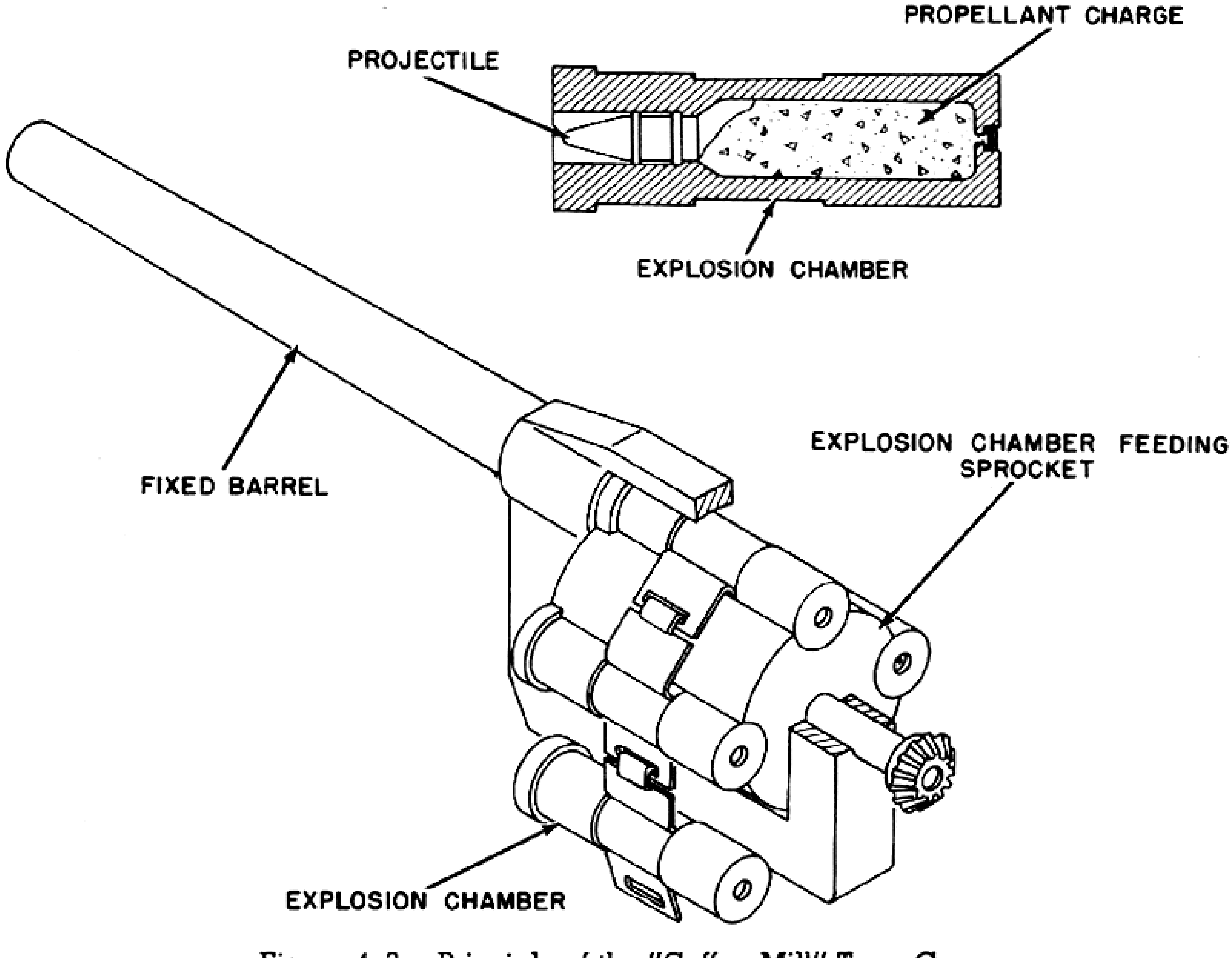


Figure 4–2. Principle of the "Coffee Mill" Type Gun.

with the barrel. Thus, each time a chamber is brought into position behind the barrel, the gun tube is completed and the weapon is in readiness for firing. This arrangement has the advantage of permitting repetitive fire without the necessity for having the weight and bulk of a large number of complete barrels. As mentioned previously in this chapter, this idea was conceived at a very early date in the history of firearms and, in fact, one of the first patented manually operated revolving type machine guns employed the multiple chamber principle. This remarkable weapon, invented in 1718 by James Puckle of England, had a number of separate explosion chambers which could be preloaded and were mounted in a circular array so that they could be successively revolved into alignment with a single barrel. The rotation was accomplished by means of a hand crank and the propellant charges were ignited by the slow-match method.

Over the years, the same general idea of having a single barrel with a number of explosion chambers appeared in a multitude of forms. In many cases, the individual explosion chambers were all bored into a single cylinder in a manner similar to that employed in the typical modern revolver hand gun. This arrangement, which is simple, easily mechanized, and effective, has been so prevalently used that in the popular mind it has become practically synonymous with the idea of the multiple chamber weapon. However, it should be realized that the revolving cylinder mechanism represents but one of the many possible devices which can be used to make use of many chambers. It may be said that the archetype of the multiple chamber weapon is found in a machine gun developed in the United States near the middle of the nineteenth century. This highly interesting weapon, the Ager "Coffee Mill" gun, which was used by the Union forces during the Civil War, was designed so that each charge of powder and ball was loaded into a separate steel container. The steel container forms the explosion chamber for the round and a percussion cap is placed on a nipple screwed into the rear end of the container. In the operation of the gun, a number of loaded containers (explosion chambers) are placed in a hopper at the top of the gun and when the operating hand crank is turned, one explosion chamber at a time rolls down into a recess at the rear of the gun barrel. The gun shown in fig. 4–2 is a simplified version of this type of weapon. A system of cogged rollers operated by the hand crank guides the explosion chamber into place and allows the chamber to be shoved forward to form a prolongation of the barrel and to be locked from behind by a wedge. As the hand crank is turned, the round is fired and the rotation of the cogged rollers causes the empty chamber to be ejected from the weapon at the side. As the fired chamber is ejected, a loaded chamber is brought into place to start a new cycle of operation.

Another unique arrangement for handling explosion chambers which are separate from the barrel is found in a hand gun developed later in the nineteenth century. Although the mechanism happened to be applied in a small caliber, the same device could have been used just as easily in a larger weapon. This gun, which has the surprisingly large capacity of 20 shots, fires cartridge ammunition and has an individual chamber for each cartridge. The separate chambers are linked together with metal plates so as to form an endless loop similar in appearance to an ordinary bicycle chain as shown in fig. 4–3. As the gun is fired, a ratchet-type cylinder within the frame pulls the chain of chambers through the frame laterally in such a way as to bring the chambers successively into alignment with the barrel. Before each cartridge is fired, the gun mechanism securely locks the chamber in place. Of course, one of the prime requirements for a hand gun is that it be compact and easy to handle. It is relatively easy to imagine what embarrassment might be experienced by a man who, in defense of his person, is required to extract from his pocket a gun with a foot or so of loose chain attached. Nevertheless, although the gun no doubt does not represent the most convenient hand arm, the basic idea is sound from the mechanical viewpoint and might even have proved to be useful in a machine gun. At any rate, it serves to demonstrate that very few stones were left unturned in the search for the ideal form of the multiple chamber mechanism.

From the preceding discussion of the type of multiple chamber weapon in which the explosion chambers are separate from the barrel, it is apparent that the basic consideration is that the chambers must be preloaded and then successively moved into place behind the barrel in order to complete the gun tube. For the present, the particular mechanism used to position the chamber, whether this be a rotary action cylinder or some other device, need not be considered and primary attention will

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be directed to the fundamental problems which arise from the very fact that the chambers are separate from the remainder of the barrel. In the following paragraphs, these problems are discussed in some length from the general point of view, first to outline the broad principles involved in weapons having the chambers separate from the barrel and second to prepare the way for a detailed analysis of the factors to be considered in the design of rotary chamber mechanisms in particular. (All of this discussion will be concerned primarily with guns of the full automatic type which employ conventional cartridge-type ammunition. Power-driven machine guns and guns which employ other types of ammunition are not included in the scope of this publication.)

The essential elements of a gun having the explosion chambers separate from the barrel are shown schematically in fig. 4–4. The explosion chamber has its bore shaped to receive and fit the cartridge and is of sufficient strength to withstand the disruptive forces produced by the explosion of the propellant charge. The barrel of the gun is fixed to a supporting frame which is fashioned to permit the explosion chamber to be held behind the barrel so as to form a prolongation of the bore. Of course, in an actual gun, a suitable mechanism must be provided to move the explosion chambers successively

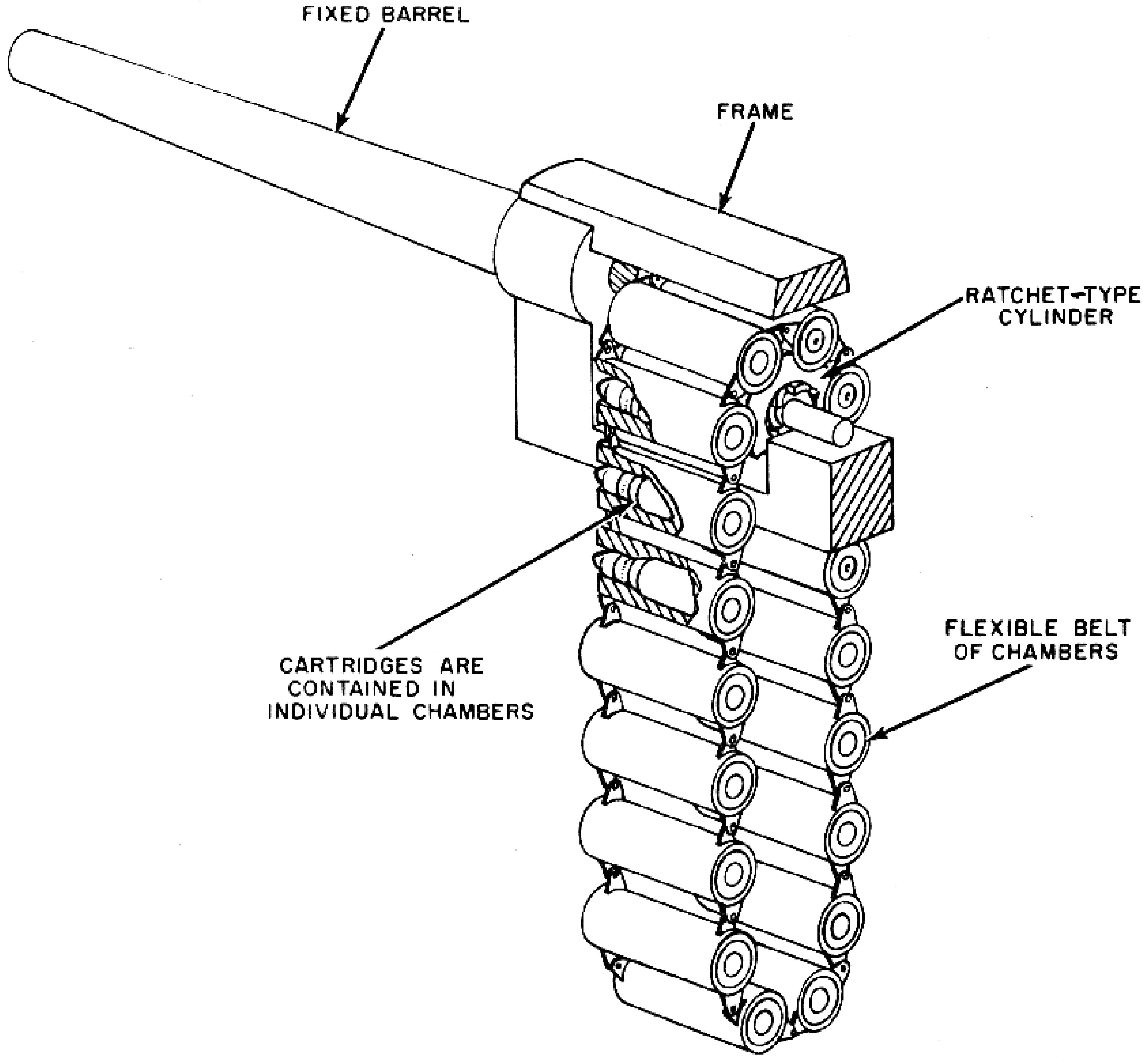

Figure 4–3. Mechanism of "Bicycle Chain" Gun.

into place behind the barrel and some form of firing device is necessary to ignite the propellant charge of the cartridge. It is important to note that since the explosion chambers must move with respect to the barrel, some operating clearance, or chamber gap, between the rear of the barrel and the front of the chamber is unavoidable.

From a careful consideration of the basic elements shown in fig. 4–4, all of the fundamental problems which arise in the design of machine guns employing separate chambers and barrel will be apparent. First, there is the problem of positioning the explosion chambers. In order for the weapon to be safe and to function properly, the explosion chamber must be placed directly in line with the bore of the barrel and must be held rigidly in this position when the gun is fired. It can be seen that if the chamber its position behind the barrel and thus may result in jamming the action of the gun. If the clearance between the base of the cartridge and the rear face of the frame is too great, another difficulty occurs. When the propellant charge is ignited, the forces produced by the explosion act in all directions on the interior of cartridge case and these forces cause the cartridge case both to be expanded and driven to the rear. The progress of the explosion is so rapid that the expanding walls of the cartridge case are pressed tightly against the supporting walls of the chamber before the case has moved very far to the rear. The pressure of the contact between the thin metal walls of the cartridge case and the walls of the chamber is so tremendous that the resulting frictional forces cause the forward portion of the case to seize firmly to the chamber. If at this point,

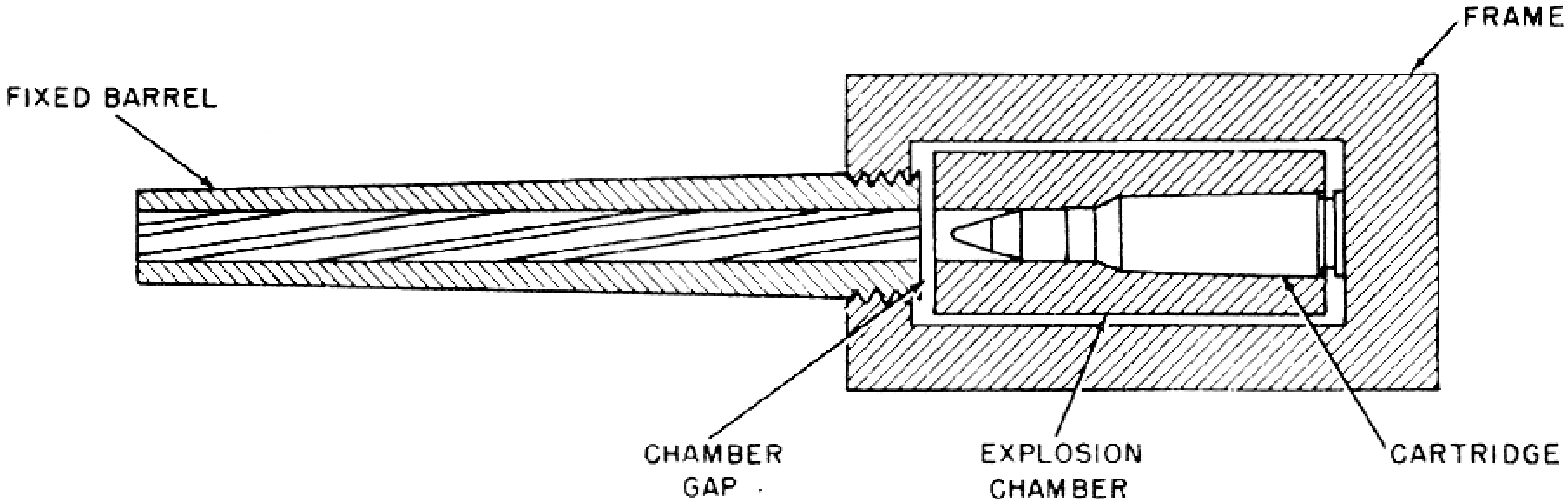

Figure 4–4. Elementary Form of Gun Having Chamber Separate From Barrel.

opening and the barrel bore are not in good alignment at the instant the projectile passes from the chamber into the barrel, the projectile will encounter an interference in its movement which could cause serious damage to the gun or projectile or at least cause shocks which would upset the accuracy of fire. (This type of defect is what causes the "shaving of lead" so commonly experienced in old or badly constructed revolver hand guns.)

In addition to accurate alignment between the chamber opening and barrel bore, it is also important for the explosion chamber to be positioned accurately so that the correct spacing exists between the rear face of the frame and the base of the cartridge when the cartridge is fully seated in the chamber. If the base of the cartridge projects too far out of the rear of the explosion chamber, it may interfere with the movement of the chamber into the base of the cartridge case is not rigidly supported by the frame of the weapon, the high pressure within the case continues to act against the base and creates tension on the case walls. Since the chamber pressure may be 50,000 pounds per square inch or more and since this pressure acts on a considerable area at the base of the case, the force exerted on the base is so tremendous that any resistance to stretching offered by the tensile strength of the thin walls of the case is entirely negligible. Therefore, the case material stretches quite readily and the base continues to move to the rear while the thin forward portion of the case remains stuck to the chamber wall. If the space between the base of the cartridge case and the supporting surface of the frame was originally too great, the case will stretch beyond the ultimate limit of the strength of the material from which it is made and will be torn in two. When this occurs, the gun will become inoperative because the device used for extraction can not remove the portion of the cartridge case which remains stuck in the chamber. Malfunctions due to cartridge case separation can only be avoided by making certain that the space between the base of the case and the supporting surface of the frame can never be great enough to permit the case material to be stretched beyond the point at which it will fail by tearing. The clearance must be set up accurately by correctly establishing the cartridge head space when the weapon is constructed and by insuring that the explosion chamber is mounted rigidly enough so that it can not move forward under the force produced by the propellant explosion. Also, it is evident that the frame itself must be made sufficiently rugged so that it will not be subjected to an excessive amount of elastic deformation when a round is fired. The reason for this requirement is that a lightly constructed frame, although it may be strong enough to absorb the explosion pressures without permanent deformation or failure by fracture, may be stretched elastically by a sufficient amount to result in a case separation. (Stretching of the frame under pressure from the base of the round has the same effect as excessive head space.)

To sum up the points made in the preceding paragraphs concerning the positioning of the explosion chamber, the chamber must be held accurately in alignment with the barrel bore at the instant of firing so that neither the projectile nor the gun will be damaged when the projectile passes from the chamber to the bore. Also, the body of the explosion chamber must be carefully adjusted to provide the correct cartridge head space and must be held in a strong and rigid mounting so that the stresses due to firing will not move the chamber body forward or stretch the frame elastically through a great enough deflection to result in excessive head space.

The next major factor for consideration is the point at which the barrel bore and the opening at the front of the chamber are contiguous. This particular factor is very important and gives great difficulty in the design of any high-powered gun in which the explosion chamber is a separate physical part from the remainder of the barrel. If the explosion chambers are simply moved laterally in order to position them successively in alignment with the barrel, it is evident that to permit the movement to occur there must be some operating clearance. Because of the necessity for this clearance, the barrel tube formed by the fixed barrel with the addition of the explosion chamber will not be a continuous tube but will be broken by a chamber gap as is indicated in fig. 4–4. Of course, the gap shown in fig. 4–4 is greatly exaggerated but even in a well-fitted revolver there will be some considerable space between the chamber and barrel. Even if the gap seems to be very narrow, it must be realized that it runs around the entire circumference of the gun bore and therefore really represents a leakage opening of significant size. In some weapons (for example, a well-built revolver hand gun), the presence of the chamber gap, although not to be desired, does not give an excessive amount of trouble. In such a gun, as in all hand guns, the chamber pressures are relatively very low and the escape of propellant gases at the chamber gap is not great enough to cause any damage or to result in a serious drop in the muzzle velocity of the projectile which is itself relatively low. However, the condition in a high-powered high-velocity gun is entirely different. In such guns, the variation of the chamber pressure during the passage of the projectile through the bore is such that the projectile will pass the chamber gap at practically the same instant that the chamber pressure reaches its peak. This peak pressure may be well over 50,000 pounds per square inch and at such a pressure the presence of even a fairly small chamber gap would result in a terrific flash at the juncture of the chamber and barrel and would cause the loss of a considerable amount of the propellant gases with a consequent drop in the muzzle velocity of the projectile. In addition, since the chamber gap is so close to the chamber space, the gases which escape through the gap would be extremely hot and would be moving at a very high velocity. Under such conditions, the erosive action of the escaping gas would be so severe that the weapon would quickly be rendered useless.

The critical nature of the problem of gas leakage at the chamber gap naturally has spurred inventors and designers of guns employing separate chambers and barrel to produce methods and devices whereby this problem could be rendered less serious or even eliminated entirely. Even in the day of the first revolving flintlock guns, attempts were made to provide gas-tight joints between the barrel and chambers by camming the cylinder forward before firing. To aid the sealing action, the chambers were counter-bored at the forward end so as to mate tightly with the rear end of the barrel. This device has been used in a considerable number of rotary chamber mechanism designs, even up to fairly recent times. Another method which has been used with some success is to arrange the mechanism so that, when the gun is ready for firing, the forward end of the cartridge case covers the chamber gap and enters the barrel for a short distance. Since the chamber gap is relatively very narrow, the cartridge case material is supported well enough to withstand the peak chamber pressure and is not blown through the gap. Although this method is highly effective in producing a sealing action, the fact that a portion of the round projects into the fixed barrel makes it necessary to cam the explosion chambers or the round itself back and forth in order to permit the chambers to be moved successively into position for firing. Still another method, which has been employed almost universally in modern high-powered weapons, is to use a gas piston seal or obturating sleeve at the forward end of the chamber opening. The piston is in the form of a hollow cylinder to permit the projectile to pass through its center and it is free to slide forward in the chamber opening. Piston rings are provided so that no gas can leak around the outer surface of the piston. After the projectile passes through the center of the piston, the high pressure powder gases behind the projectile act on the rear face of the piston and immediately drive the piston forward. Before the projectile reaches the chamber gap, the action of the high chamber pressure thrusts the piston against the rear face of the barrel with tremendous force, thus spanning the cylinder gap and creating a gas-tight seal.

Another point of interest which affects the problems encountered in sealing the chamber gap is the length of the moving part containing the explosion chamber. Fig. 4–5 is a graph which shows how the chamber pressure varies with the position of the projectile in the bore of a typical high-powered aircraft cannon of 20-mm caliber. Note that at the instant the projectile has moved only approximately four inches (0.33 foot) down the bore, the chamber pressure has reached its maximum value of 45,000 pounds per square inch. When the projectile has moved approximately eight inches down the bore, the pressure is considerably lower having decreased to about 38,000 pounds per square inch. At a propectile bore travel of 12 inches the pressure is still lower (approximately 30,000 pounds per square inch) and by the time the projectile has moved 18 inches, the pressure has dropped to approximately 21,000 pounds per square inch or less than half of the peak chamber pressure. From the preceding numerical values, it is evident from the standpoint of sealing alone that great benefit can be attained by intentionally making the moving part containing the explosion chamber as long as is practical so that the projectile must travel a considerable distance before passing across the chamber gap. By this apparently simple expedient, the gas pressure exerted at the gap can be reduced substantially with a corresponding reduction in the difficulty of obtaining adequate sealing. However, although each additional inch of bore travel makes sealing proportionately easier, the weight problem places a definite limit on the permissible length of the moving part containing the chambers. For example in a six-chambered revolver, increasing the length of the cylinder by one inch would mean that the weight of the gun would be increased by an amount at least as great as the weight of a piece of barrel five or six inches long. Since weight is such an important factor in most weapons, it is more than probable that any advantage gained by lengthening the cylinder would be insignificant when compared with the disadvantages of greatly increased weight and bulk.

In a thorough consideration of the elementary guns shown in fig. 4–4, there are several other points which require some mention. A gun having the basic parts shown in the figure could certainly be made to fire one round of ammunition but, in order for the gun to be capable of repetitive fire and to function as a full automatic machine gun, the factors involved in moving the explosion chambers and in loading and clearing them must be given careful consideration. The first of these factors is the source of power used for operating the gun mechanism. As has been pointed out previously in this publication, a gun placed in the category of full automatic weapons must derive the power required for its operation from the energies released by the explosion of the propellant charge of the ammunition. Actually, few modern high-rate-of-fire machine guns of the type designated as aircraft cannon derive all of their operating energy exclusively from the propellant explosion. In many cases, various auxiliary sources of power are employed. Although the major task of imparting the required motions to the heavier operating parts is accomplished through the medium of energy derived from the powder gases, some of the functions of the weapon are performed by mechanisms which receive power from external sources. For example, in many modern weapons, the feed mechanism which keeps the weapon supplied with the moving parts of the gun, thereby permitting these parts to move at maximum velocity in order that the gun may attain the highest possible rate of fire. In most modern aircraft cannon, the energy for firing the propellant charge usually is not obtained by the impact on the primer of a sliding part of the gun mechanism but firing is accomplished by the application of a voltage obtained from an external source

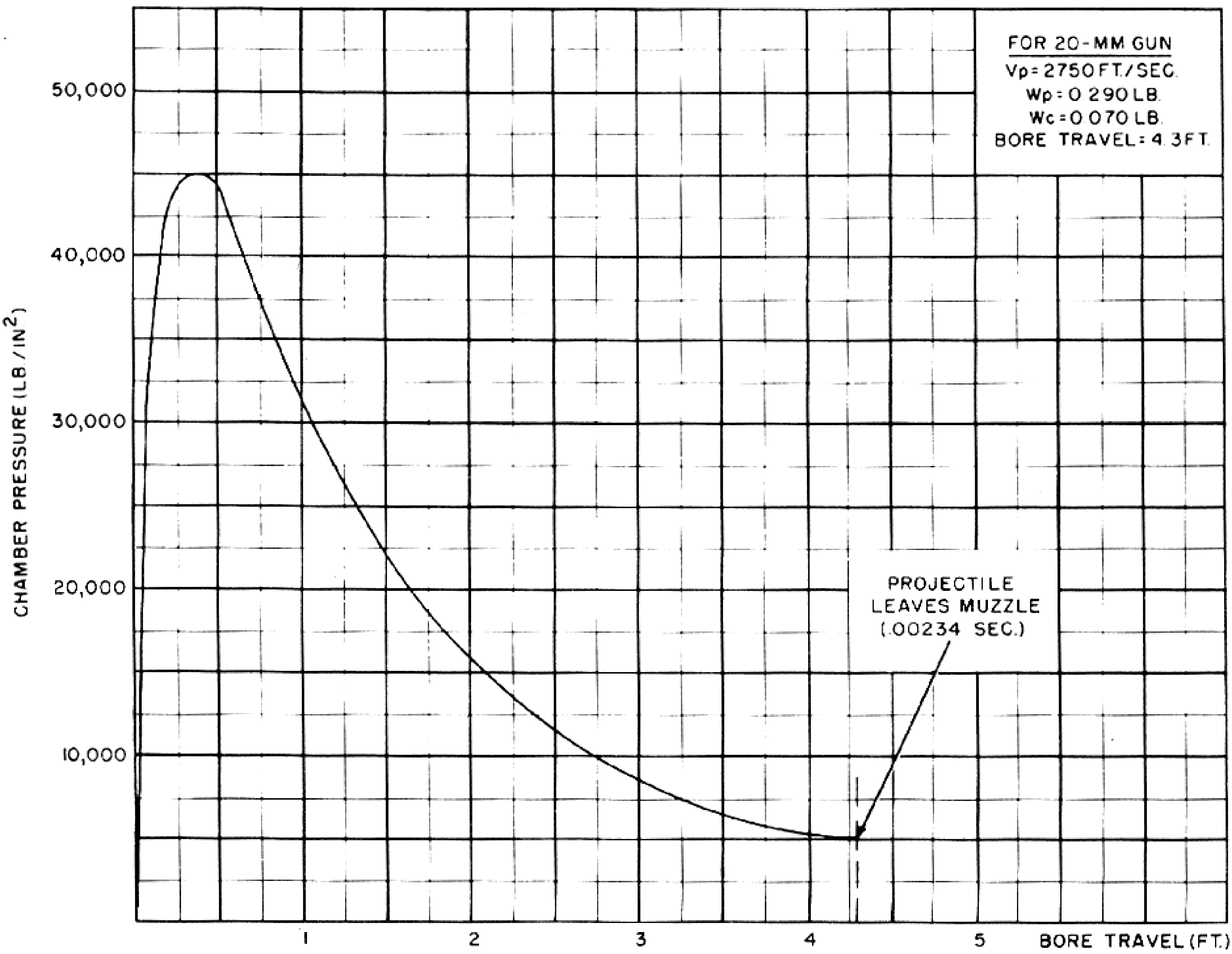

Figure 4–5. Graph Showing Variation of Chamber Pressure With Bore Travel of Projectile.

ammunition may be driven either by an electric motor or by a pneumatic device operating off a source of high pressure air. In most cases, this is done in order to simplify the gun mechanism by eliminating the devices which would be required to obtain the energy for feeding from the gun itself. Sometimes the use of external energy for feeding is resorted to so that excessive operating energy will not be extracted from of electrical energy. The charging of the weapon is another function which is performed by means of energy provided from outside of the gun itself. The charging device may be powered manually or pneumatically and in the type of device called a percussion charger or cartridge charger, the power for charging is supplied by the discharge of a blank cartridge of small caliber.

In spite of the fact that auxiliary power may be employed in the operation of a machine gun, the gun is considered to be in the full automatic classification as long as the major functioning assembly of the gun mechanism itself receives its power from the explosion of the propellant charge. In the case of a weapon having the chamber separate from the remainder of the barrel as shown in fig. 4–4, this means that the propellant explosion must at least be used to impart the required motion to the component which contains the movable explosion chambers, whether these chambers are all bored into a cylinder or are separate units of the various forms previously mentioned in this chapter. If this minimum requirement is not met, the weapon must be classed as a power-driven machine gun of a type which is not within the scope of this publication.

The various systems which can be used to derive and handle the energy provided by the explosion of the propellant charge are the same for multiple chamber weapons as for any other type of full automatic machine gun. All of the successful full automatic multiple chamber machine guns developed up to the present date have employed either recoil actuation or gas actuation since these operating systems seem to be particularly well adapted to the requirements of this type of weapon. By its very nature of involving a linear movement to the rear, the blowback system does not appear to be as well suited for application in a conventional rotary action cannon or other multiple chamber weapon. However, there have been special forms of rotary action weapons in which a linear motion of the cartridge case to the rear after firing is used to great advantage. This motion is utilized not only for the purpose of deriving operating energy, but also to provide for the actuation of a very effective system for sealing the chamber gap between the rear end of the fixed portion of the barrel and the front end of the explosion chamber.

Thus, it is evident that, in theory at least, all of the available systems for deriving operating energy from the explosion of the propellant charge can be used with good effect in multiple chamber weapons as well as in weapons of the reciprocating type. For the present, the particular manner in which these systems are employed and the form of the mechanisms used to apply the derived energy are not important. The main point is that in order to produce a full automatic weapon, one system or a combination of systems must be used and, as a minimum, must be employed to impart the required motions to the explosion chambers.

After a means has been provided for imparting the required motions to the explosion chambers, the next important factor for consideration in producing a full automatic multiple chamber gun is the problem of reloading during firing. In the Ager "Coffee Mill" gun previously mentioned in this chapter, the solution to this problem was achieved by the simple expedient of providing so many chambers that reloading during a burst of any reasonable duration was unnecessary. That is, the individual explosion chambers were loaded in advance with powder and ball and each was provided with a percussion cap. The chambers were than handled like modern-day cartridges except that it was only necessary for the gun mechanism to place them successively behind the barrel, fire them, and then eject them. From many standpoints, this is an excellent and convenient system except for the very obvious disadvantage as regards the weight and bulk of the individual explosion chambers. In the era of cap-and-ball weapons, the time required for reloading chambers apparently provided ample justification for tolerating excessive weight, as is evidenced by the ponderous construction of all of the multiple firing weapons of those days which had a capacity for any considerable number of shots. However, it is readily apparent that for any modern high-rate-of-fire, high-powered machine cannon, the idea of using an unlimited number of individual explosion chambers is entirely impractical. For a heavy caliber machine cannon firing over 1000 rounds per minute, the mere weight and bulk of the required number of chambers would certainly be prohibitive even if the difficulty of providing a sufficient belt pull to move the chambers rapidly through the weapon is ignored. It is hardly surprising, therefore, that weapons employing a large number of separate explosion chambers fell into almost complete disuse immediately after the introduction of cartridge ammunition. The use of metallic cartridge ammunition, in which the projectile, powder charge, and percussion primer are all neatly and ruggedly assembled into one compact, easily handled unit, made it possible to load an entire round into a chamber with great rapidity and also put breech loading on a practical basis because of the sealing function performed by the cartridge case.

Although these advantages eliminated many of the shortcomings previously experienced with powder and ball, the use of metallic cartridge ammunition introduced the new problem of removing the spent cartridge case from the chamber after firing to permit the loading of a fresh cartridge. In repeating and semi-automatic weapons and in most machine guns, the problems of loading fresh cartridges into the gun and of extracting the fired cases from the chamber do not present any very great difficulties if the loading and extraction functions are given proper consideration in the design of the weapon. However, in guns having very high rates of fire and particularly in guns of the multiple chamber type, a special loading and extraction problem arises. It is not the mere process of inserting the loaded cartridge or of removing the cartridge case from the chamber that produces the problem but it is the small time that is allowable for the process to occur. For example, consider an automatic weapon which fires at a cyclic rate of 1500 rounds per minute. With a firing rate of this magnitude, only 0.04 second is allowable for the entire chain of events which must occur during each firing cycle. The particular series of events which is necessary for the automatic functioning of the weapon will of course depend on the particular design characteristics of the mechanism but it can be seen that with such an extremely brief time interval available, the problems attendant upon any mechanical function can be greatly multiplied. For this reason, the means which are used to load the chambers of a multiple chamber weapon and to extract the fired cartridge cases must be given very careful consideration in the design. The consideration must cover, not only the mechanisms which accomplish the functions and the power sources used to drive the mechanisms, but must also take into account the timing of the functions, so that they can occur with no interference from the remainder of the moving parts of the weapon.

Another important factor in the design of a multiple chamber weapon is the control and dissipation of the recoil forces resulting from the firing of the cartridges. If the weapon is recoil-operated, a considerable portion of the recoil energy may be put to use in providing power for driving the gun mechanisms, but in a gas-operated gun, the forces of recoil do not contribute to the action and must be absorbed entirely by the mounting of the weapon. In a multiple chamber gun, the principles relating to recoil are the same as for any other gun. The ignition of the propellant charge produces an explosive combustion which causes the rapid generation of an extremely high gas pressure in the chamber of the gun. The expansion of these high-pressure gases drives the projectile forward through the bore of the gun and since the gases move down the bore after the projectile, the center of mass of the gases also moves forward. (Because of the fact that the gases are not moving forward as a single body but rather are expanding in the bore, the forward velocity of the center of mass of the gases is only approximately one-half of the projectile velocity.) As long as the projectile is still moving down the gun bore, the same pressure which acts to produce the forward motion of the projectile and powder gases also acts at the chamber end of the gun to produce an equal and opposite reaction which tends to drive the entire gun rearward. The force resulting from this reaction is called the "recoil force" and its magnitude at any instant depends on the chamber pressure which exists at that same instant.

After the projectile leaves the muzzle of the gun, the recoil force does not cease to act immediately but continues in existence as the reaction to the forward movement of the powder gases as they pass out of the gun muzzle. The recoil force does not actually fall to zero until the so-called residual powder gas pressure in the barrel has become equal to the atmospheric pressure. (In a representative 20-mm gun this does not occur until approximately eight milliseconds after the ignition of the propellant charge.)

The combined effect of the recoil force which exists before the projectile leaves the muzzle and the recoil force produced by the residual pressure is to impart a rearward velocity to the gun and to create a kinetic energy in the gun mass. The magnitudes of the velocity and of the kinetic energy depend on the power of the cartridge, the mass of the parts subjected to the recoil action, and the manner in which the gun is mounted. In an analysis of the conditions of recoil, it is usually desirable to consider first what velocity and energy would be obtained if the gun is assumed to be mounted so that it is not subjected to retardation from friction or any other restraint. This hypothetical condition is referred to as the condition of "free recoil". With no restraint of any kind imposed upon the gun, the impulse of the recoil force (acting over the entire time of action of the powder gas pressure, including the duration of the residual pressure) will impart a rearward momentum to the gun which is equal to the total effective forward momentum imparted to the projectile and powder gases. The velocity corresponding to this value of momentum will depend on the mass of the recoiling parts; the smaller the mass, the higher will be the velocity. When the residual pressure has reached zero, the gun will have achieved its maximum rearward velocity. Since it is assumed that there are no external restraining forces in the condition of free recoil, the gun will continue to move at this velocity indefinitely.

Although the assumption of free recoil is useful for analytical purposes, this condition is of course never encountered in practice. Under actual conditions of use, any gun must have its recoil motion controlled and limited so that the recoil travel is held to some reasonable value. This must be accomplished by the application of restraining forces which produce the condition known as "retarded recoil". With small-caliber, low-powered weapons it is often possible to hold the parts subjected to the recoil forces in a rigid mounting in such a manner that the forces are directly absorbed by the mounting with no appreciable rearward movement of the gun. However such a mounting would be entirely out of the question in the case of a larger caliber, high-powered weapon. For example, the maximum recoil force in a 20-mm gun can amount to from 20,000 to 30,000 pounds or more and with forces of this magnitude it is essential to provide some sort of shock-absorbing mount. Such a mount must permit some motion of the gun during and after the action of the recoil force so that the momentum of the recoiling parts can be cancelled through the application of a relatively small retarding force which acts on the gun through a considerable interval of time and distance, thus gradually reducing the recoil velocity to zero.

The amount of energy which must be absorbed by the mount and the magnitude of the required restraining force depends on several factors. Assuming a cartridge of given power, the most important single factor is the weight of the recoiling parts. The transfer of kinetic energy to the gun occurs mainly during the early stages of the propellant explosion when the recoil forces are extremely high. Since whatever restraining forces are applied to the recoiling parts must of necessity be relatively small (in the order of a few thousand pounds at the most) and the maximum recoil forces will be in excess of 20,000 or 30,000 pounds (for a 20-mm gun), it can be seen that for the short period of action of the recoil forces, the restraining forces can have but little effect. Accordingly, for the duration of the high powder gas pressure, the recoil forces are almost unopposed in imparting velocity to the gun. Therefore, during the greater part of the action of the powder gas pressure, the only significant factor limiting the velocity produced by the impulse of the propellant explosion is the mass of the recoiling parts. With this in mind, it is evident that a heavy gun will recoil with low velocity and low kinetic energy while a light gun will recoil more violently and with greater energy.

Having a given cartridge and having recoiling parts of some definite mass, these factors more or less determine the general order of magnitude of the recoil energy and velocity. The remaining point to consider is how the energy and velocity of recoil can be dissipated by the recoil system of the weapon. Since the problem is concerned with the absorption of the kinetic energy of recoil, the answer lies in methods whereby this energy can be expended in the performance of mechanical work. If the gun is to be recoil operated, a considerable portion of the energy can be converted to useful purposes in operating the gun mechanism. Making use of a portion of the energy in this manner means that the task of the recoil system of the gun mounting will be lightened and the problem of disposing of excess recoil energy will be minimized. Indeed it is often the case that the energy requirements of a recoil-operated gun mechanism are so great that it becomes necessary to augment the recoil energy through the use of muzzle boosters and other such devices in order to obtain effective operation. In such situations, the problem is often how to find special means of increasing recoil rather than to minimize it.

On the other hand, in a weapon such as a gas-operated machine gun, the recoil energy is not put to any useful purpose and is only a source of inconvenience. Since the energy is not dissipated in operating the gun mechanism, a recoil system must be provided in the gun mounting to absorb and dispose of it by causing it to be expended in doing other mechanical work. This means simply that the recoiling parts must be restrained by a force that acts over a distance, which constitutes the definition of work. Accordingly, a high-powered gas-operated machine gun is mounted in a slide so that it can move to the rear under the action of the recoil forces. The mounting is equipped with some sort of restraining device which disposes of the greater part of the recoil energy and also is provided with some means for storing a portion of the energy to be utilized for returning the gun to the battery position. In a medium-caliber aircraft machine cannon, the recoil energy is usually dissipated as heat in a nest of ring springs or in a hydraulic buffer while the portion of the recoil energy used for driving the gun back to battery is stored in a spring. Larger guns are usually provided with a hydraulic recoil brake and a pneumatic device called a recuperator, both of which absorb the recoil energy. Most of the energy is expended in the brake in the form of heat and the relatively small amount of energy stored in the recuperator is utilized for returning the gun to the battery position.

The design characteristics of the recoil system of a machine gun depend to a large extent on the requirements of the installation and also are affected strongly by the desired rate of fire. From the standpoint of simplifying design problems, it is of course desirable to subject the recoil system to the smallest possible load; that is, to employ the minimum restraining force. However, since the amount of work which must be done in order to expend the recoil energy is more or less fixed and predetermined, it follows that the use of a smaller restraining force will require a longer recoil travel. In most cases, the requirements of the installation do not permit any great amount of recoil travel and even if a long travel were allowable, an excessive movement would create other serious design difficulties. Faced with these conflicting desires for a small restraining force and a short recoil travel, the designer is usually forced to favor a short travel and to accept the difficulties which arise from a high restraining force and the resulting high trunnion reaction of the mount.

Another very pressing reason why it is necessary to maintain a short recoil stroke in high-rate-of-fire guns can be demonstrated by a simple analysis of the time available for the completion of the recoil and counter-recoil travels of a sample machine gun. As the sample, consider a gun having a rate of fire of approximately 1500 rounds per minute and assume that the weight of the gun and the power of the cartridge are such that the initial velocity of the recoiling parts is approximately 10 feet per second. (This is a reasonable value based on an average of conventional multiple-chamber guns in the 20-mm to 30-mm class.) Now, at a rate of fire of 1500 rounds per minute, the recoiling parts must complete their recoil travel and their counter-recoil travel back to the firing position within 1500/50=.04 second. This is the maximum time allowable for these motions because the operation of the gun will not be stable if the firing cycle takes less time than the combined time for recoil and counter-recoil. Since the recoiling parts must reverse their motion at each end of their travel and since this reversal can not occur instantly, it is safe to estimate that their average velocity of movement for a complete cycle of operation will be at the most approximately half their maximum velocity or about 5 feet per second. Multiplying this average velocity by the available time of 0.04 second shows that the total distance travelled can be only $5\times12\times.04=2.4$ inches. This is the combined recoil and counter-recoil movement and therefore the recoil movement can be only half of this distance or 1.2 inches. From the foregoing analytical estimates it can be seen that the recoil travel of a high-rate-of-fire gun is definitely limited to a rather short distance simply because the average recoil velocity is necessarily fairly low and the time available for the complete recoil cycle is so short. As a matter of fact, the estimated value of 1.2 inches is somewhat on the high side. In existing 20-mm multiple-chamber aircraft cannon, the recoil distance is more in the order of from 0.25 to 0.50-inch. This shorter travel is necessary because of the fact that a considerable portion of the recoil energy is dissipated and therefore the average velocity of counter-recoil is much lower than the average velocity of recoil.

With such short recoil travels, the average restraining force imposed on the gun by the recoil system must be fairly high. Assume for instance that the recoiling parts of the gun used as an example weigh approximately 100 pounds. The stipulated initial recoil velocity of about 10 feet per second results in a kinetic energy computed as follows:

$$K.E.=\frac{1}{2}MV^2=\frac{1}{2}\frac{100}{32.2}10^2$$

$$=155.3 \text{ (foot-pounds)}$$

If this entire amount of energy is to be absorbed over a travel of only 0.25 inch, the average force exerted over that distance must be:

$$F=\frac{K.E.}{D}=\frac{155.3}{.25}\times12=7450 \text{ (pounds)}$$

In an actual gun, a portion of this force would be provided by a spring which stores sufficient energy to return the gun to battery and the remainder of the restraining force would be supplied by a device like a ring spring buffer which converts a large percentage of the energy it receives into heat. In any case, the entire restraining force of 7450 pounds is transmitted to the gun mounting and appears as the trunnion reaction of the gun. This approximate analysis shows that the conditions of recoil in a high-rate-of-fire multiple-chamber weapon are such that a short recoil travel and a high trunnion reaction can not be avoided. For this reason, the design problems associated with the recoil system of such a gun are rather critical and must be treated with great care.

The last point for consideration in an analysis of an elementary multiple-chamber weapon is the question of timing. Although the timing involved in a multiple-chamber weapon is from the general standpoint much less of a problem than in a reciprocating weapon, there are certain factors which require some attention. Of particular interest are the limitations which affect the rate of fire theoretically attainable. These limitations can be examined best by considering the sequence of events which must occur during a complete automatic firing cycle. To start, assume that a loaded chamber has been positioned accurately in alignment with the barrel bore and that the gun is fully prepared for firing. From the instant that the firing device is actuated to ignite the primer until the instant that the chamber pressure has decreased to a low enough value to permit the chamber to be moved may require an elapsed time somewhere in the order of 10 milliseconds. After the chamber is fired, it must be moved out from behind the barrel while the next loaded chamber is moved into firing position. The time required for this movement is not fixed definitely but depends entirely on the design of the gun mechanism and the amount of power utilized to operate it. It should be realized that the mechanism used to move the chambers must of necessity be rather heavy and have a correspondingly great inertia. In order to move a loaded chamber into firing position, this heavy mechanism must first be unlocked, then accelerated to some high velocity, and finally decelerated until it comes to rest at the firing position, where it is again locked. Even if the explosion chambers are spaced very close together, the distance through which the mechanism must move is considerable and the separate actions of unlocking, acceleration, deceleration, and locking each require some small but significant amount of time. At a very high rate of fire, the time allowable for an entire firing cycle is extremely short and the time which can be permitted for any of the events during the cycle is much shorter. This means that the mechanism must be subjected to tremendous accelerations in order for it to accomplish its required movements within the allowable time.

To demonstrate the order of the linear accelerations which can be expected in a high-rate-of-fire multiple-chamber gun, consider a 20-mm weapon which fires at the rate of 1500 rounds per minute. At this rate of fire, the time allowable for each complete firing cycle is only 0.04 second. Of this total time, an interval of about 0.010 second is required for ignition of the propellant, the combustion of the powder charge, and the decrease of the chamber pressure to a level low enough to permit the chambers to be moved. Accordingly the time remaining during which the chambers can be moved is now only 0.03 second. Of this time, it is reasonable to allow a total interval of at least five milliseconds for the action of the device which unlocks the mechanism before the movement of the chambers starts and again locks the mechanism at the completion of the movement. Now the time remaining for the movement to occur is only 0.025 second. During this extremely brief interval, the heavy gun mechanism must be accelerated to some fairly high velocity and then decelerated until it comes to rest. For the purpose of approximate analysis, let it be assumed that the linear distance separating the chambers is approximately two inches. Let it be assumed further that the operating cams are formed to produce the entire movement in equal periods of uniform acceleration and uniform deceleration.

On the basis of the foregoing data, the time available for the acceleration phase of the movement is half of 0.025 second or 0.0125 second. During this interval, the mechanism must move half of the total two-inch travel, or one inch (.0833 foot).

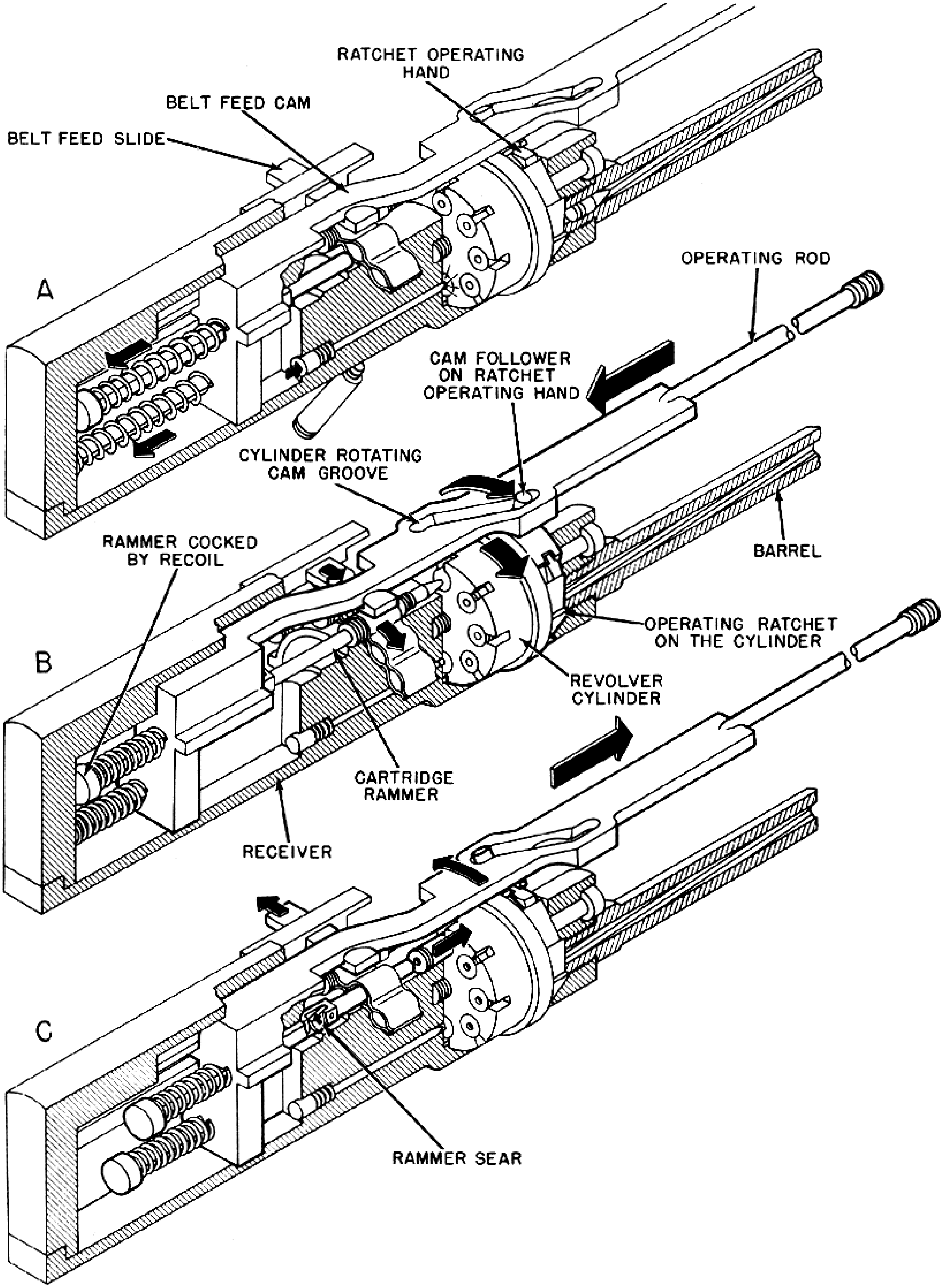

Figure 4–6. Simplified Schematic of a Typical Gas-Operated Rotary Action Cannon.

The required uniform acceleration can be found by using the standard relation between distance, acceleration, and time as follows:

$$S=\frac{1}{2}\text{ at }2$$

Solving for "a" gives:

$$a=\frac{2S}{t^2}$$

Making the necessary substitutions and evaluating "a":

$$a=\frac{2\times.0833}{(.0125)^2}$$

$$a=1066\ (\text{ft./sec.}^2)$$

Since it is assumed that the deceleration period is the same as the acceleration period, the value of the deceleration will also be 1066 feet per second per second. This is a high value and is equivalent to approximately 33 times the normal acceleration of gravity. An idea of the magnitude of the force required to produce this acceleration can be had by assuming that the equivalent mass subjected to the acceleration is 50 pounds in weight.

$$F=Ma=\frac{W}{g}a$$

$$=\frac{50}{32.2}\times1066$$

$$=1655\ (\text{pounds})$$

Of course, the preceding calculations are based on highly simplified conditions but they do give a fair indication of the general order of the time intervals, accelerations, and forces which can be expected in a high-rate-of-fire multiple chamber gun. Although the analysis is primarily concerned with the movement of the chambers, it can be seen readily that the entire design problem will be similarly affected by the extremely short time available for each weapon function. In order to obtain smooth high-speed operation, every function must be timed with great precision. Ignition of the propellant charge must occur at exactly the correct instant, unlocking must be neither premature nor late, the application of the force which moves the chambers must take place at the instant the unlocking action is completed, and locking must occur just as the loaded chamber reaches the firing position. Even a slight delay at any of these critical points can seriously cut into the time available for the remainder of the operation. A similar necessity for precise timing and extremely rapid action exists in all phases of the operation of a high-rate-of-fire multiple-chamber gun. The loading operation, the ejection of spent cartridge cases, and the conditions of recoil are all subject to the same stringent requirements. In fact, it has been facetiously remarked that the designer of these weapons is an unfortunate individual who is continuously snatching at the coat-tails of the fleeting and infinitesimal instant.

PRINCIPLES OF ROTARY CHAMBER MECHANISMS

The preceding analysis deals primarily with the general operating and design characteristics which are inherent in any full automatic multiple-chamber weapon in which the chambers are separate from the barrel. In the analysis, consideration was given to those basic features which are significant regardless of what particular type of mechanism is employed. However, there is one type of multiple-chamber mechanism which has had a very prominent place in modern gun developments. This mechanism, the rotary action, will be treated in detail in the following paragraphs of this chapter.

The elements of a rotary action are shown schematically in fig. 4–6A. The essential parts are the cylinder (sometimes called the cartridge drum), the barrel, and the frame. A complete revolver cannon must also have some means for utilizing the recoil or a gas piston for automatically indexing the cylinder and must be provided with a recoil system, firing device, and feeder. The particular mechanism shown in fig. 4–6 is taken from the Clarke patent previously mentioned in this chapter. This is a gas-operated weapon and the illustration shows all of the principal parts except for the recoil system and extractor. Fig. 4–6A shows the condition of the mechanism immediately after firing and fig. 4–6B shows the condition with the piston slide driven fully to the rear.

Cycle of Operation

The operating cycle of a typical rotary action weapon is relatively very simple and occurs as follows:

The cycle starts with a cartridge in the chamber at the 180-degree position. This particular weapon has eight chambers bored in the cylinder and at the start of the cycle, the chambers at the zero degree, 45-degree, 90-degree, and 135-degree position are loaded. The chambers on the left side of the cylinder are unloaded. When the cartridge in the chamber aligned with the barrel is fired, the pressure of the powder gases drives the projectile and the gases forward through the bore and at the same time drives the entire gun to the rear in recoil. (The force of the recoil is absorbed by the recoil system.) When the projectile passes the gas port in the barrel, the powder gases flow into the gas cylinder and exert a rearward thrust on the gas piston. The time at which this occurs will depend on the location of the port and ordinarily will be from 0.001 to 0.002 second after ignition of the propellant charge. The piston action and the cylinder rotating cam groove in the piston slide are controlled in the design so that the cylinder is not rotated immediately but rotation is delayed until the pressure in the barrel has dropped to a safe operating limit a few milliseconds after the projectile has left the muzzle. As the piston slide moves to the rear, the cam follower in the cylinder rotating cam groove is driven to the right, causing the operating hand to engage the ratchet on the cylinder and to rotate the cylinder. The hand rotates the cylinder sufficiently to bring the next loaded chamber into alignment with the barrel. The rearward movement of the piston slide also extracts the empty case from the fired chamber and causes the belt feed cam to move the belt feed slide so as to position a fresh cartridge in front of the rammer. As the piston slide moves forward again (fig. 4–6C), the rammer pushes the cartridge out of the belt into the empty chamber now at the zero-degree position. At the same time, the belt feed slide is retracted and the ratchet operating hand is moved back to pick up the next notch in the operating ratchet on the cylinder. This completes the operating cycle and the next cycle starts when the round now in the 180-degree position is fired.

Analysis of Rotary Action Features

As mentioned earlier in this chapter, the revolver is merely one special form of a multiple-chamber weapon in which the chambers are separate from the barrel. As a starting point for an analysis of the important features of the revolver cannon, it is of interest to consider why the rotating cylinder is preferred over other forms of mechanism for moving chambers successively into position. The advantage of the rotating cylinder can be appreciated most readily by comparing a revolver with a so-called "harmonica" gun. In a harmonica gun, the chambers are bored into the edge of a flat plate and to bring the chambers successively into alignment with the barrel, the plate slides laterally across the back of the gun. For a limited number of shots, this type of mechanism can function very well, but it has several obvious and very serious drawbacks. First, the flat array is wasteful of space and awkward. Also, the overall shape and balance of the weapon changes as the chamber plate slides laterally during firing. Of even greater importance is the fact that, to fire a continuous burst of any great duration, the motion of the plate must be reversed during firing. This means that immediately after the reversal, the next chamber to come into line is the same one which was fired just an instant before. A condition of this sort obviously makes it practically impossible to fire continuously at a high rate.

The rotating cylinder eliminates all of the disadvantages of the harmonica gun. The mechanism is compact and relatively easy to control. The shape of the weapon remains symmetrical throughout its operation and the balance remains practically unchanged. The most significant advantage is that the cylindrical arrangement of the chambers gives what is in effect an endless succession of chambers because after a chamber is fired, there is time available for extraction and reloading while the other chambers are being fired.

Although the revolver is very simple from the functional point of view, there are a number of problems connected with the design of revolver cannon which have defied complete solution for over 80 years. In revolver hand guns, all of which use comparatively low-powered ammunition and are fired slowly, these problems either do not exist to any serious extent or have been overcome adequately through good design and careful manufacture. Nevertheless, the operating conditions in high-powered, high-rate-of-fire revolver cannon are so radically different that expedients that have been fairly successful in hand guns fail completely when applied in aircraft cannon.

One of the most difficult problems in a revolver cannon is the leakage of high pressure powder gases which occurs at the joint between the forward end of the cylinder and the rear end of the barrel. Another serious difficulty that occurs with long bursts at high rates of fire is the tremendous amount of heat absorbed by the cylinder. Also there is a critical requirement for high precision in the cylinder indexing mechanism to insure that the chambers will be accurately aligned with the barrel bore. Finally, the fact that the projectile must have a rather considerable free run before it engages the rifling in the barrel causes an additional source of trouble. These four problems, although they may appear at first glance to be simple enough, have been proved by experience to be the stumbling blocks which have stood in the way of rotary chamber mechanism development throughout the entire history of modern machine guns. Because of the importance of these problems, they will be covered in some detail in the following paragraphs and the devices which have been so far applied for their solution will be analyzed in order to give an indication of what progress has been made and what work yet remains to be done.

First consider the problem of gas leakage. That this difficulty has existed and has been recognized for many centuries is very clear from the history of revolver weapons. In the very early days of firearms, when the tools and techniques for constructing accurately fitted mechanisms were not available, all revolving firearms that enjoyed any success were built on the "pepperbox" principle. That is, they employed a number of complete barrels rather than a single barrel with a separate revolving cylinder containing the individual chambers. Although the concept of using a separate cylinder was conceived at a very early date, it was not until the eighteenth century that the art of machining had advanced sufficiently to permit the actual construction of practical revolving cylinder weapons. It is highly significant that almost immediately after these guns appeared, there were many attempts to provide a positive means of sealing the joint between the cylinder and barrel. These attempts have continued, intermittently, from that day on.

Some of the sealing methods used in the hand guns of the past were fairly effective, but none of them have stood the test of time well enough to survive. In the modern revolver hand gun, the only precaution taken to limit leakage is the provision of a close fit between the cylinder face and the rear of the barrel. This does not by any means eliminate the leakage, even in a well-constructed weapon. In any such gun that has been fired several times, a considerable amount of powder fowling will be evident around the front of the cylinder and when the gun is fired at night, a substantial flash will be observed at the chamber gap. In this connection, it is interesting to note that a silencer, which works very effectively on a single-shot arm, is useless on a conventional revolver because the blast at the chamber gap produces just as much noise as the muzzle report. Thus it appears that, for hand guns at least, experience has proved it more practical to ignore the problem of leakage than to complicate the weapon with sealing devices. With pistol ammunition, which is all low-powered, the leakage problem is just not severe enough to warrant the use of remedial gadgets or special and expensive mechanisms.

Unfortunately, it is not possible to treat the gas leakage problem so lightly in a revolver weapon which employs high-powered ammunition. Leakage effects which are minor in pistol calibers become major problems at the extremely high chamber pressures produced by modern aircraft cannon ammunition. Earlier in this chapter, the problem of leakage was treated in general terms under the heading, "Principles of Multiple Chamber Weapons." At this point, it is appropriate to review the facts which are applicable to revolver weapons in particular and to consider in more detail the various devices used to prevent leakage in these weapons.

When a rotating mechanism weapon is fired, the pressure of the powder gases builds up with extreme rapidity and drives the projectile out of the cylinder into the barrel. It happens in most revolvers that the projectile passes into the barrel at practically the same instant that the chamber pressure reaches its peak value. In a modern aircraft cannon, this peak pressure may be in the vicinity of from 50,000 to 60,000 pounds per square inch, and as the projectile passes into the barrel, this tremendous pressure is suddenly brought to bear on the joint between the barrel and cylinder. If the joint is not tightly sealed, a very undesirable situation exists. Any considerable gap will result in a violent and destructive blast which could easily ruin the gun and anything near it. Even the presence of a small opening can cause serious difficulties because the high-pressure gases are at such an extremely high temperature and pass through the opening at such a great velocity that there will be a very rapid erosion at the joint. After a few shots, the damage caused by the erosion could be so great that the gun may fail to function or at least may become unsafe for further use. Blast and erosion are not the only difficulties which can result from ineffective sealing at the joint between the cylinder and barrel. It must be realized that the powder gas pressure continues to act at the joint for the entire time the projectile is being driven through the gun bore. If the leak is bad enough to permit the escape of any significant amount of the powder gases during this time, there may be a considerable loss in the muzzle velocity of the projectile.

There are three basic methods which have been used over the years for the purpose of sealing the joint between the cylinder and barrel to prevent the escape of the powder gases. The oldest of these methods has been used ever since the day of the flintlock and cap-and-ball revolvers and consists of a device for camming or wedging the cylinder forward before the gun is fired. This action closes the chamber gap and presses the forward face of the cylinder tightly against the rear face of the barrel. Another arrangement, which was conceived as soon as metallic cartridge ammunition came into general use, is to move the cartridge forward before the gun is fired so that the neck of the cartridge case is moved over the chamber gap and enters the barrel for a short distance. When the cartridge is fired, the neck is expanded and tightly seals the gap. The third method is that used in most of the present-day revolver cannons. This method uses a sealing piston or sleeve at the front end of each chamber opening in the cylinder. As the projectile passes through the sleeve, the force of the explosion drives the sleeve forward and holds it tightly against the rear face of the barrel until the pressure within the bore decreases to a relatively low value. Thus, during the action of the powder gas pressure, the sealing sleeve spans the chamber gap and holds the leakage to a minimum. In the following paragraphs, the three sealing methods mentioned here are analyzed to indicate the nature of the design problems involved in each of them and to explain further their functioning.

The method of camming the cylinder forward to effect the seal may take several forms. In its simplest form, the rear of the barrel and the front of the cylinder are merely machined to a smooth flat surface so that they will mate closely when the cylinder is cammed forward. Although this method has the advantage of ease of manufacture, it is not very effective because of the virtual impossibility of insuring a tight metal-to-metal contact around the entire periphery of the joint. Any slight defect of the surfaces, or the presence of particles of dirt or fouling in the joint, will adversely affect the sealing action. Even a small inaccuracy in the squareness of the mating surfaces or in the axial alignment of the mechanism will cause a gap to exist over a portion of the joint. If there is an imperfect seal for any of these reasons, the enormous pressure of the propellant explosion will force high-speed jets of extremely hot gas through the gaps. The resulting erosion will quickly ruin the mating surfaces and make further sealing impossible. Because of the sensitivity of this method to slight defects, it is not suitable for use in high-powered weapons.

A great improvement in the sealing action can be obtained by machining a conical surface at the rear of the barrel to mate with a conical counterbore at the forward face of the cylinder. When the cylinder is cammed forward, the surfaces have an action similar to that of an automobile valve. In moving together, the tapered surfaces have somewhat of a self-aligning action and under the high pressure of the camming mechanism, a metal-to-metal contact over a considerable area is more probable than with flat surfaces. However, with steel mating surfaces, the sealing action is still seriously affected by the presence of dirt or surface defects.

Still better results can be achieved by the use of soft metal sealing rings, two forms of which are shown in fig. 4–7. In the first type shown, a copper ring is expanded into a counterbore at the front face of the cylinder and has a conical mating surface of the type just described. When the cylinder is moved forward, the soft copper conforms quite readily to the surface at the rear of the barrel and produces a much better seal than would be obtained with both surfaces made of steel. A superior method of using sealing rings is shown in fig. 4–7B. With the arrangement shown in fig. 4–7A, the gas pressure acts directly on the joint and tends to force through at any point where a slight opening might exist or the contact pressure may be light. The only factor tending to prevent leakage is the force produced on the mating surfaces by the

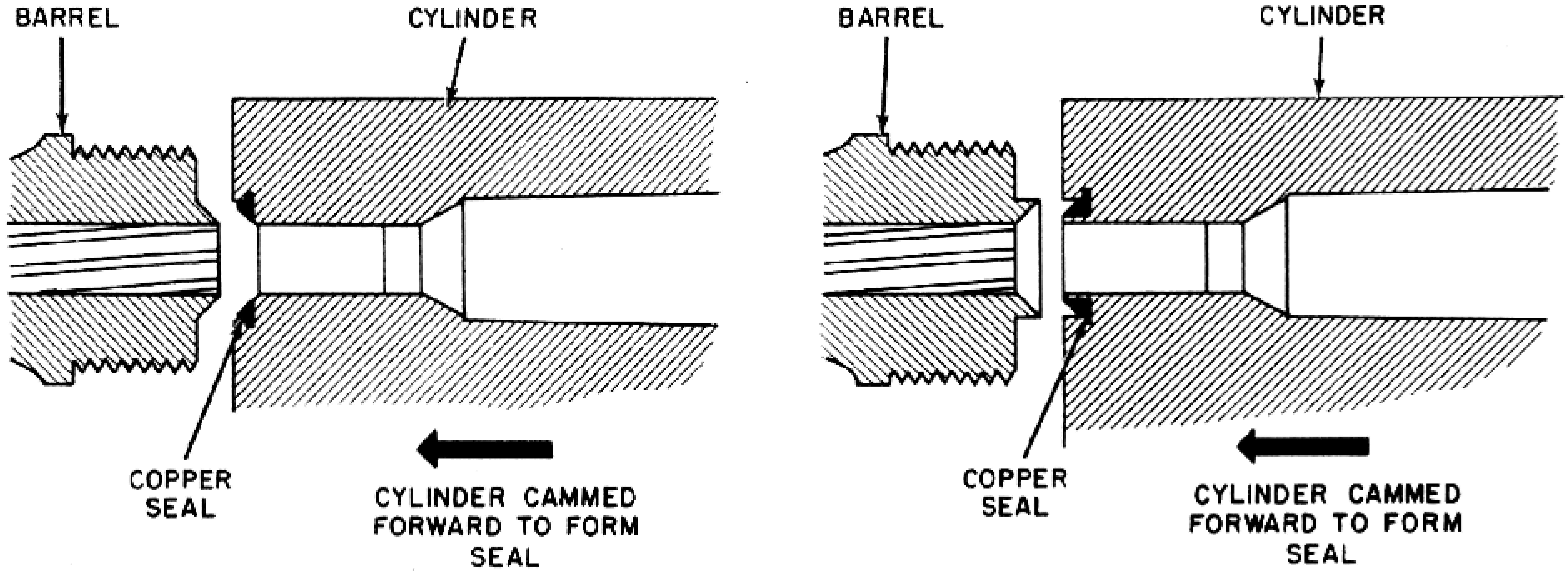

Figure 4–7. Use of Sealing Rings at Chamber Gap.

camming mechanism. On the other hand, a seal of the form shown in fig. 4–7B will tend to be expanded by the explosion of the propellant charge. Therefore the mating surfaces are forced together, not only by the thrust of the camming mechanism, but also by the extremely high pressure of the powder gases. Under the combined actions of these forces, a very tight seal is effected and leakage is practically nonexistent. It is interesting to note that this excellent sealing method can be found in percussion cap revolvers which date from more than 100 years ago.

Although good sealing can be obtained in a revolver by camming the cylinder forward and using sealing rings, the method is accompanied by certain difficulties. The necessity for the sliding motion of the cylinder complicates the cylinder mounting and increases the problems involved in the design of an accurate cylinder indexing mechanism. Also, the reciprocating motion which must be imparted to the cylinder requires additional mechanism to be built into the gun and this mechanism must be ruggedly constructed in order to handle the large forces it must absorb. Furthermore, the forward motion of the cylinder must occur before a round is fired and then, after the chamber pressure has decreased to a safe value, the cylinder must be withdrawn before it can be rotated to place the next round in the firing position. Because the cylinder is of necessity a fairly heavy part and therefore has considerable inertia, both the forward and rearward motions will require some small but significant amount of time which will cut into the time available for the other events of the firing cycle. In a high-rate-of-fire gun where the firing cycle time is in the order of only a few hundredths of a second, the time required for moving the cylinder in and out can easily have a tendency to slow down the rate of fire. Another important point is that the sealing rings must be quite soft to function properly and hence can be dented or deformed easily. If such damage to a ring occurs either through some malfunction of the mechanism or as the result of careless handling during cleaning or maintenance, it is likely that the high-pressure powder gases will quickly blow the seal out entirely, thus producing a very dangerous condition.

The next sealing method for consideration is that in which the cartridge case is pushed forward so that the neck of the case enters the barrel for a short distance. Here, again there are several possible ways of arranging the mechanism. In one method, as shown in fig. 4–8, a so-called "buried" projectile is used, that is, the neck of the cartridge case extends entirely over the projectile. When the cartridge is seated in the chamber opening, a small portion of the neck of the case projects beyond the front face of the cylinder. After the chamber has been positioned behind the barrel, the entire cylinder is moved forward to close the gap between the cylinder and barrel and the projecting neck of the cartridge case enters the barrel. The neck of the case thus spans the small seam where the cylinder joins the barrel. The explosion of the propellant charge causes the cartridge case material to be expanded tightly against the inside of the barrel so that the gas pressure

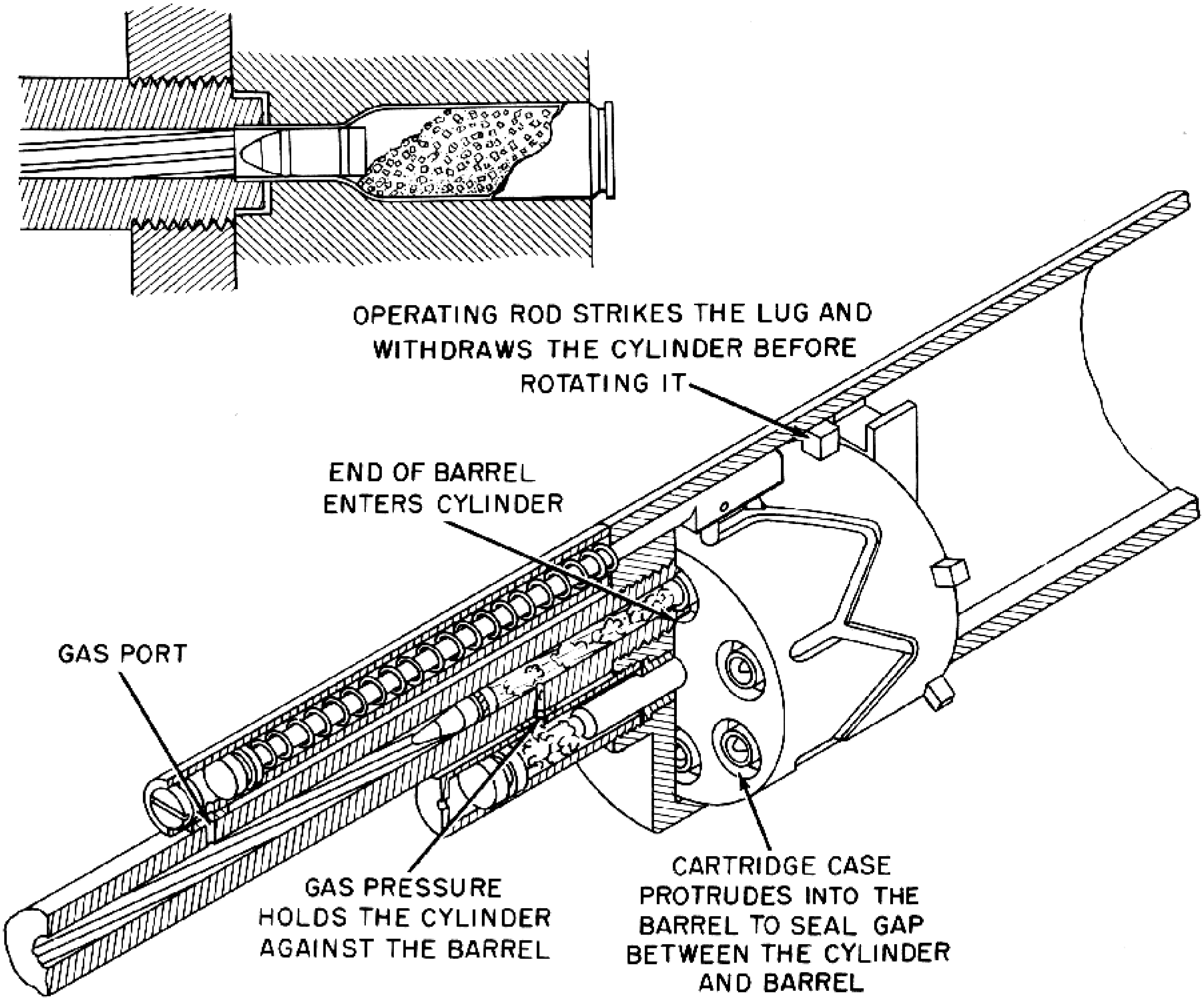

Figure 4–8. Method of Sealing With Neck of Cartridge Case (With "Buried" Projectile Ammunition).

is entirely sealed off from the seam. In spite of the fact that the cartridge case material is quite thin at the neck, there is no tendency for the case to be blown out at the seam, providing of course that the gap is not excessively large. The permissible width of the gap depends entirely on the thickness of the material at the neck of the case. For the thickness found in typical 20-mm cartridge cases, experience has shown that a gap of over 1/32 inch can be tolerated without failures. In a well-constructed weapon there should be no trouble experienced in keeping the final width of the gap well below this figure and consequently there will be little danger of case blowouts.

The objections to this method of sealing are similar in some ways to those cited for the method previously described because its use requires the cylinder to be cammed forward to effect the seal. Hence it has the same mechanical difficulties and the same tendency to slow down the rate of fire. The form of the ammunition also presents problems, particularly in the larger calibers where it is necessary for the projectiles to be provided with rotating bands. With ordinary ammunition, the cartridge case is crimped to the projectile behind the rotating band but with the "buried" projectile type of cartridge, the case must cover the entire projectile. Such a round is not only difficult to assemble properly, but the projectile is also required to move through the neck of the case for a considerable distance when the gun is fired and therefore may not receive proper support. In addition, the round is of an awkward shape for rapid feeding and the thin, unsupported front portion of the case can easily be damaged in handling or in the ramming phase of the loading cycle.

If ammunition of conventional form is to be used, it is not practical to use the method of sealing described above because it would be necessary for the cartridge to protrude too far beyond the front face of the cylinder. The exposed portion of the cartridge would have to include the entire length of the projectile forward of the crimp as well as the part of the case neck which is to enter the barrel. This means that the cylinder would have to be cammed forward and back again through this whole distance each time the gun is fired. Such an excessive reciprocating motion of the cylinder would be entirely out of the question in any high-rate-of-fire rotary action mechanism.

Dating from about the turn of the century, there have been several instances of a rather clever type of rotary chamber mechanism which makes it possible to use conventional ammunition in such a way that the principle of neck sealing can be employed without the necessity for imparting a reciprocating motion to the cylinder itself. In this mechanism, the cylinder is mounted and rotated in the conventional manner but until a chamber reaches the firing position, the round in that chamber is not pushed all the way home (fig. 4–9). When the chamber does reach the firing position, a sliding bolt drives the

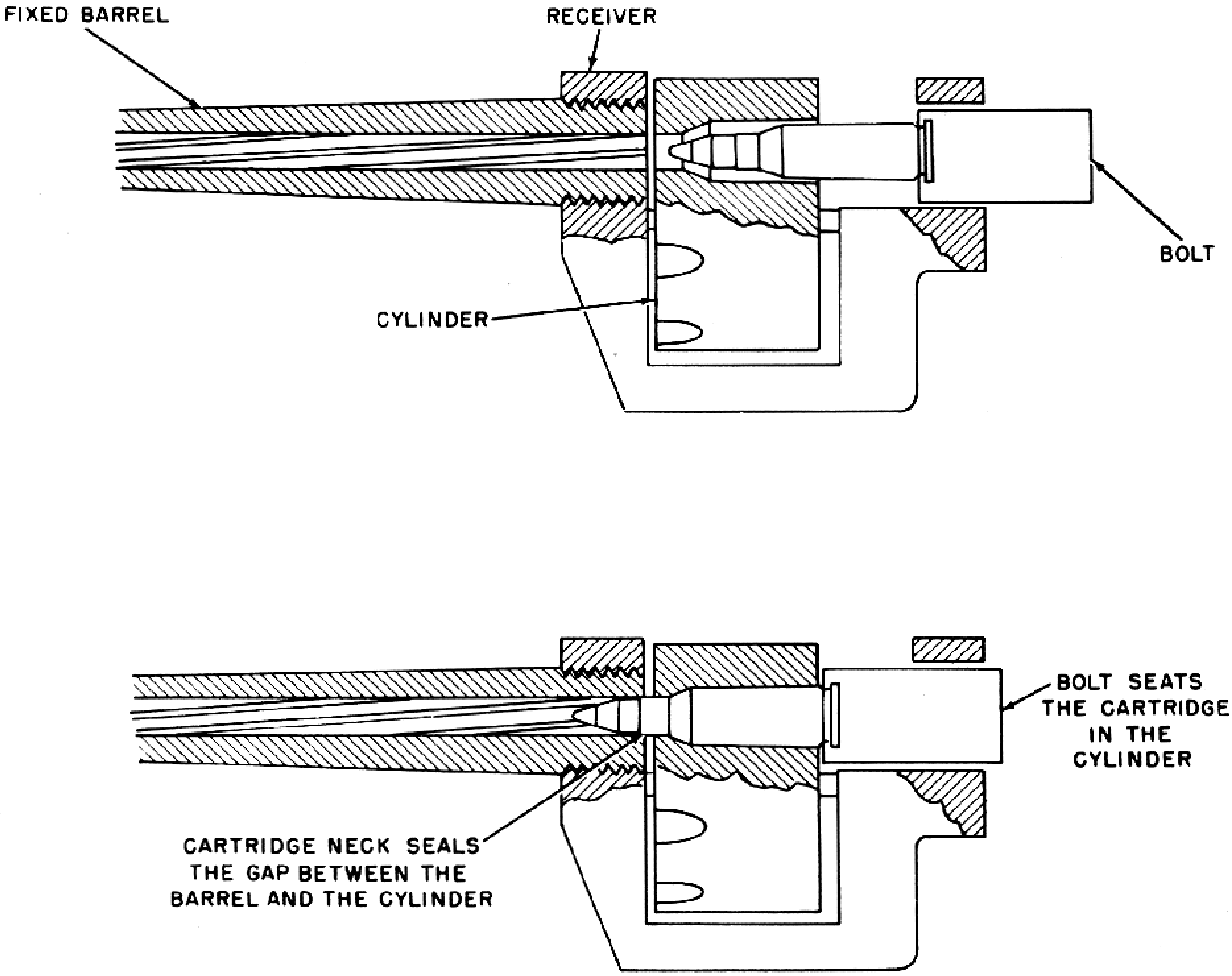

Figure 4–9. Method of Sealing With Neck of Cartridge Case Using Conventional Ammunition.

cartridge forward to seat it fully in the chamber and the bolt is then locked in place. The distance through which the cartridge moves is sufficient to cause the projectile and a small portion of the cartridge case neck to enter the barrel as is required to produce the sealing action. After the cartridge is fired and the chamber pressure decreases to a safe operating limit, the bolt is unlocked and moves to the rear to extract the spent cartridge case.

From the preceding description, it is evident that this mechanism combines the functions of both a revolver action and a reciprocating bolt action. The revolution of the cylinder can be accomplished by the same methods as are employed in a conventional revolver and the bolt can be operated in essentially the same way as in an ordinary reciprocating action. However, there are a number of points concerning the reciprocating portion of the mechanism which require further consideration.

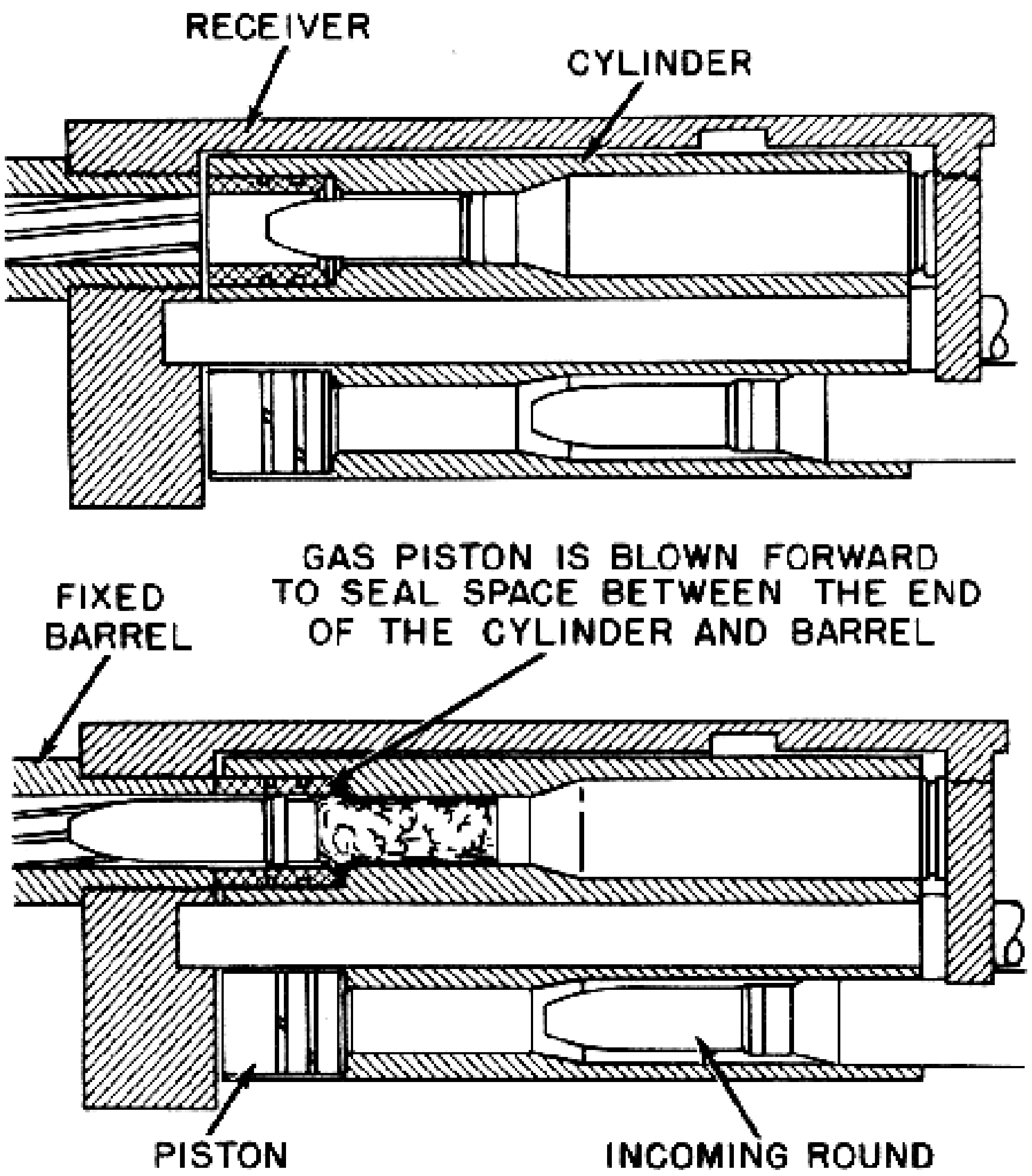

Figure 4–10. Action of Gas Piston Seal.

The characteristics of the bolt mechanism will depend to a large extent on the manner in which extraction is accomplished. In the preferred method of operation, the bolt moves back only through a sufficient distance to be in a position to engage the next round. This means that the bolt only partially extracts the cartridge case and the completion of extraction and ejection is delayed until the rotation of the cylinder moves the cartridge case off to one side of the bolt mechanism. This same movement of the cylinder will bring a fresh cartridge into the firing position and the bolt is then released to push this cartridge home. With this type of operation, it can be seen that the length of the bolt stroke is very short when compared with the bolt stroke of an ordinary reciprocating gun. Since the distance moved by the bolt need only be as great as the length of the exposed portion of the projectile plus a small part of the cartridge case neck, the bolt stroke will only be from one-third to one-half the length of the complete round. On the other hand, the bolt stroke in a conventional reciprocating weapon must be at least as long as the entire round and usually is considerably longer. The advantage of the very short bolt stroke required in the combination action is that the bolt motion can occur at a relatively low velocity. On account of this low velocity, the accelerations and shocks to which the bolt is subjected during firing are well below the critical and limiting values experienced in ordinary high-rate-of-fire reciprocating actions. Therefore, the mechanism is capable of producing very high cyclic rates without the difficulties usually associated with sliding bolt mechanisms.

Except for the fact that the action of the bolt must be synchronized with the indexing of the cylinder, the design of the bolt mechanism of a combination gun is governed by essentially the same principles used for conventional reciprocating guns. The energy for operating the mechanism can be obtained conveniently from recoil or gas actuation and the blowback action produced by the residual pressure can also be utilized with good effect. Because the principles of the blowback, recoil, and gas systems are covered in the preceding chapters of this publication, they will not be repeated here.

The third method of sealing to be covered in this analysis is that which makes use of sealing pistons mounted in the cylinder at the forward end of each chamber opening as shown in fig. 4–10. The piston is in the form of a sleeve with an internal diameter just large enough to permit the projectile to pass through it. At the instant the rotating band of the projectile passes the rear face of the piston, the high-pressure powder gases expanding behind the projectile get behind the piston and drive it forward with great force. The piston moves forward so quickly that it moves across the chamber gap and its front surface becomes tightly pressed against the barrel face before the rear part of the projectile has entered the barrel. As the projectile moves through the barrel, the gas pressure acting on the rear of the piston maintains a tight metal-to-metal seal at the face of the barrel and the piston rings prevent the escape of gas around the outside of the sleeve. When the residual pressure in the bore falls to a relatively low value, the forward force on the piston decreases to the point where the cylinder can be rotated to bring the next round into position for firing.

The gas piston method of sealing the chamber gap is very simple from the functional viewpoint and does not add greatly to the cost and complexity of the gun. In addition, when it is properly used, it produces a quite effective sealing action. However, like all of the other sealing devices described up to this point, the use of piston seals involves a number of important problems which must be given careful consideration in design.

The sealing action produced by the piston is similar in nature to that produced by the first method described in this analysis. That is, the main sealing action results from a high-pressure metal-to-metal contact between two flat surfaces. When the surfaces are in good condition, accurately aligned, and free of dirt particles, they can bear tightly against each other over a sufficient contact area to effect an excellent seal. However, if there is any defect which prevents good contact, the sealing action will be imperfect and the consequent leakage of the extremely hot high-velocity powder gases will quickly erode the surfaces. The seal will then quickly deteriorate and soon become useless.

Another very serious problem arises from the tremendous force applied to the piston by the peak chamber pressure. As mentioned previously, the peak pressure produced by modern high-powered aircraft cannon ammunition can range anywhere from 45,000 to 65,000 pounds per square inch. In a 30-mm gun, the sealing pistons will have an internal diameter of approximately 1.2 inches and a reasonable wall thickness for the piston is about 0.3 inch. This means that the area exposed to the forward acting pressure of the powder gases will be nearly 1.5 square inches. If it is assumed that the peak chamber pressure is 65,000 pounds per square inch, the force which drives the piston forward will be in the order of 98,000 pounds. Since the piston is relatively light in weight, it will be driven forward with great violence and will strike the barrel face with a very sharp impact. Under these conditions, the rear face of the barrel and the front surface of the piston are subjected to a severe hammering and the entire body of the piston must absorb an intense shock. To add to these difficulties, the temperature of the piston rises rapidly during a burst and may quickly reach the point where it tends to weaken the piston material. All of these factors make it extremely difficult to make effective use of piston seals in rotary action cannons which employ very high-powered ammunition. Even when special alloy steels are used, the pistons tend to break down quickly, either from battering at the sealing surface or from actual crushing of the piston body itself.

The use of piston seals creates other problems which are not directly related to the sealing action but do affect the design of the gun itself. One of these problems can be appreciated readily by those familiar with the Williams floating chamber device which is used to cause a .22 caliber cartridge to produce the same recoil as the round used in a .45 caliber automatic pistol. In a revolver weapon, the piston seal produces the same effect of magnifying force, although the presence of the increased force is not evidenced in the same way. The forces resulting from the action of the piston seal and the effect of these forces can be seen in fig. 4–11.

If it were not for the presence of the piston seal, the only rearward force produced by the pressure of the powder gases would be the force due to the pressure on a portion of the base area equal to the bore cross-section area. The rearward pressure on the remainder of the base area is cancelled by an equal and opposite pressure which acts forward on the tapered portion and shoulder of the cartridge case. The effective pressure is transmitted through the base of the cartridge case to the frame of the weapon. The force produced by the pressure creates a tension in the frame and also is the force which causes the weapon to move in recoil.

The action of the piston seal produces an additional force within the weapon. As indicated in fig. 4–11, the powder gas pressure thrusts the piston seal forward and at the same time acts against the surface at the bottom of the counterbore in which the piston slides. The forward acting force is transmitted through the piston to the barrel and thence to the frame while the rearward force is also transmitted to the frame through the cylinder and cartridge case. These forces are equal and opposite and therefore do not intensify the recoil but they do act to cause an additional tension in the frame. As previously shown, this additional force can be almost 98,000 pounds (for a 30-mm gun with a peak chamber pressure of about 65,000 pounds per square inch). Since the effective force on the base of the cartridge case due to the pressure acting on the bore cross-section area is only approximately 74,000 pounds, it is evident that the use of the piston seal can more than double the tension in the frame. With a total tension of 172,000 pounds instead of only 74,000 pounds, it will be necessary to use a much stronger and heavier frame structure than if the piston seals were not used.

Depending on the form of the ammunition fired by the gun, it is possible that the presence of the piston seals may result in a further design disadvantage. In designing the cylinder of a revolver machine gun, it is desirable to space the chambers as closely as possible by keeping the walls between the chambers at the minimum safe thickness. A compact arrangement, such as is shown in fig. 4–12A, makes it possible to hold the cylinder to a small diameter and to minimize its weight and inertia. This not only makes for a less bulky weapon, but also decreases the power required for operation and lessens the strain on the rotating mechanism.

In order to withstand the forces to which they are subjected, piston seals must have a substantial wall thickness. If an attempt is made to counterbore the chambers for receiving suitable seals, a situation like that shown in fig. 4–12B may result. The counterbores might actually overlap or the walls remaining between them might be entirely too thin for safety. To provide sufficient room for the counterbores, it is necessary to respace the chambers as shown in fig. 4–12C. Therefore, the cylinder will be larger and heavier and the design will suffer from all of the consequent disadvantages. Of course, these remarks apply only when the ammunition is nearly cylindrical in form, that is, when the cartridge case is not much larger in diameter than the projectile. When the cartridge case is strongly bottle-necked, there may be ample metal for accommodating the seals at the forward end of the cylinder even when the chambers are spaced as closely as possible at the rear.

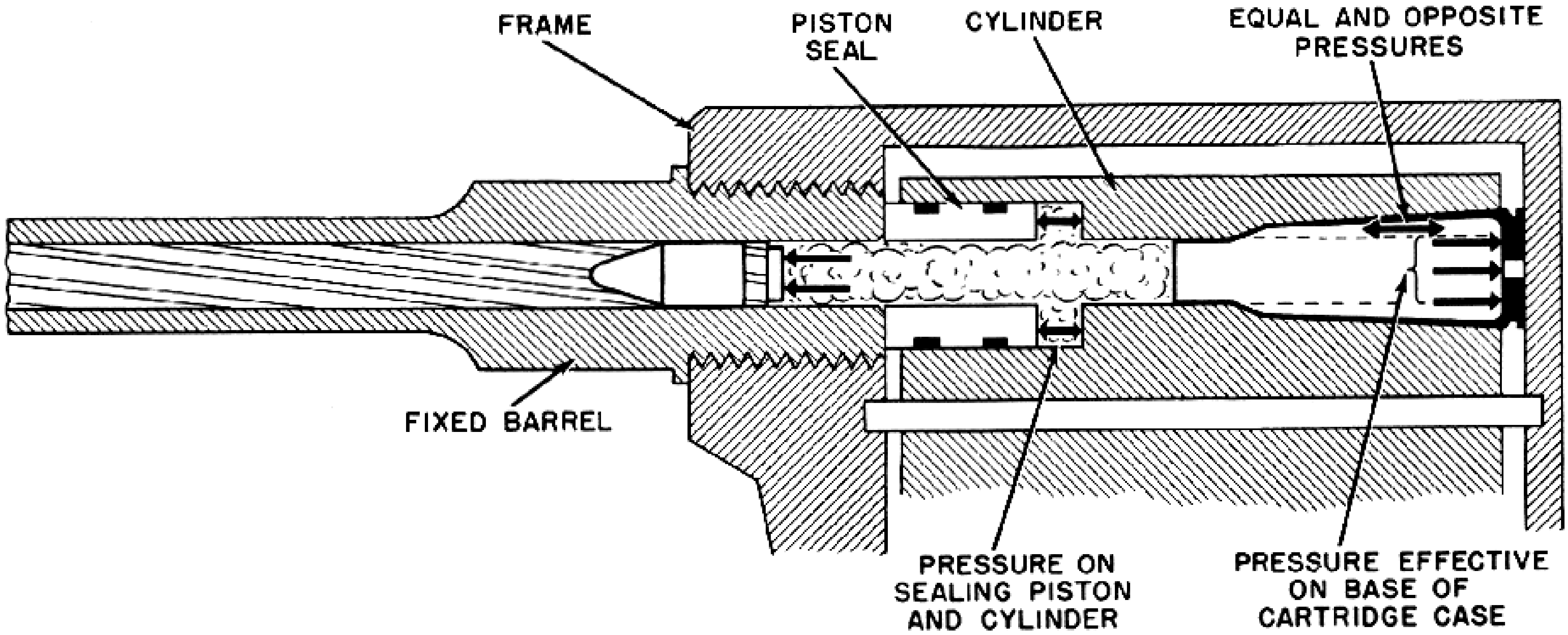

Figure 4–11. Effect of Piston Seal on Force Applied to Revolver Frame.

The preceding paragraphs are concerned with the problem of gas leakage in full automatic rotary action machine guns. The next important problem for consideration is caused by the great amount of heat absorbed by the cylinder during long bursts at the extremely high rates of fire being attempted with modern rotary action cannon. The magnitude of this problem can be illustrated readily by one rather startling fact. The ammunition used in one modern 30-mm revolver gun is loaded with a 1060-grain propellant charge and the gun is designed to fire at a rate of 1200 rounds per minute. Since there are 7000 grains to the pound the amount of powder burned per minute is:

$$\frac{1060}{7000} \times 1200 = 181 \text{ (pounds)}$$

It is truly amazing to realize that this amount of smokeless powder would more than fill two large feed-sacks and that it is burned at such a rate that it all would be consumed in one minute inside a steel cylinder which weighs only about 50 pounds and is less than one foot long. The rate at which thermal energy is released in firing a weapon of this type is tremendous, particularly when the relatively small physical dimensions of the cylinder are taken into account.

During a sustained burst, the cylinder of a high-rate-of-fire rotary action mechanism absorbs enough heat to cause its temperature to rise quite rapidly. Even with bursts of moderate length fired at intervals, the heat will be retained in the cylinder between bursts and can build the temperature up to the danger point in a relatively short period of time. When the temperature of the cylinder reaches a level of from 600° to 800° F., it is possible for a "cook-off" to occur. This condition is particularly dangerous in a rotary action weapon because of the fact that the gun may stop firing with live cartridges in chambers which are not aligned with the barrel. If these cartridges should cook off, the results would be disastrous.

The heat problem in high-rate-of-fire rotary chamber mechanisms is so critical that it either places a severe limitation on the number of rounds which can be fired over a given period, or requires the development of an effective method of cooling the cylinder. Cooling by normal air flow around the cylinder is not likely to be successful, particularly because a large portion of the cylinder is usually covered by the other parts of the gun. The fact that the cylinder revolves will probably make the use of jacketing and liquid coolant impractical. One method of cooling which can be used is to spray a refrigerant gas through the chambers after the fired cartridge is ejected. Further heat removal could be accomplished by using the same means to cool the outside of the cylinder. In any case, the cooling system used for the cylinder will be the major factor affecting the ability of the gun to deliver a high volume of fire.

The third problem which has proved to be a stumbling block in the development of high-rate-of-fire rotary action cannon is the requirement for high precision in the cylinder indexing mechanism. This problem arises because of the necessity for maintaining a very accurate alignment of the chamber with the barrel bore at the instant the gun is fired. In revolver hand guns, this same alignment requirement exists but is much less critical. With low velocity bullets made of soft lead, a small misalignment is not too serious because the worst that can happen is that the gun will shave some lead and the accuracy of fire may be upset. However, in aircraft cannon, the effect of misalignment can be very dangerous. If the chamber and barrel bore are not concentric within 0.005 inch, it is likely that the rotating band of the projectile will be sheared off. This will not only cause the flight of the projectile to be very

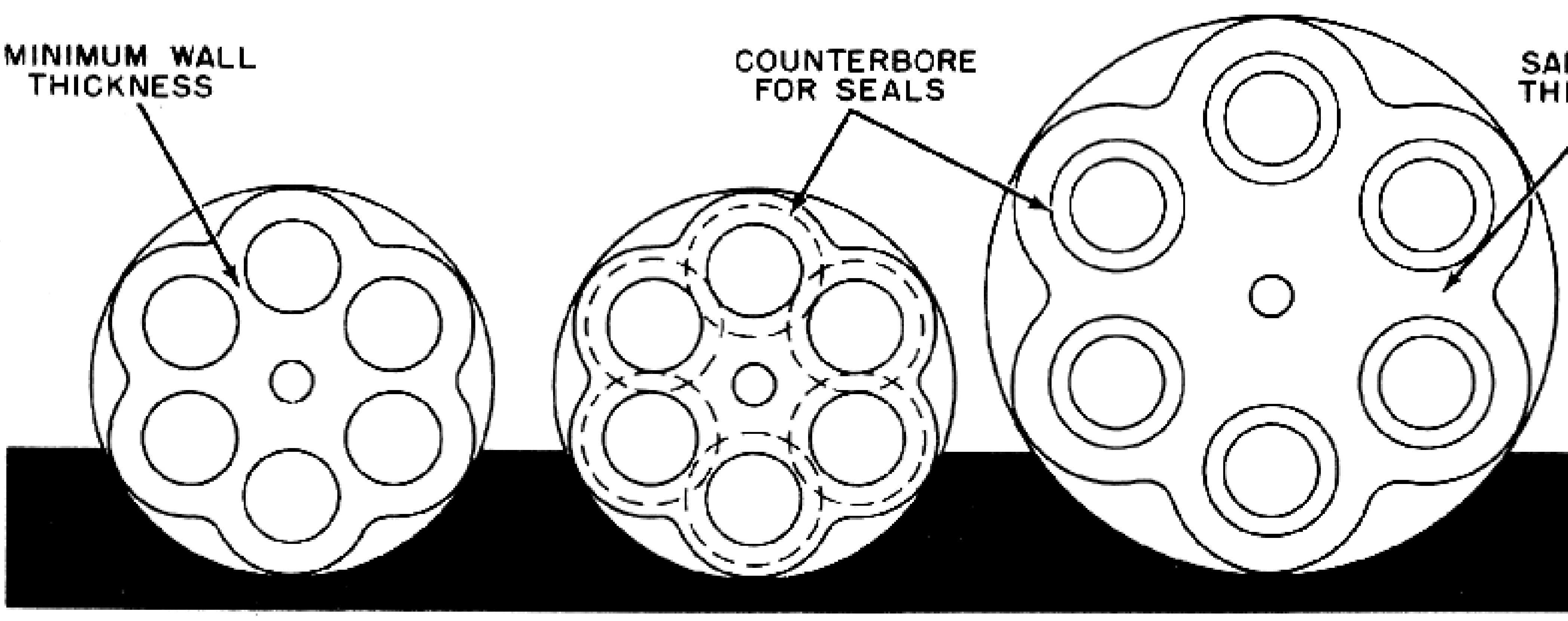

Figure 4–12. Effect of Space Required for Piston Seals.

erratic but the sheared-off band may jam the mechanism or may become caught in the barrel in such a way as to create a dangerous condition. A slightly greater eccentricity can be really disastrous. The projectile enters the barrel at a very high velocity and if it encounters any positive interference as it does so, it may tend to twist and batter itself within the barrel. The possible consequences of such an occurrence, particularly with H. E. ammunition and a chamber pressure in the order of 60,000 pounds per square inch, are not pleasant to contemplate.

The problem of insuring that the chamber and barrel bore will always be concentric within 0.005 inch at the instant of firing is extremely difficult in a high-rate-of-fire revolver. The mere accumulation of dimensional tolerances creates a terrific production problem. The following are some of the factors which must be considered: First, the chambers must be bored in the cylinder so that their axes are accurately parallel and all lie precisely on a true circle of a definite diameter. The angular spacing of the chambers around this circle must also be held accurately. The cylinder must be mounted on an axle which must also be concentric with the circle and the bearings in which the axle turns must permit no side play or runout. The bearings must be located in the frame so that the chambers will line up accurately with barrel bore. If the barrel is screwed into the frame, the concentricity of the bore and the threads must also be held. The fact that the tolerances on all of these dimensions are directly cumulative makes it very difficult to achieve the required alignment between the barrel and cylinder.

The foregoing points are only concerned with the machining and mounting of the rotary chamber mechanism in relation to the barrel. An even more complicated chain of dimensions may be involved in the indexing mechanism and some of the tolerances on these dimensions will accumulate with the tolerances on the dimensions previously mentioned. Although modern manufacturing methods permit very accurate control of dimensions, extremely close control is expensive. It can be seen that even with very small tolerances, the specified 0.005-inch concentricity between the chambers and the barrel is really an exacting requirement.

No matter how accurately a revolver machine gun may be built, the problem of alignment does not end when the weapon is at last completely assembled. Even if the dimensions have been controlled so that the cylinder can be indexed to bring each chamber into alignment with the barrel within the tolerance, there is no assurance that this will still occur when the weapon is burst fired at high cyclic rates. In a high-powered weapon fired at a high rate, the entire gun structure and the mechanism are subjected to very large forces and dynamic disturbances which can cause considerable elastic deformations in the parts. Vibrations, thermal expansion, and other influences can all contribute to dimensional changes which can upset the alignment achieved with the gun in the static condition. To make matters worse, the occurrence of even a small amount of normal wear at certain critical points can quickly destroy the usefulness of the weapon.

Thus it is evident that the proper functioning and reliability of a rotary action cannon is critically dependent on the simple factor of alignment between the chambers and the barrel. This alignment is so difficult to achieve and maintain that the development of rotary chamber mechanisms has been slowed down very seriously. It is possible that this problem may be solved by the development of some device which will provide a direct and positive means for bringing the chamber into alignment with the barrel. It also may be that the fundamental difficulty should be sidestepped completely by using a mechanism which moves the round forward so that the projectile enters the barrel before firing.

The last of the four problems which have bottlenecked rotary action development for over 80 years is concerned with the free run of the projectile before it enters the barrel. In an ordinary rotary chamber mechanism, the projectile must travel for a distance approximately equal to its own length in passing from the cylinder into the barrel. In moving through this distance, the projectile is driven by very high chamber pressures so that it picks up speed very rapidly. By the time the rotating band engages the rifling in the barrel, the projectile is moving forward at high velocity but has not yet started to spin. When the rotating band meets the rifling, the band is immediately engraved and the twist of the rifling causes a torque to be exerted on the projectile. With standard rifling, the applied torque is very large because the rifling attempts to produce instantaneously the rotation speed called for by the twist of the rifling and the high forward velocity of the projectile. Naturally, the projectile has a considerable inertial resistance to rotation and the force required to overcome this resistance to rapid angular acceleration may be greater than the shear strength of the rotating band. If this is the case, the surface of the band may be stripped off completely before the projectile has acquired any considerable spin velocity and the flight of the projectile after it leaves the muzzle will therefore be unstable. A condition of this sort is certain to make the gun hopelessly inaccurate.

Some improvement of this condition may be possible with the use of progressive twist rifling, particularly if the rifling starts at zero twist and increases gradually to full twist. Rifling of this type would tend to accelerate the spin of the projectile more smoothly so that there would be a much better chance of not stripping the rotating band. However, if the projectile is moving too rapidly when it engages even this type of rifling, the rotating band may still be stripped. Although the acceleration would be smooth, it would have to be quite high and it is possible that the rotating band could not stand the required force.

Another solution to this problem would be to employ the combination type of action in which the round is moved forward so that the projectile enters the barrel before firing. If this is done, there will be no free travel of the projectile and the rifling will function in the normal manner with no danger of stripping the rotating band.

PART XI

SCHEMATIC ILLUSTRATIONS OF REPRESENTATIVE MECHANISMS

Chapter 5

FEED SYSTEMS

A. Lever Type

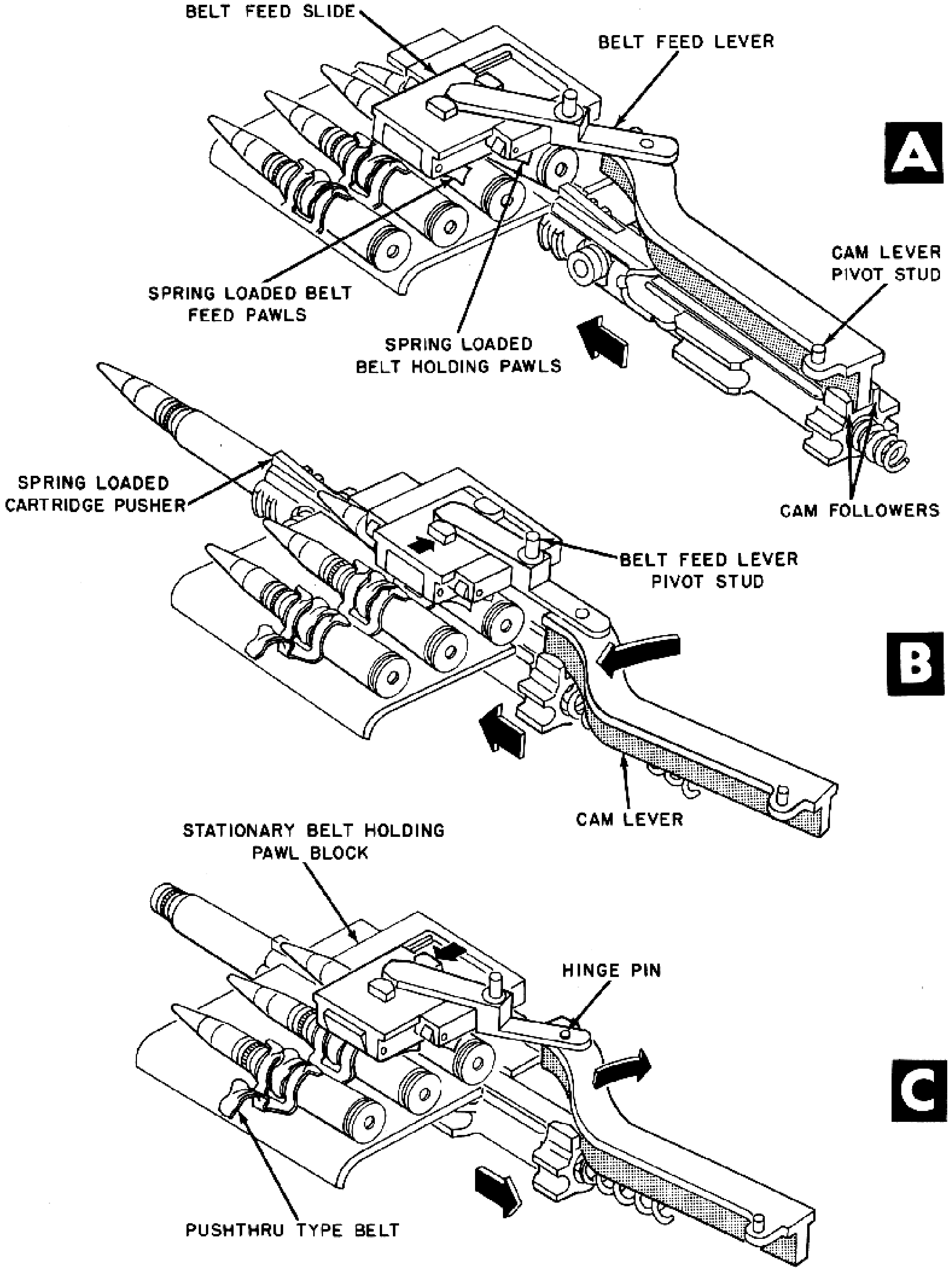

Figure 5–1. Cam Followers on Bolt Actuate Belt Feed Lever.

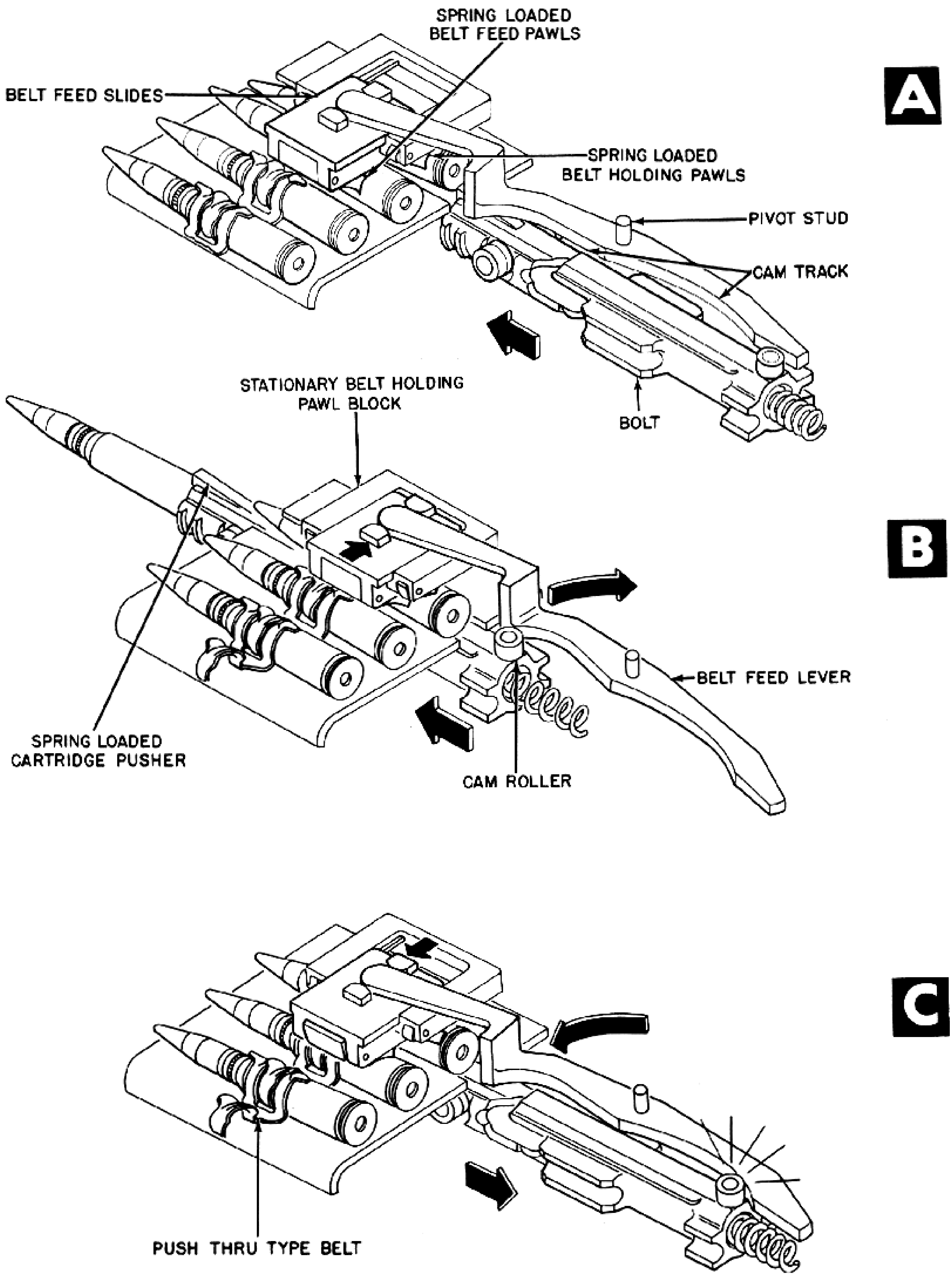

Figure 5–2. Roller on Bolt Actuates Feed Lever.

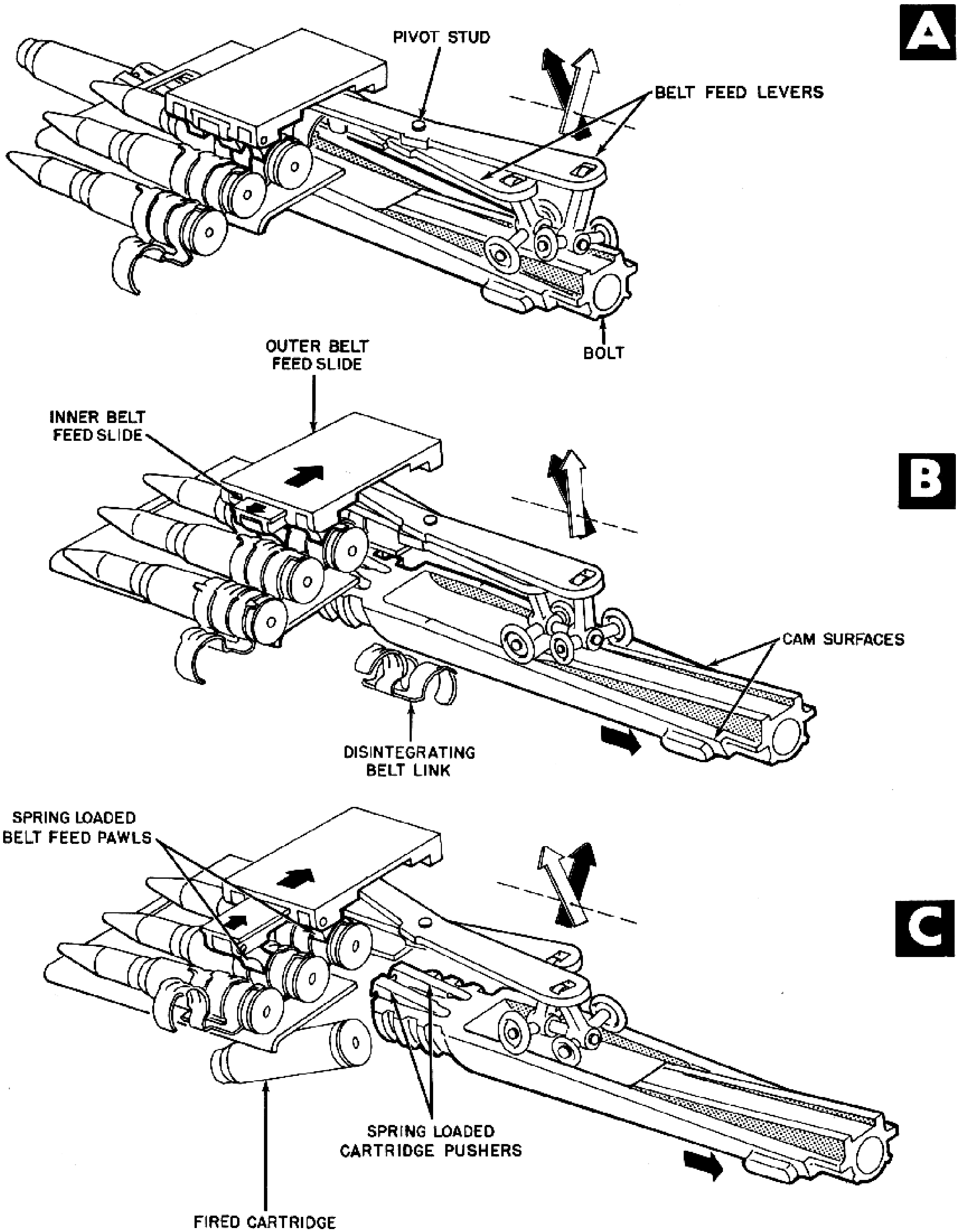

Figure 5–3. Cam Surfaces on Bolt Actuate Belt Feed Lever.

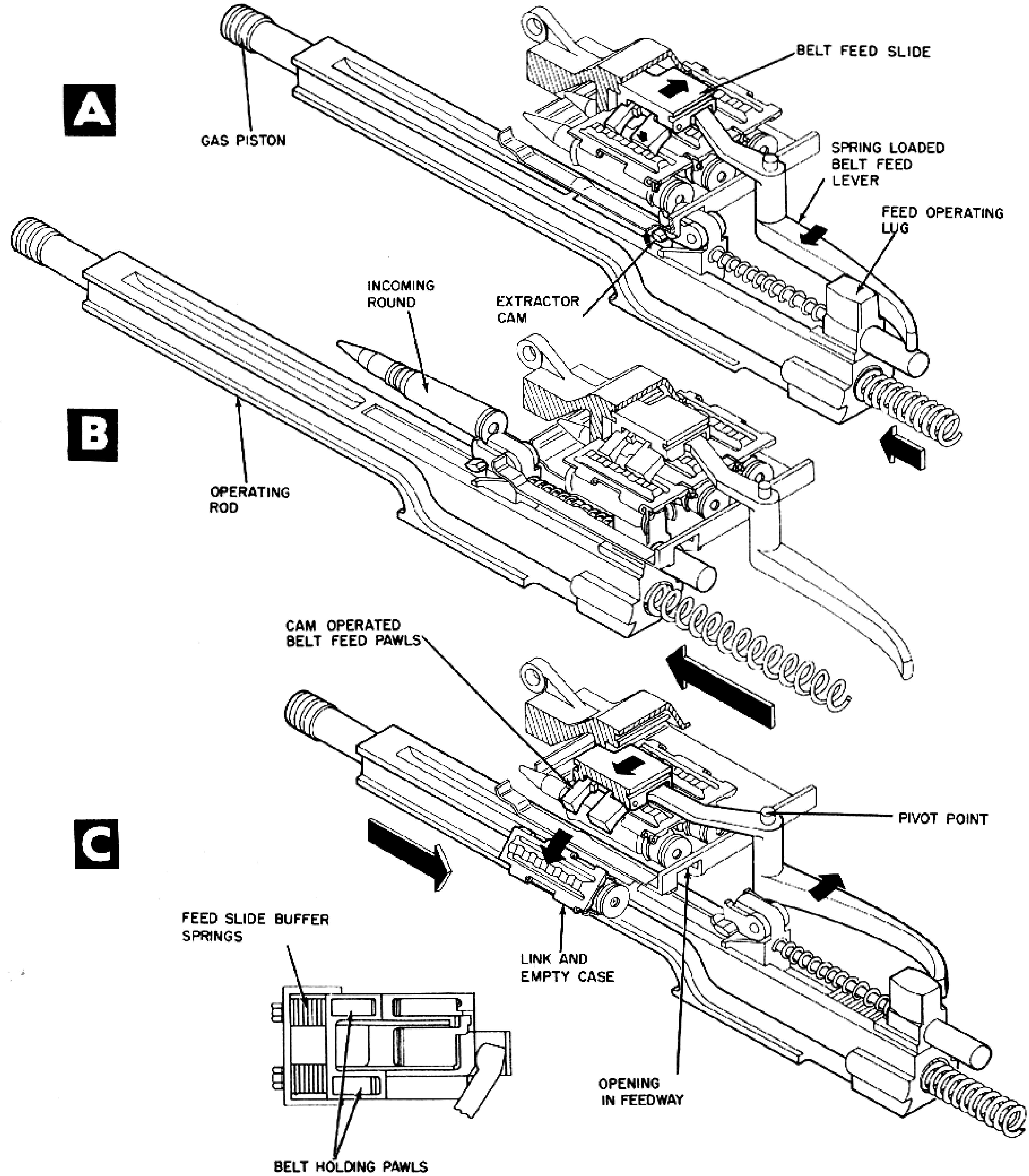

Figure 5–4. Lug on Operating Rod Actuates Belt Feed Lever.

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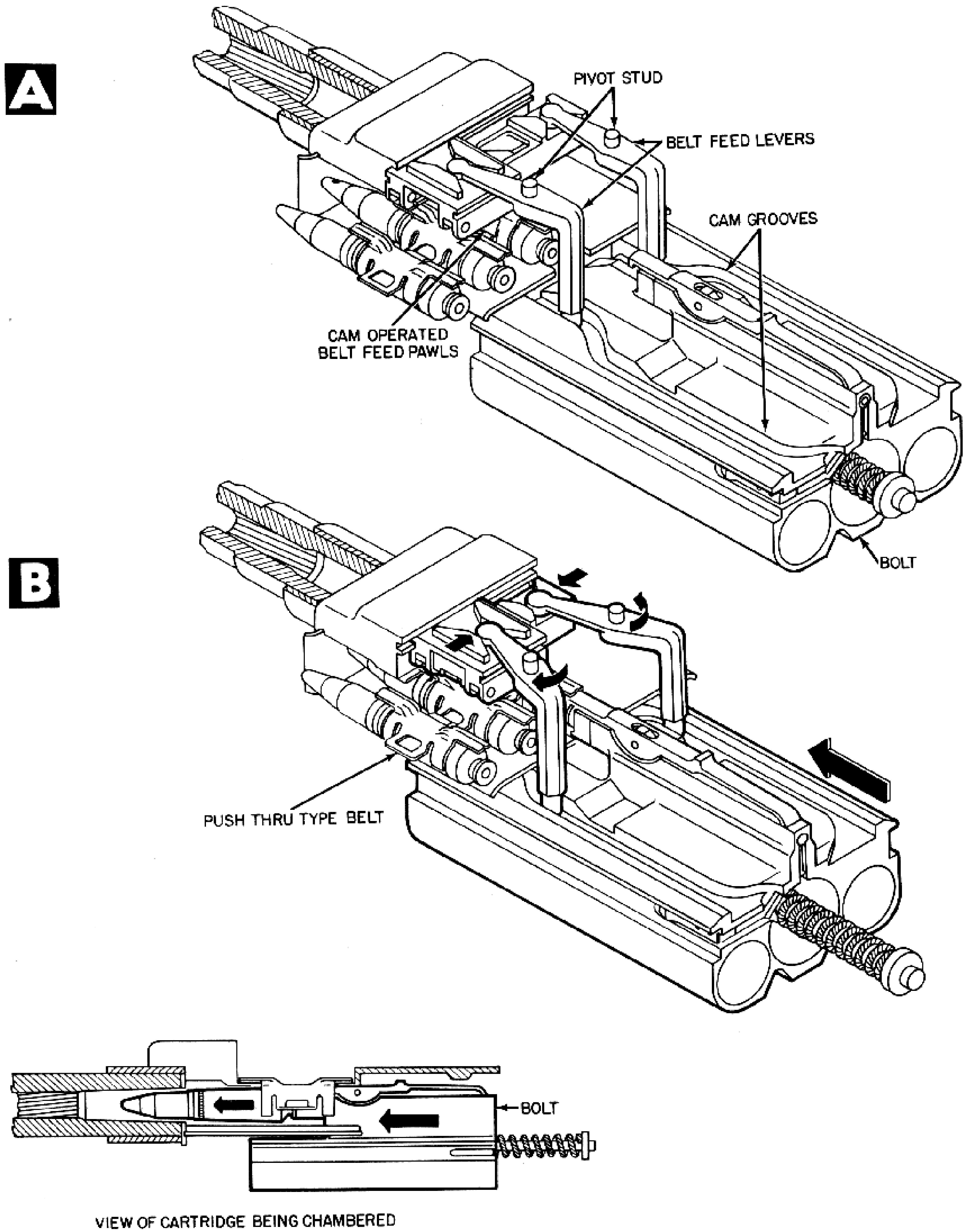
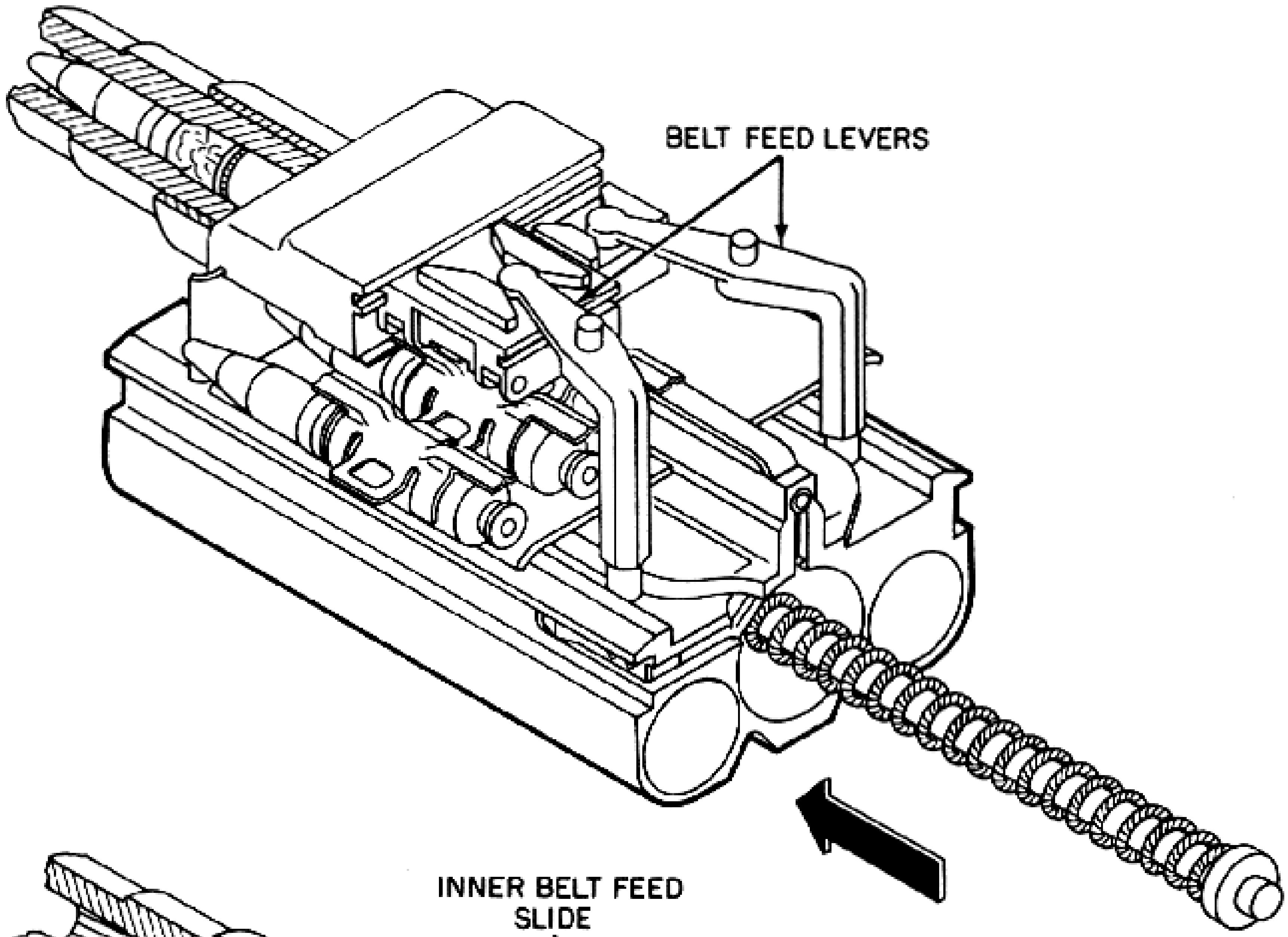


Figure 5–5. Cam Grooves in Bolt

C



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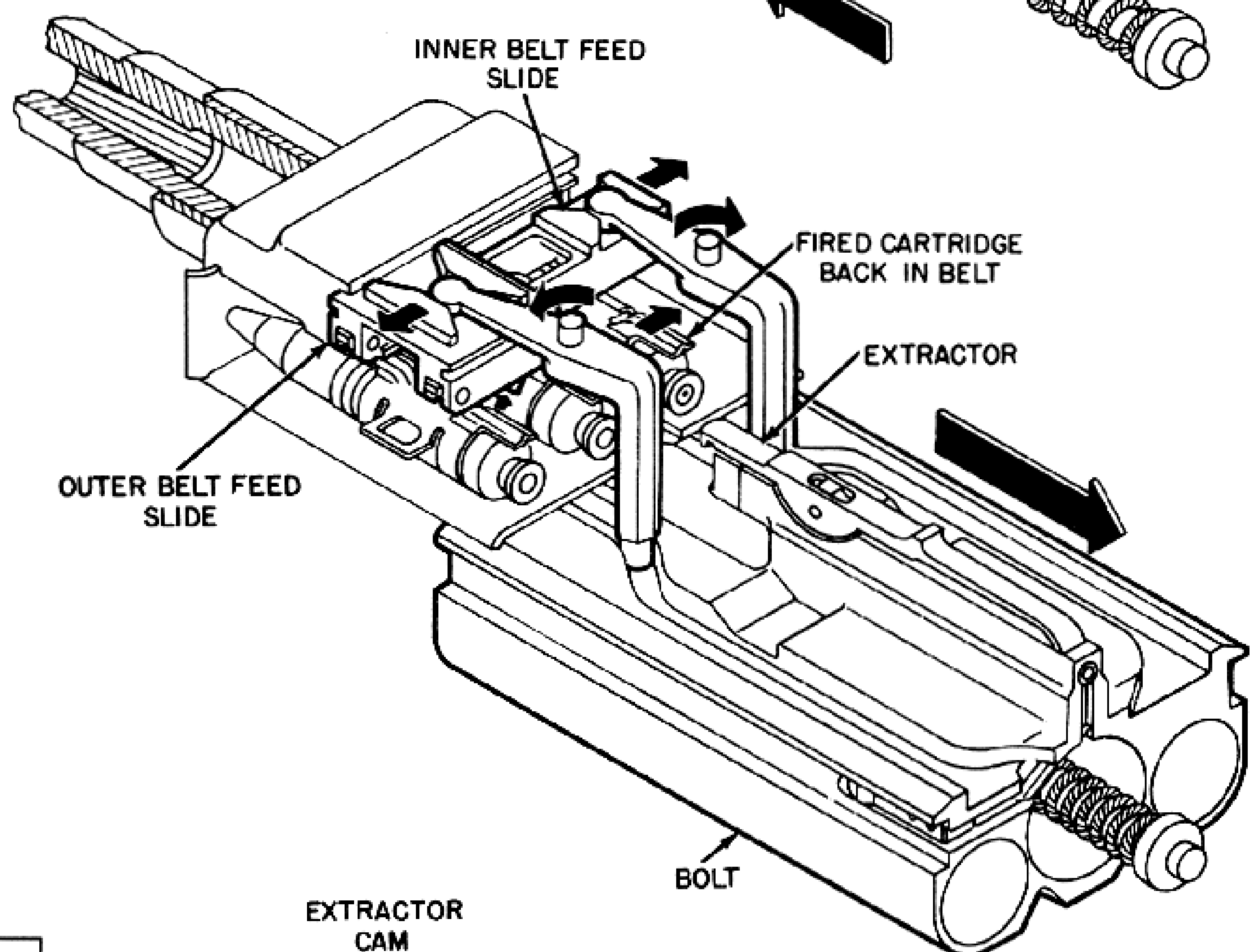
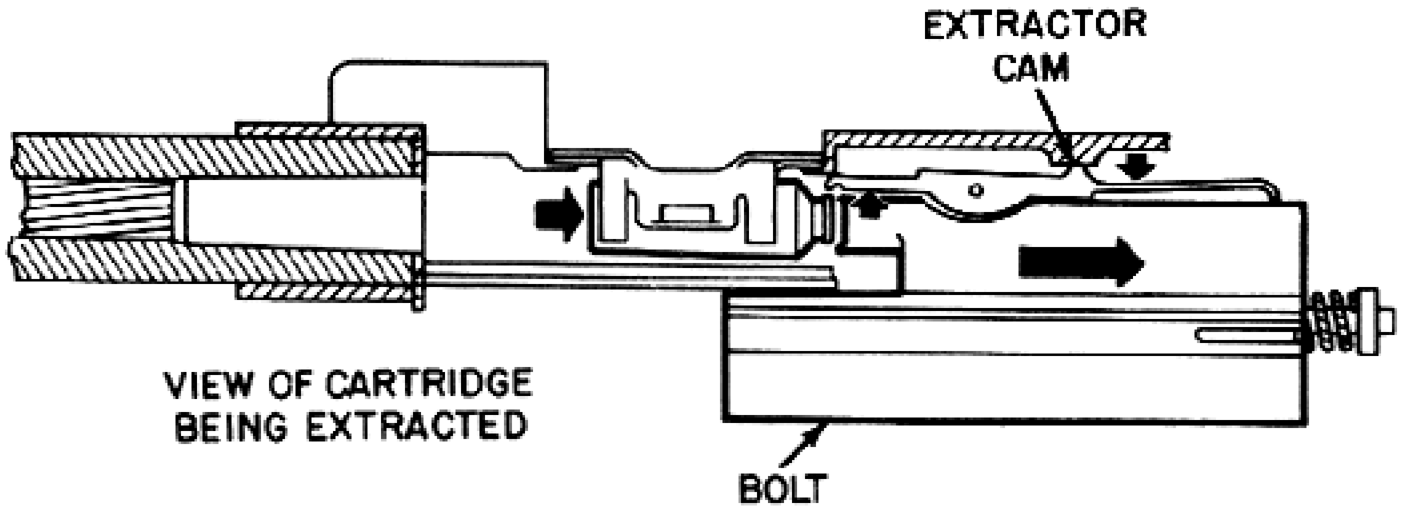




Actuate Belt Feed Lever.

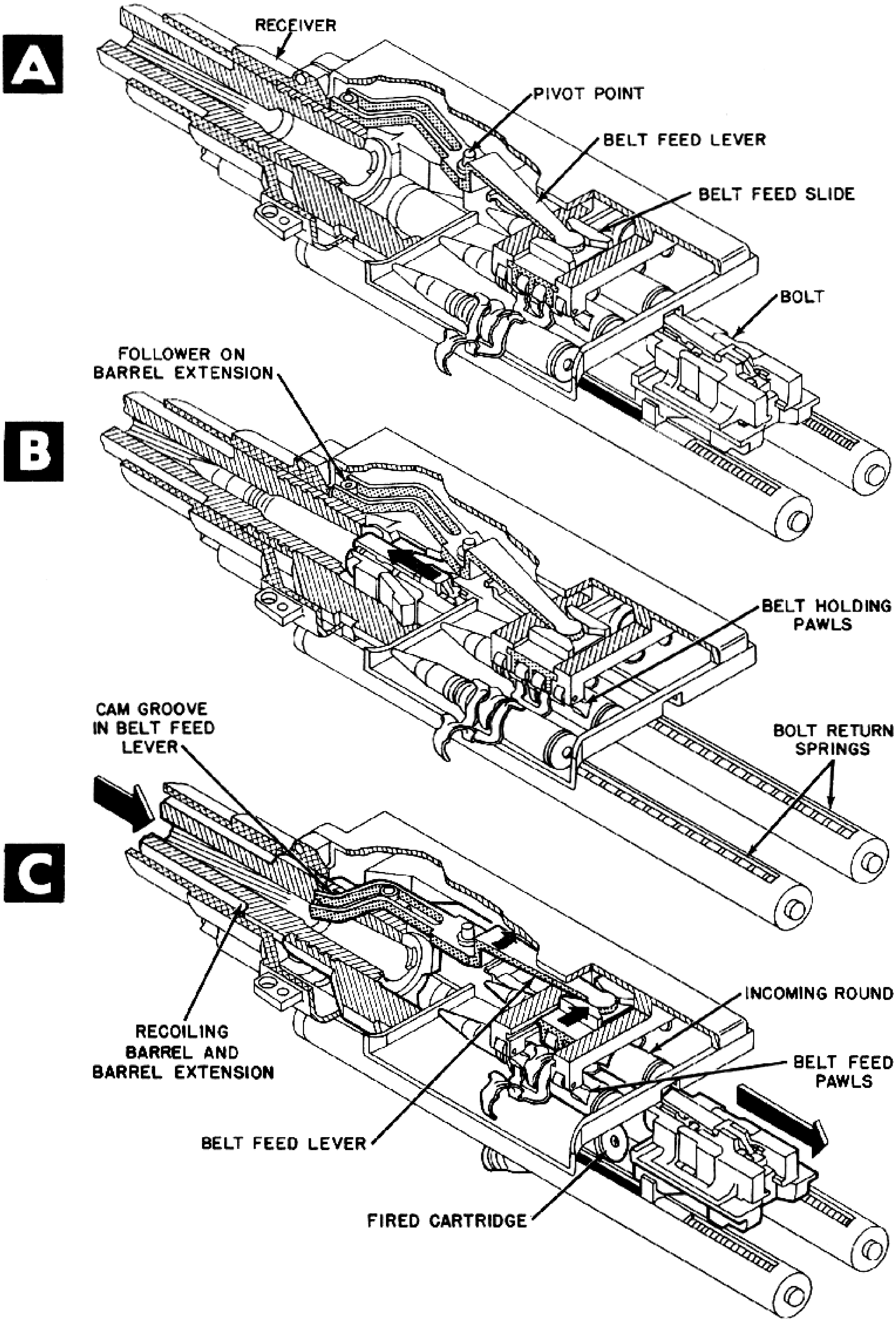


Figure 5–6. Follower on Barrel Extension Actuates Belt Feed Lever.

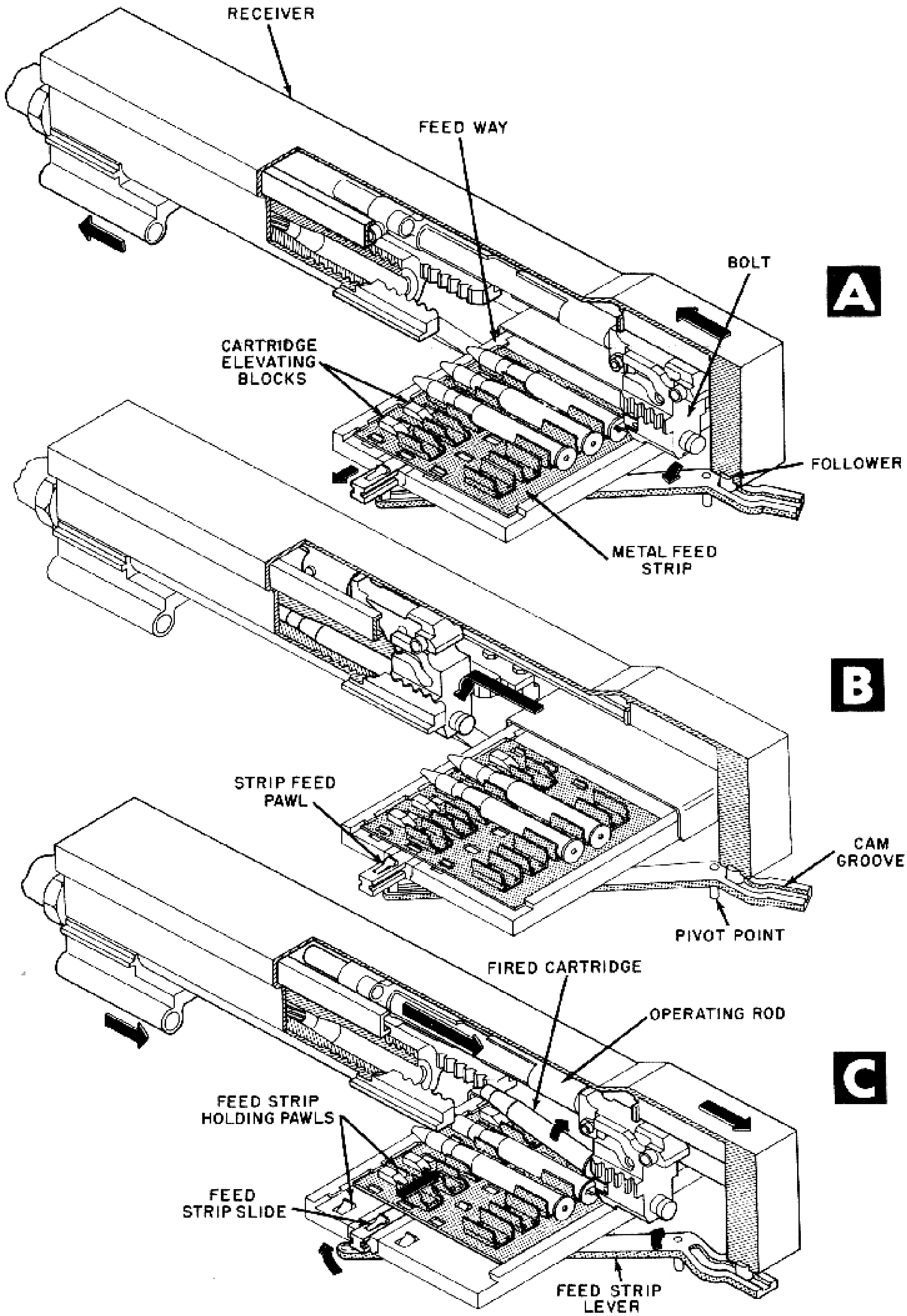


Figure 5-7. Follower on Receiver Actuates Strip Feed Lever.

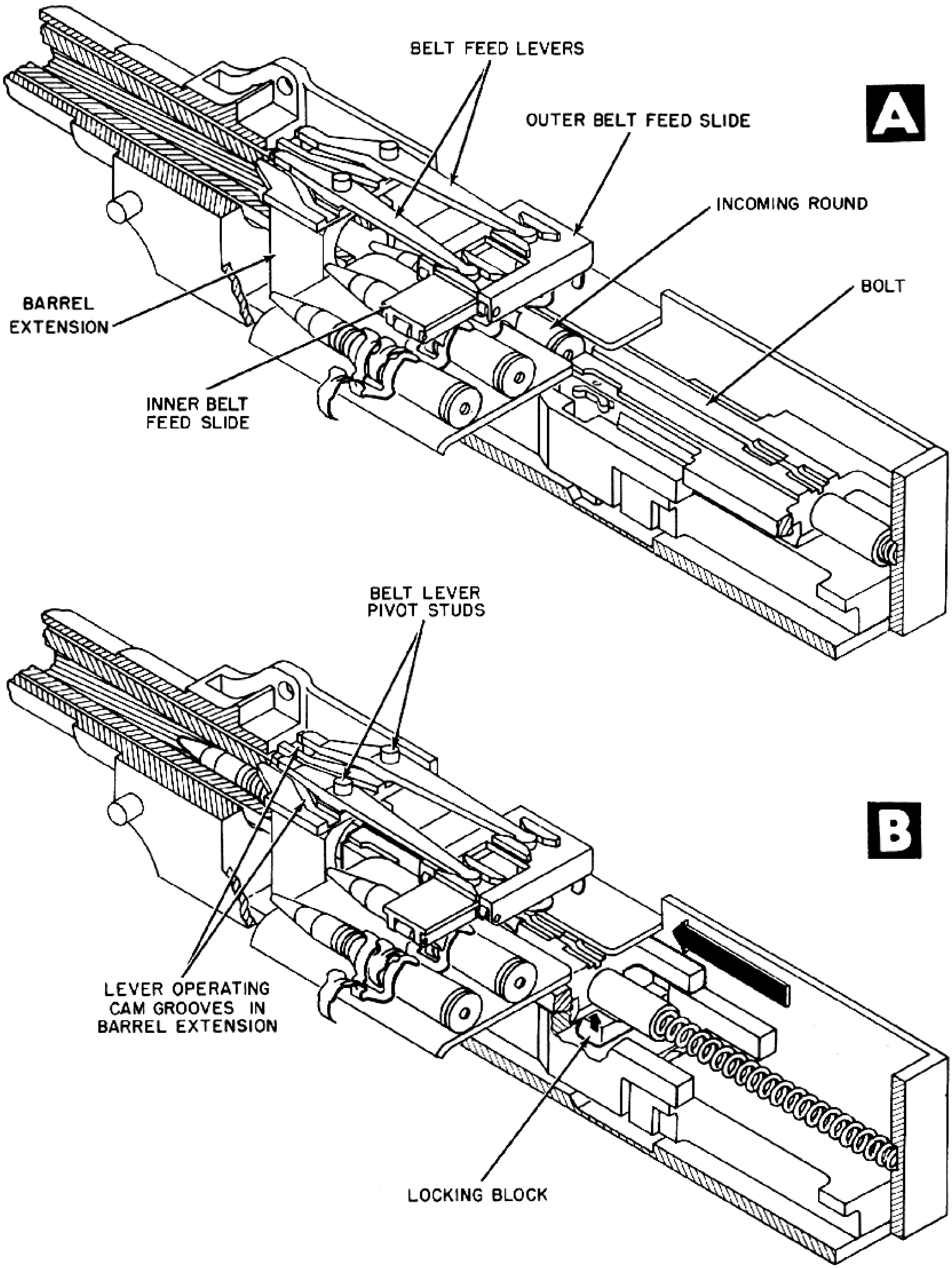
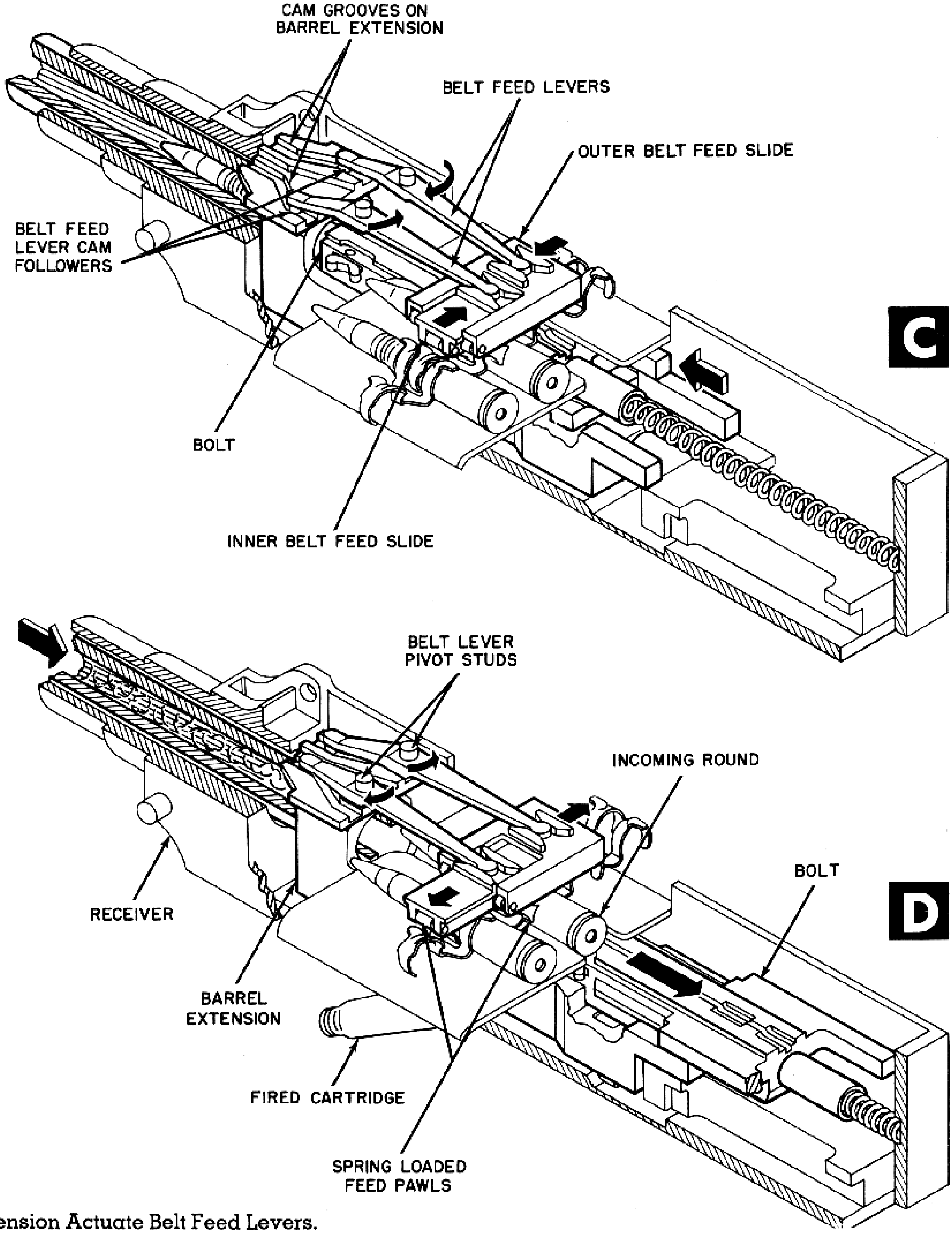


Figure 5–8. Cam Grooves in Barrel



Extension Actuate Belt Feed Levers.

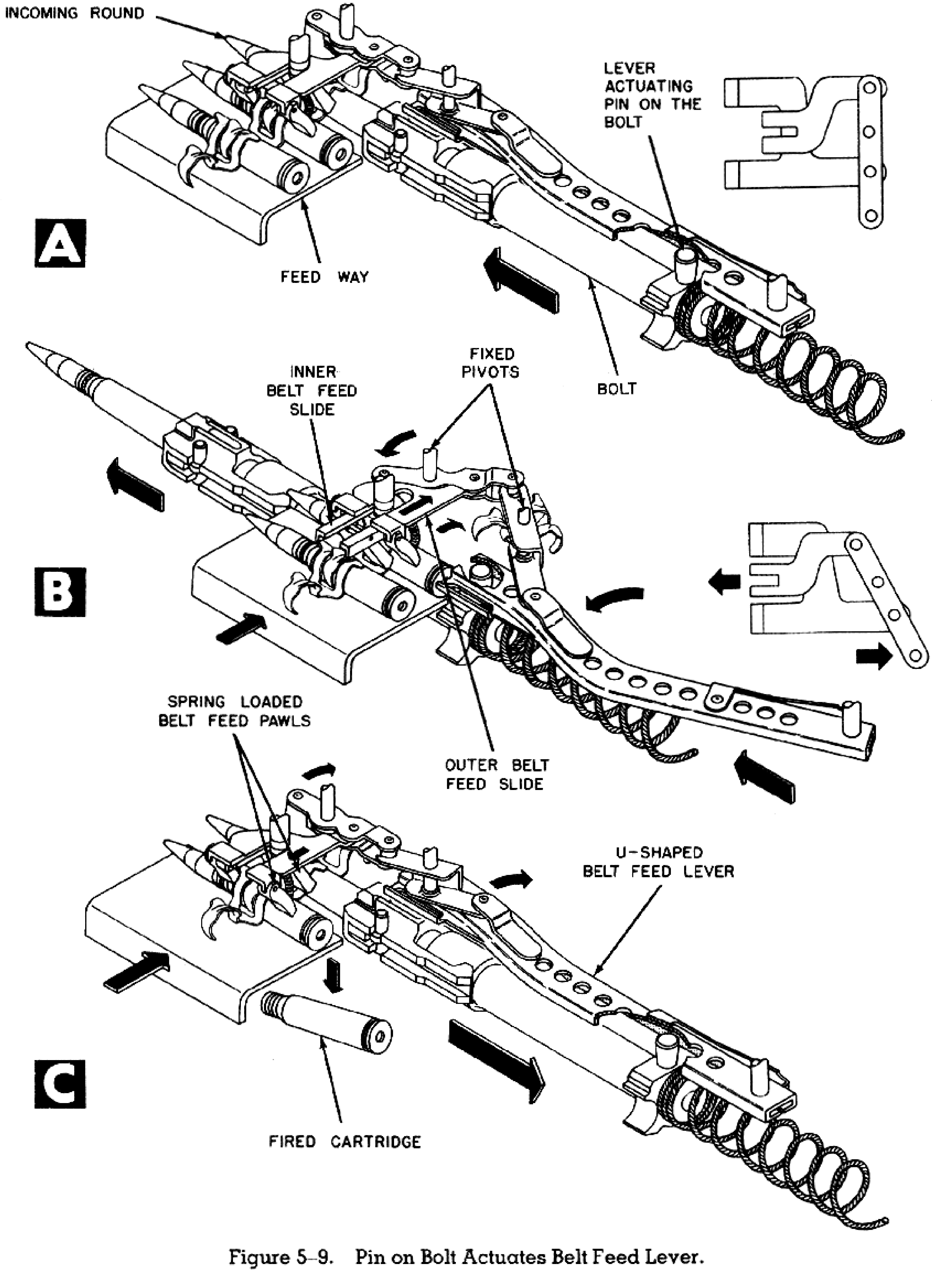


Figure 5–9. Pin on Bolt Actuates Belt Feed Lever.

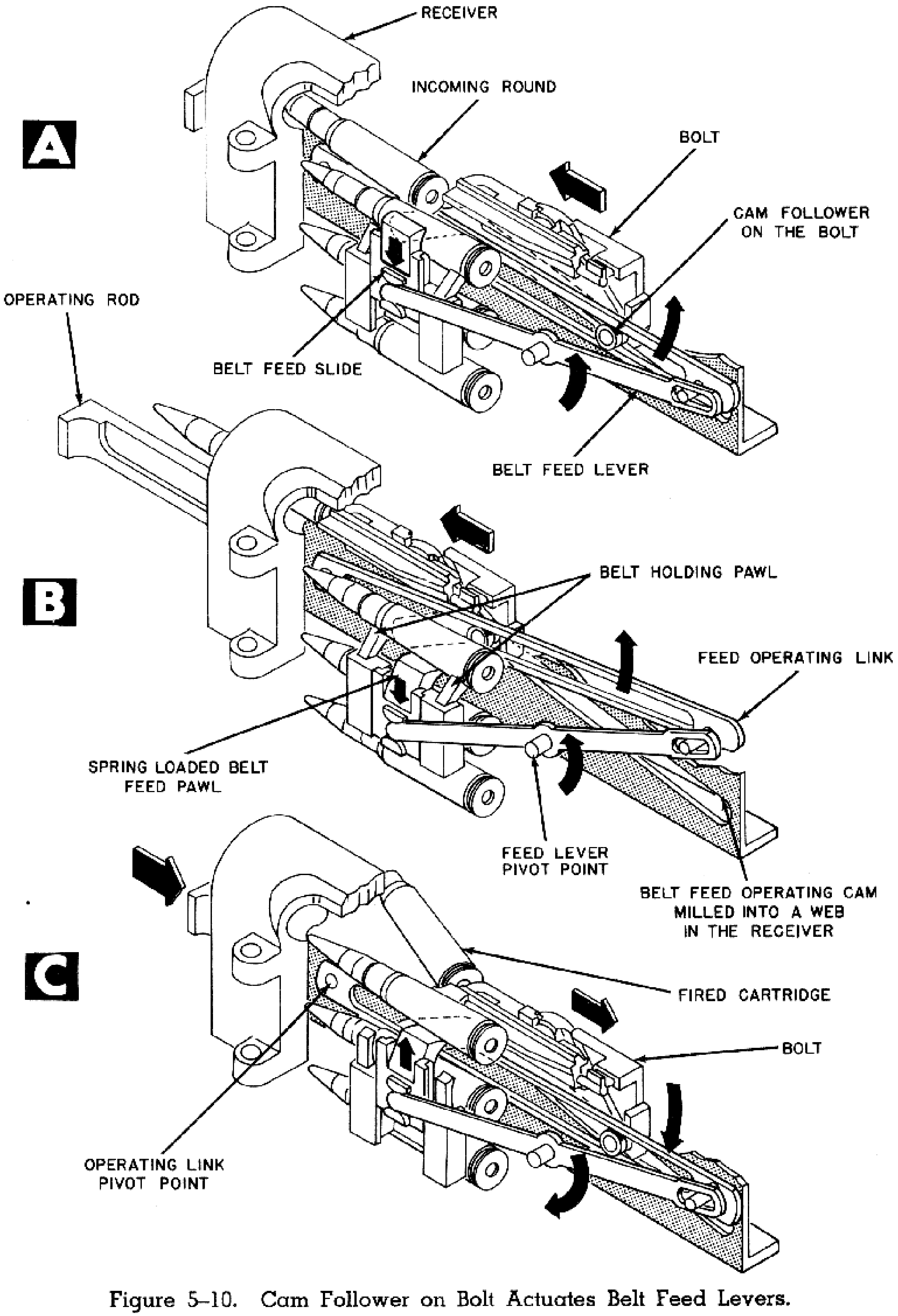


Figure 5-10. Cam Follower on Bolt Actuates Belt Feed Levers.

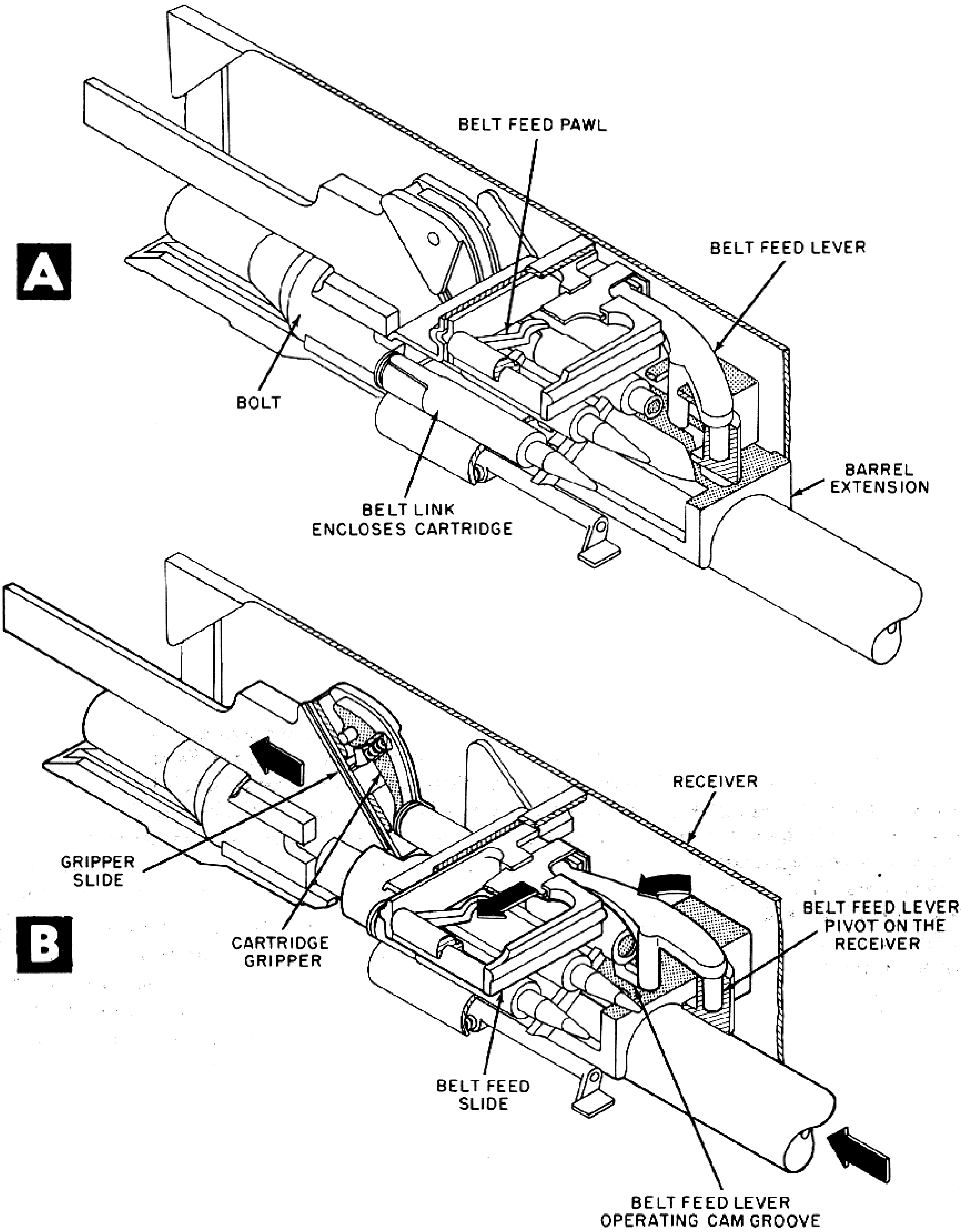
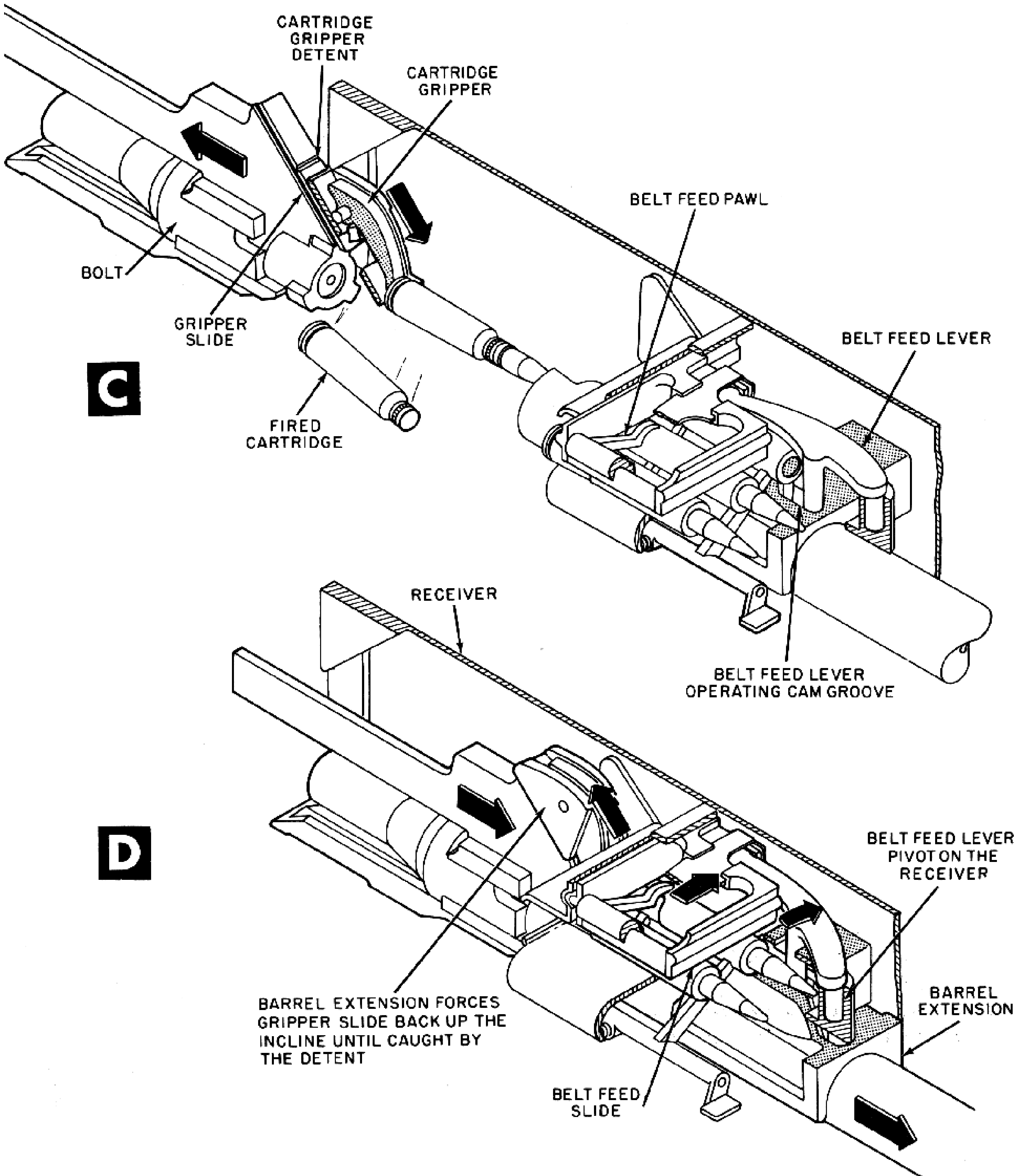


Figure 5–11. Cam Groove in Barrel



Extension Actuates Belt Feed Lever.

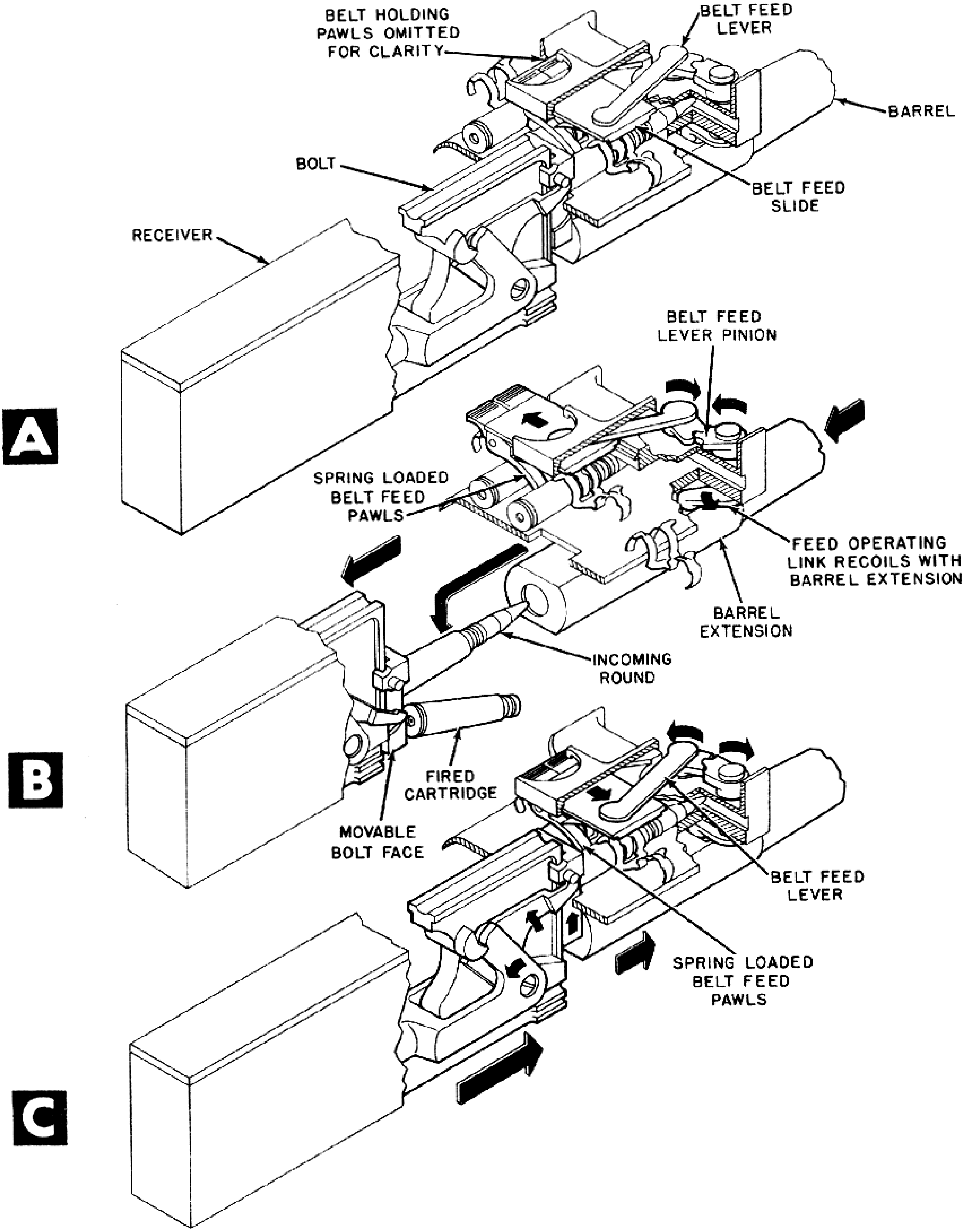


Figure 5–12. Recoiling Barrel Extension Actuates Belt Feed Levers.

B. Cam Operated

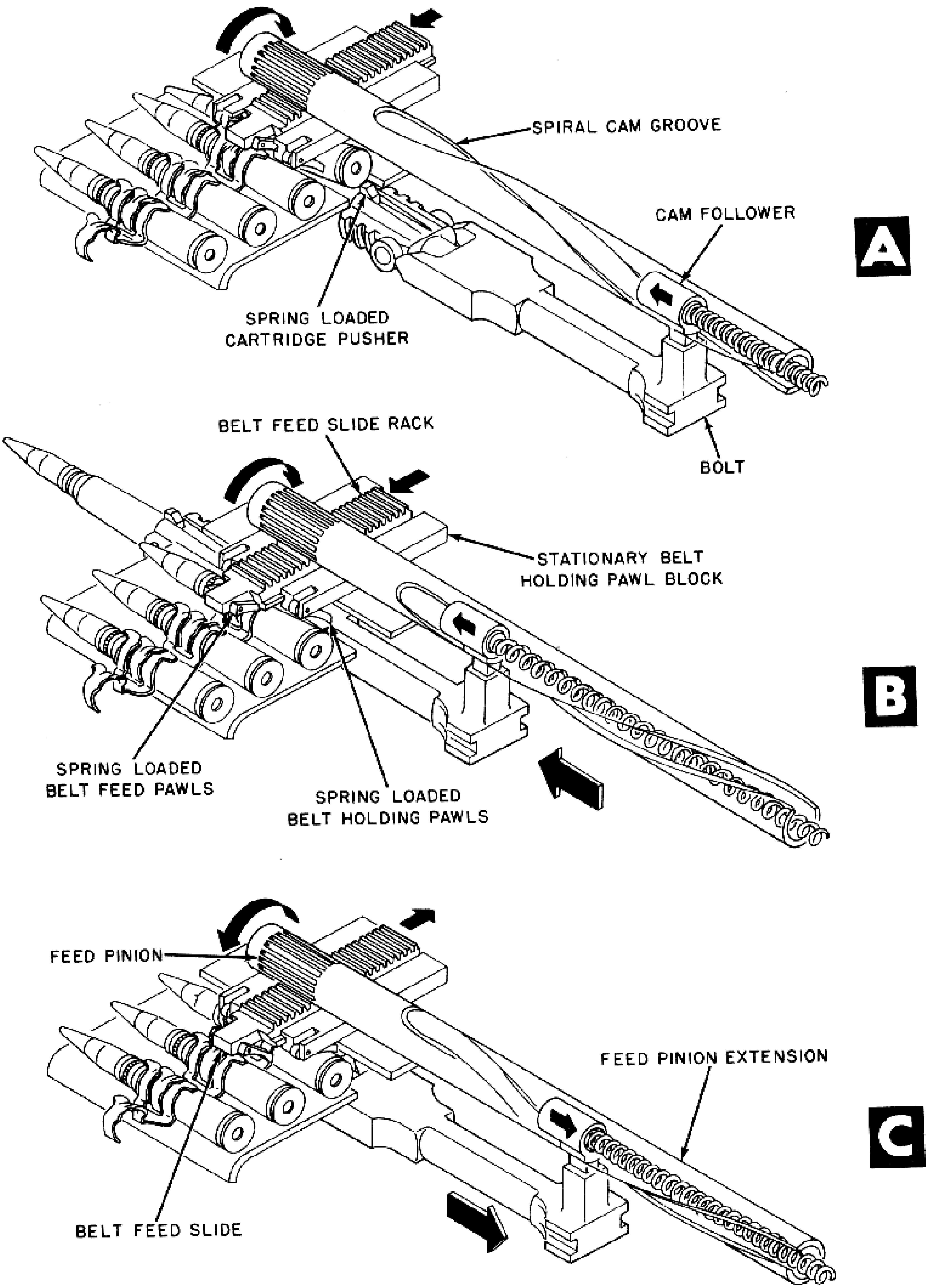


Figure 5–13. Follower on Bolt Rotates Feed Pinion Extension.

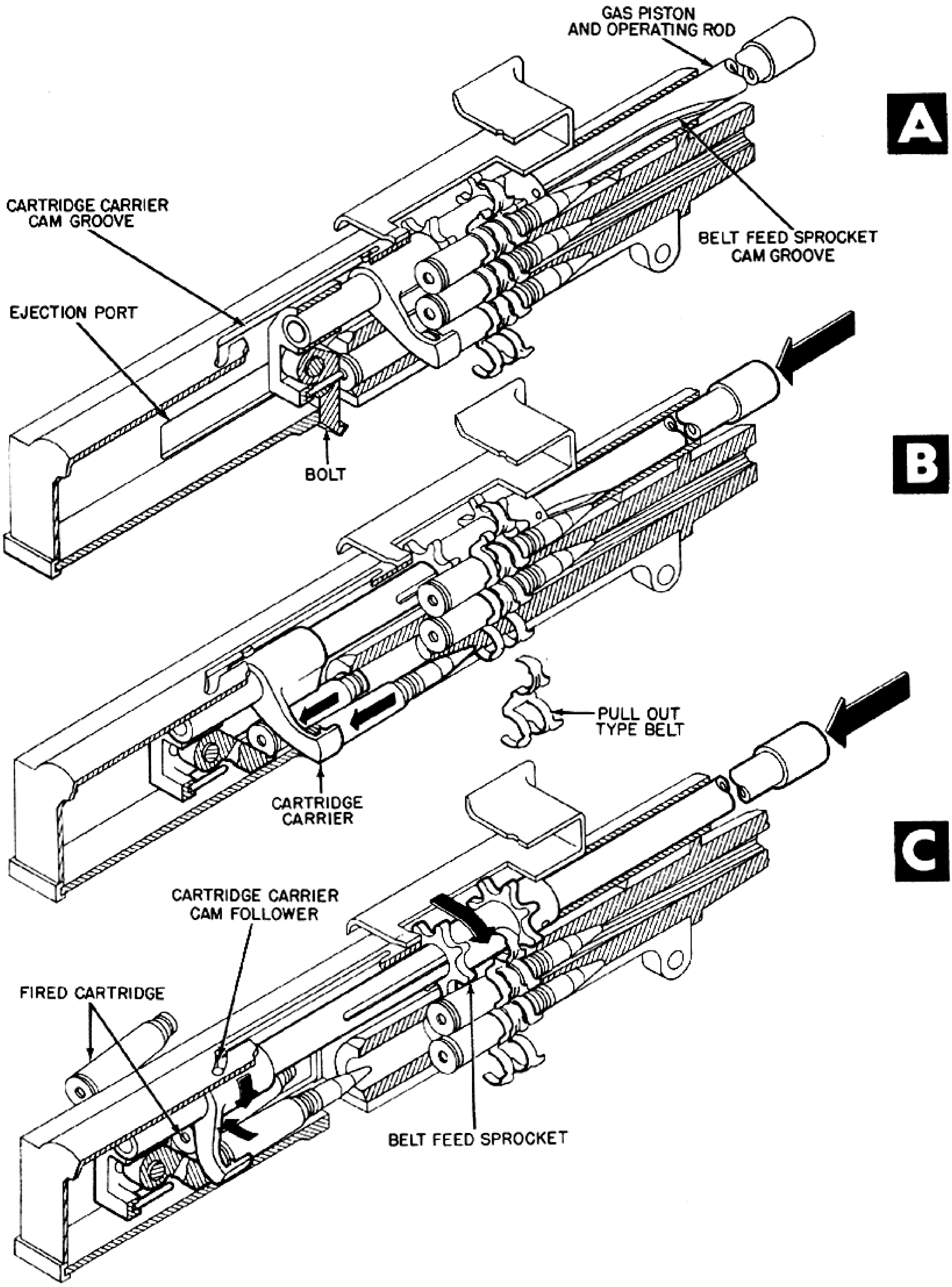


Figure 5–14. Piston Operated Feed Sprocket.

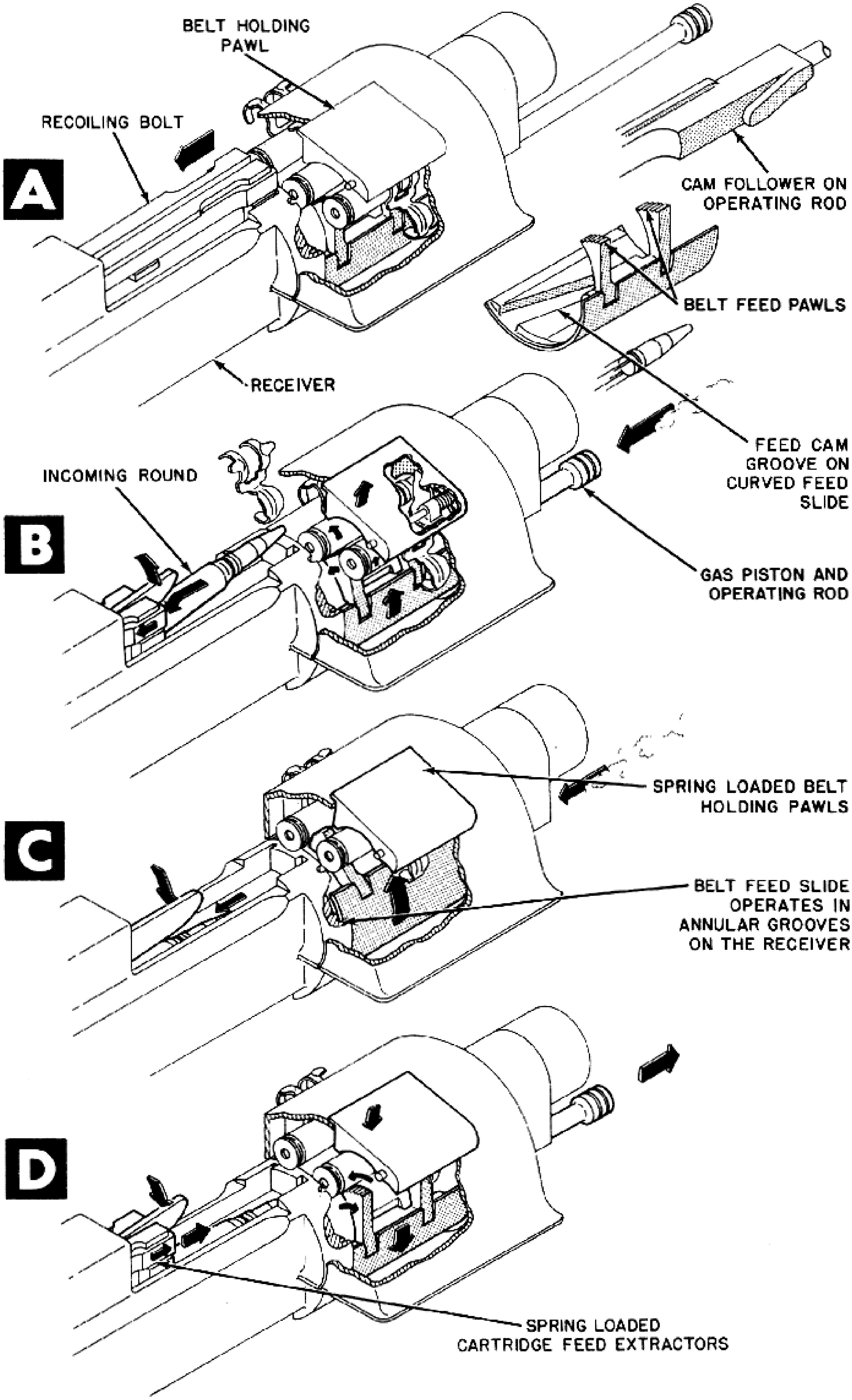


Figure 5–15. Cam on Operating Rod Rotates Belt Feed Slide.

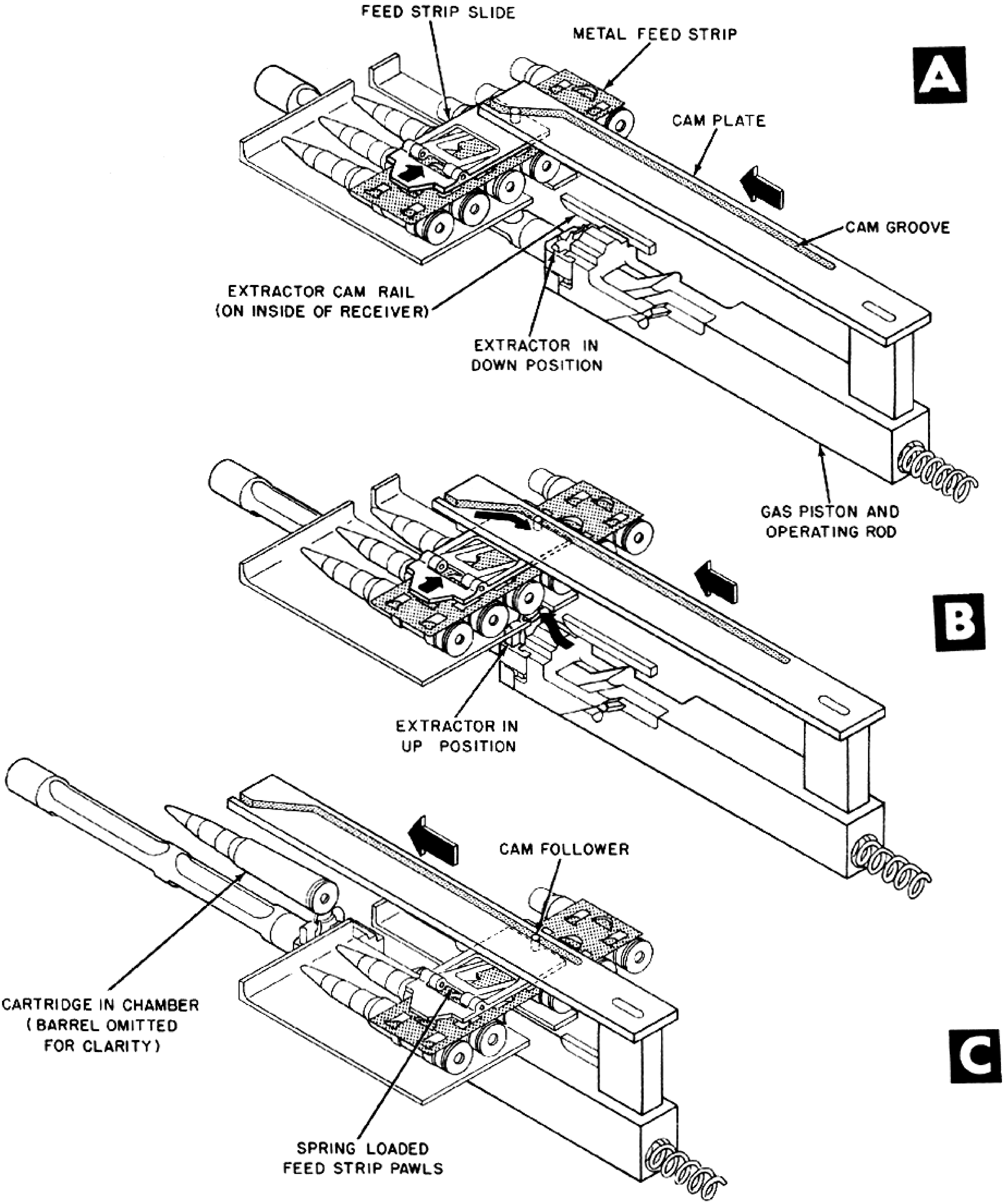
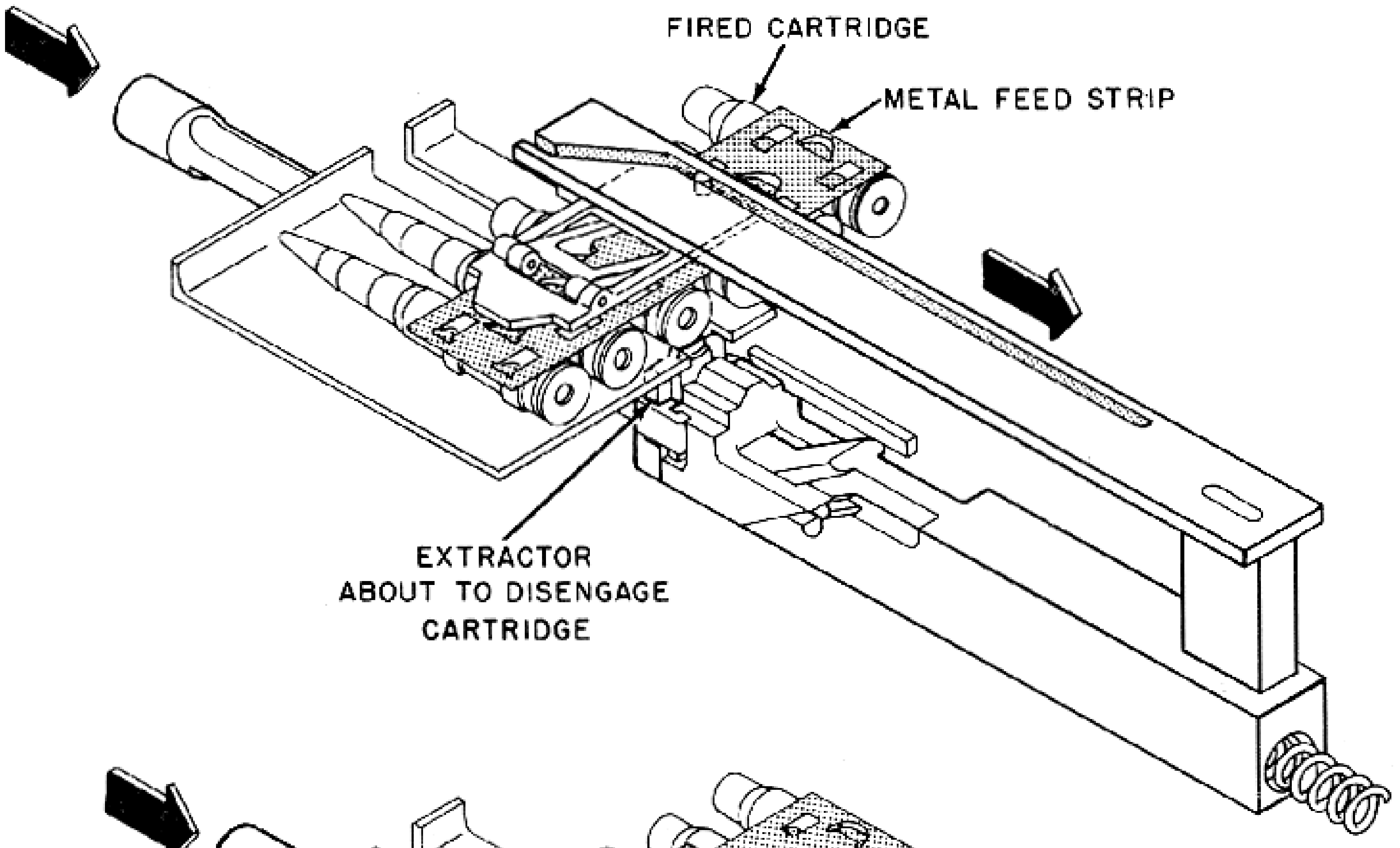


Figure 5–16. Cam Plate Attached to Operating



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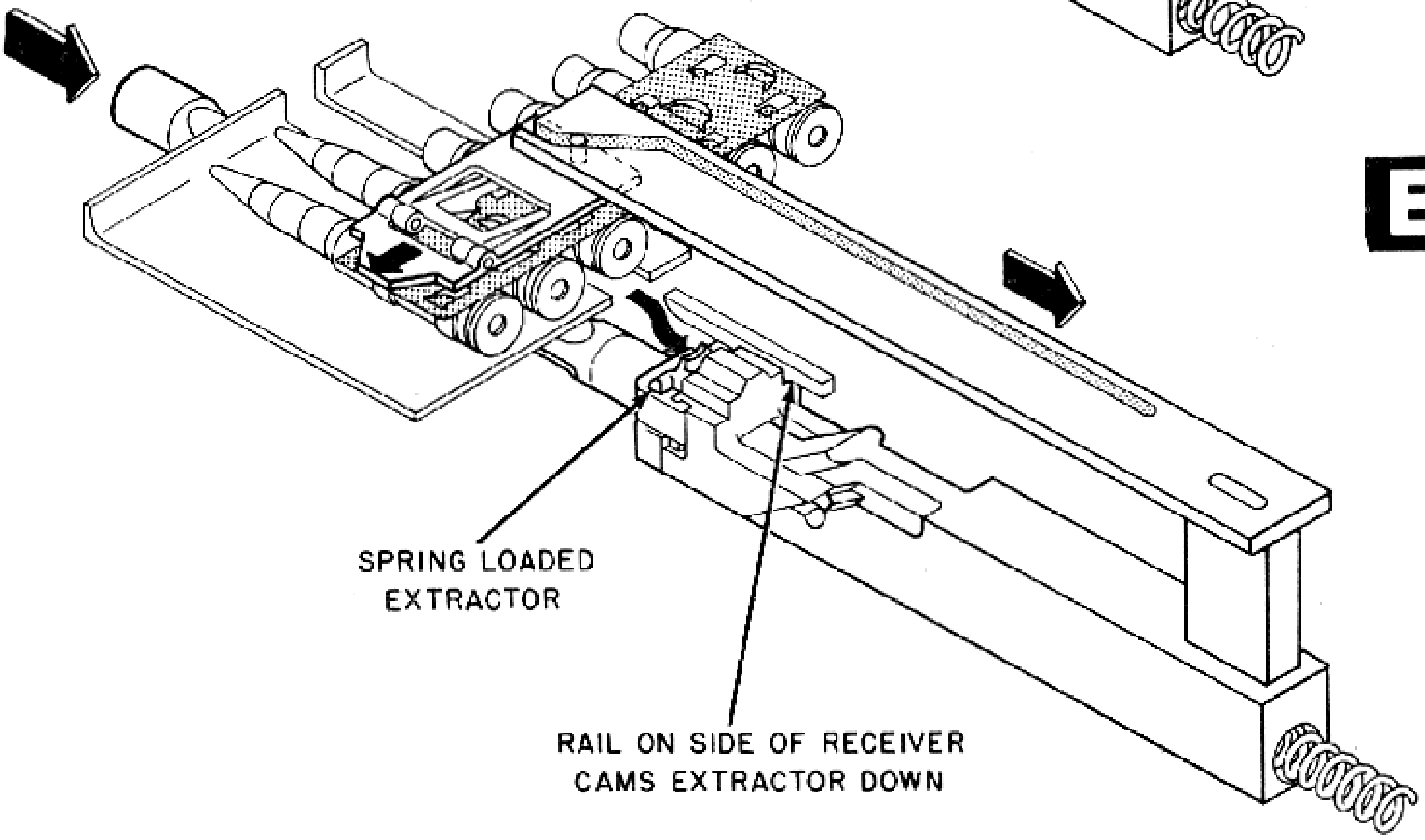

E

Rod Actuates Feed Strip Slide.

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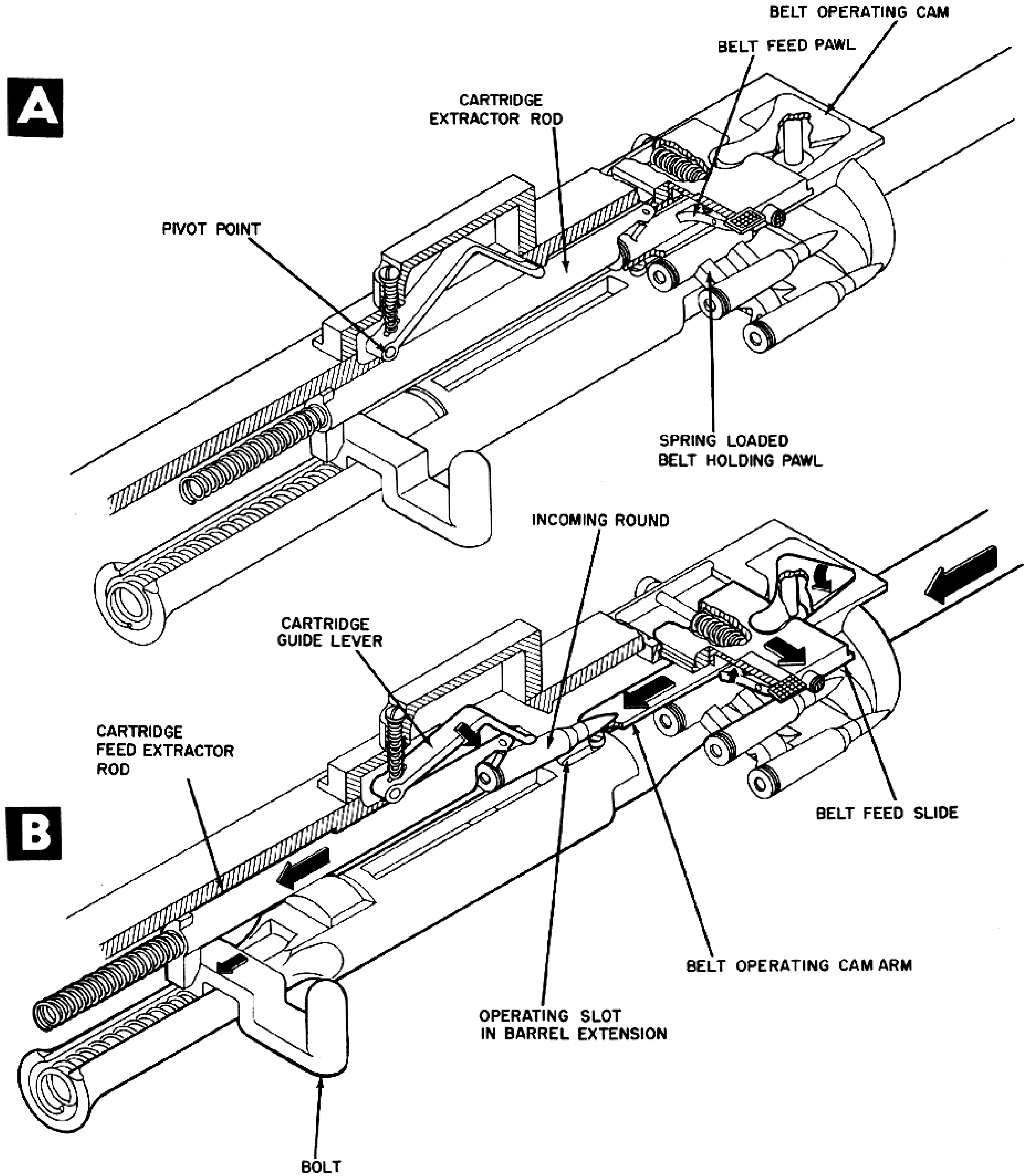
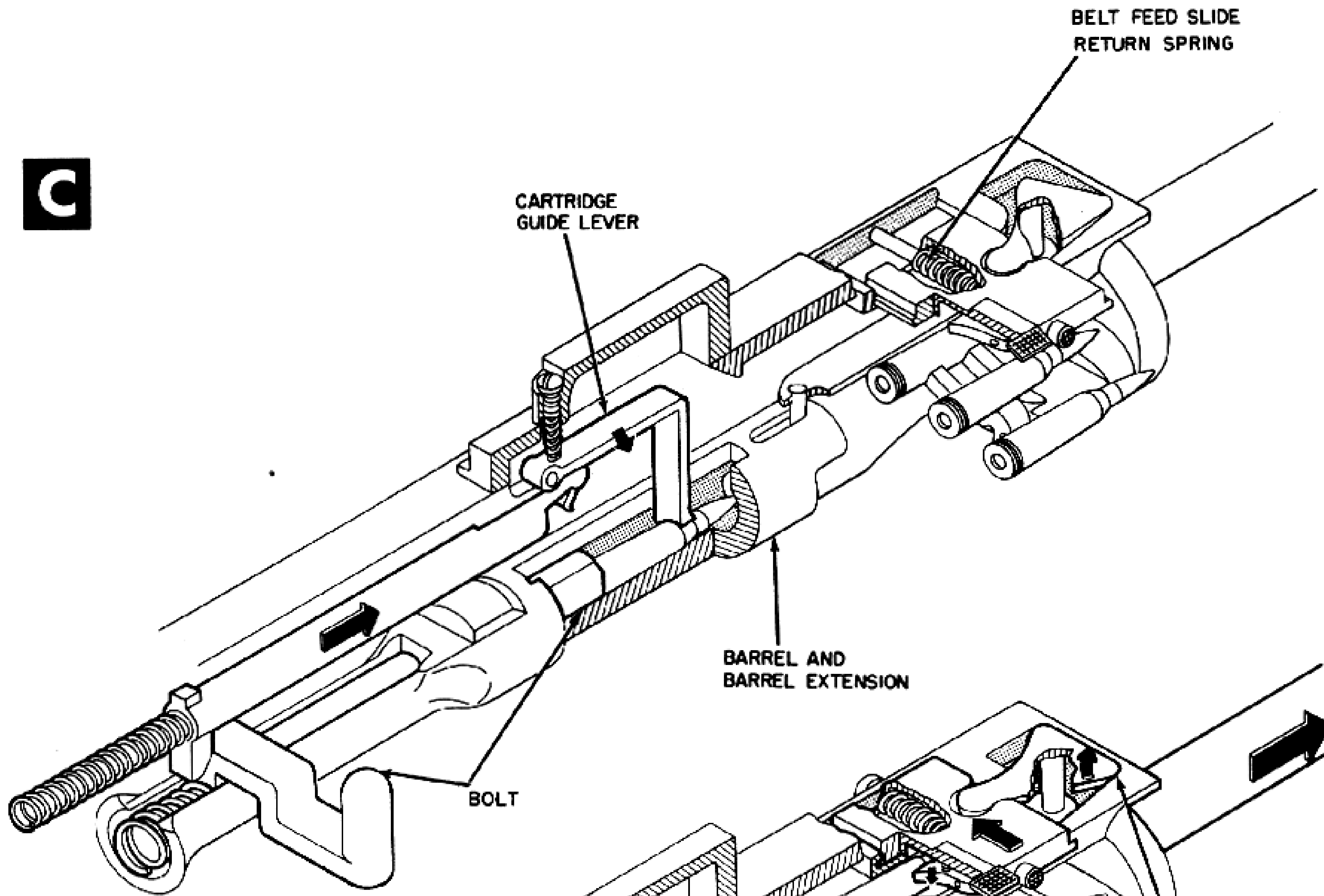


Figure 5–17. Recoiling Barrel Extension

C



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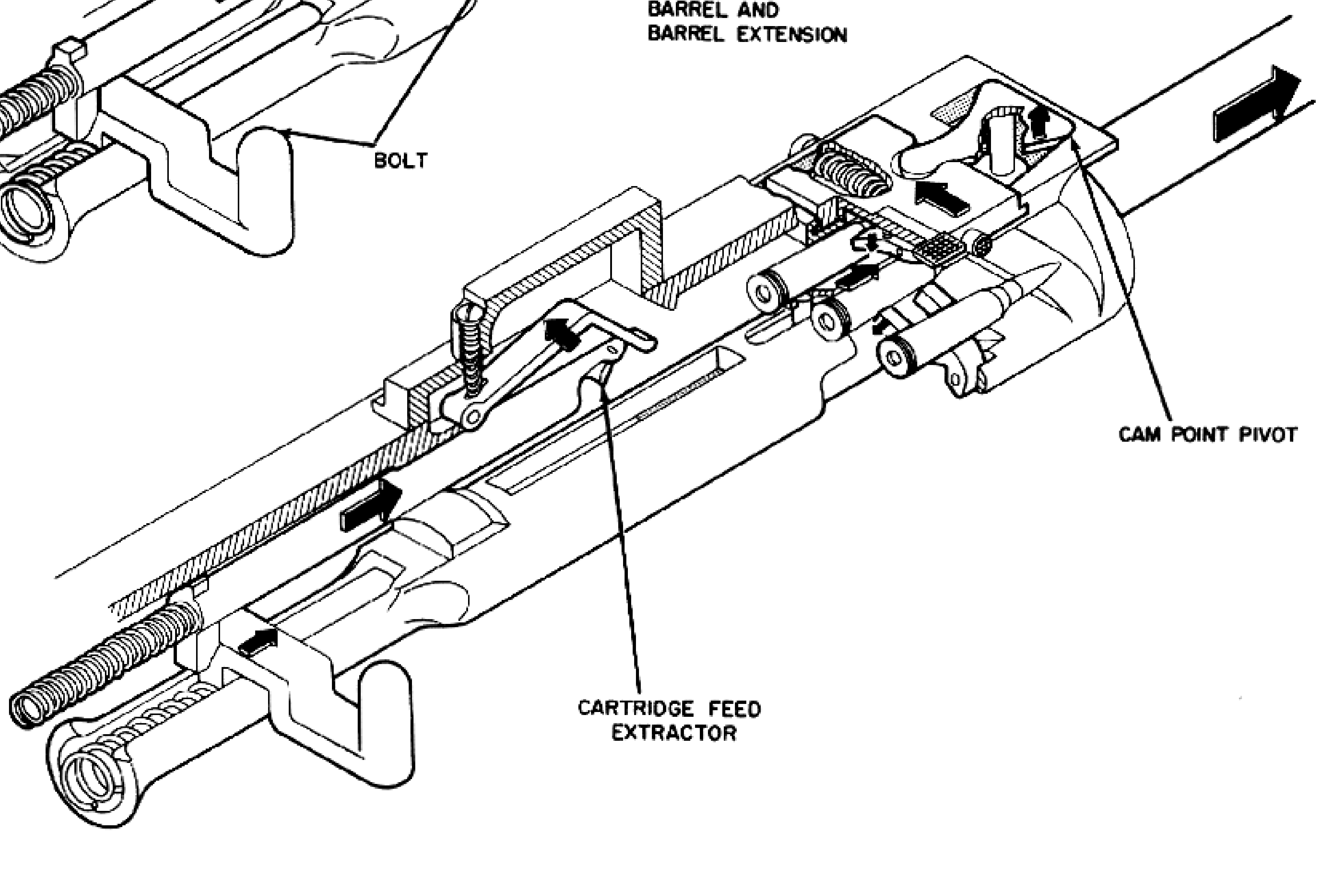


Actuates Belt Feed Slide.

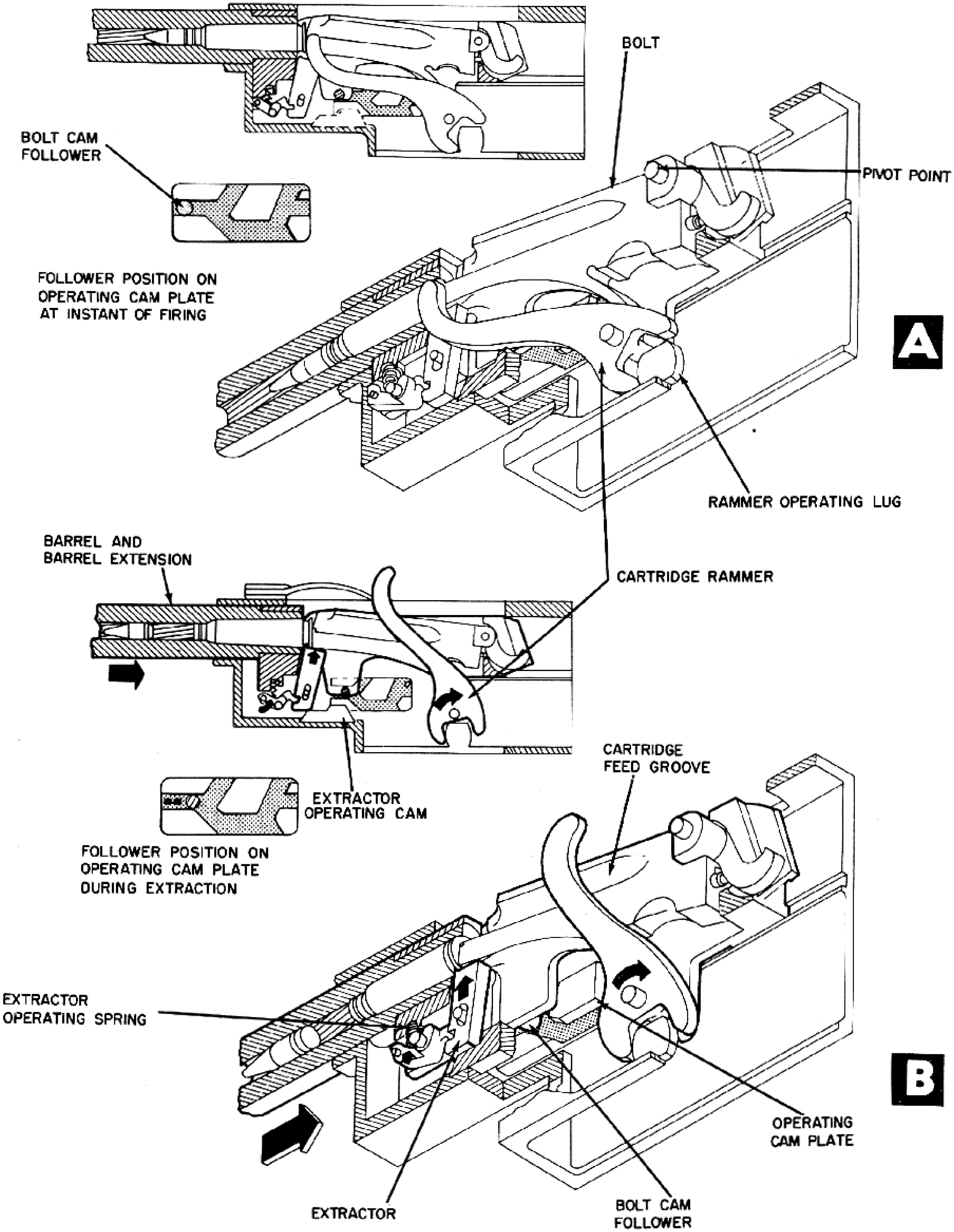
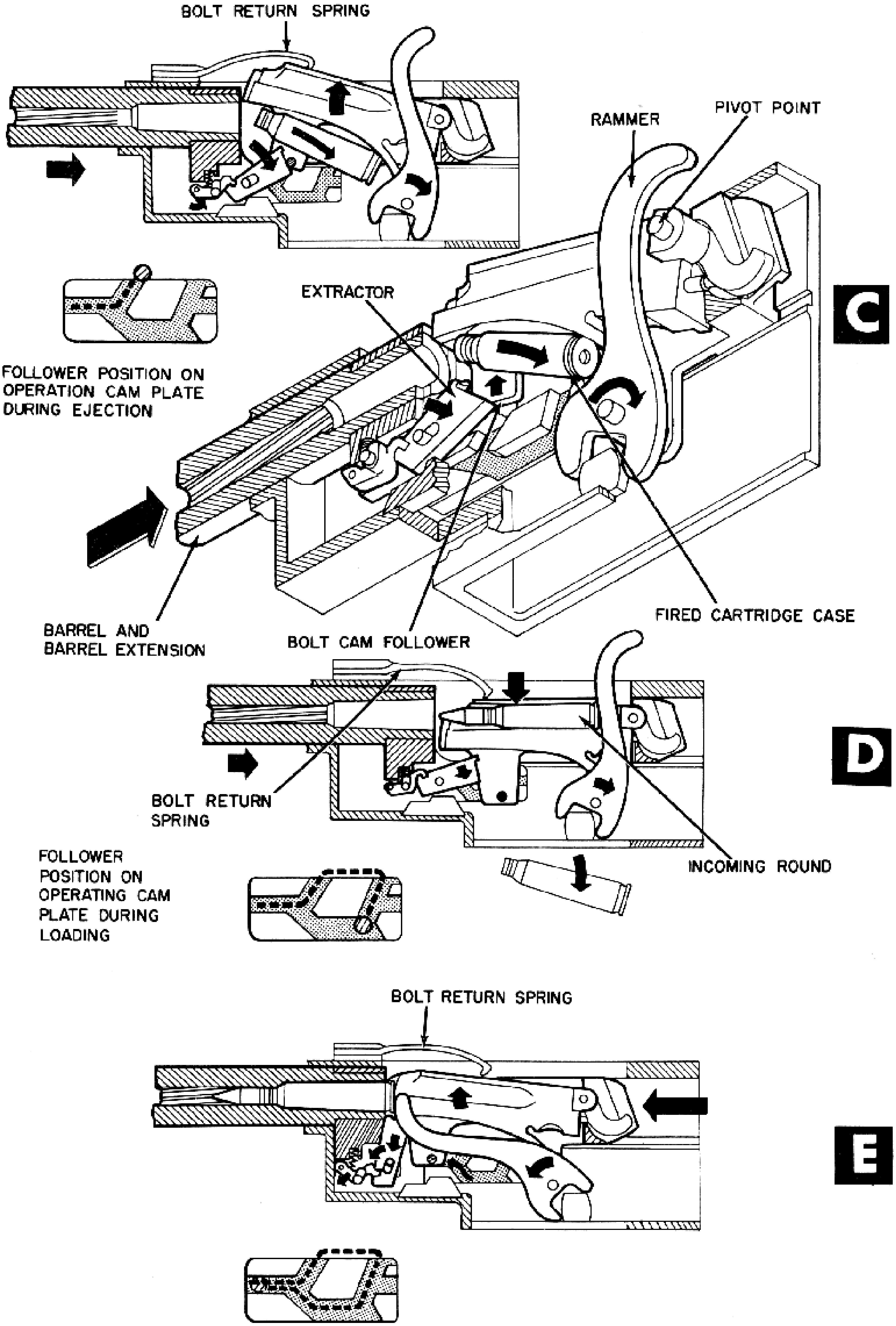


Figure 5–18. Lug on Receiver Operates



Cartridge Rammer.

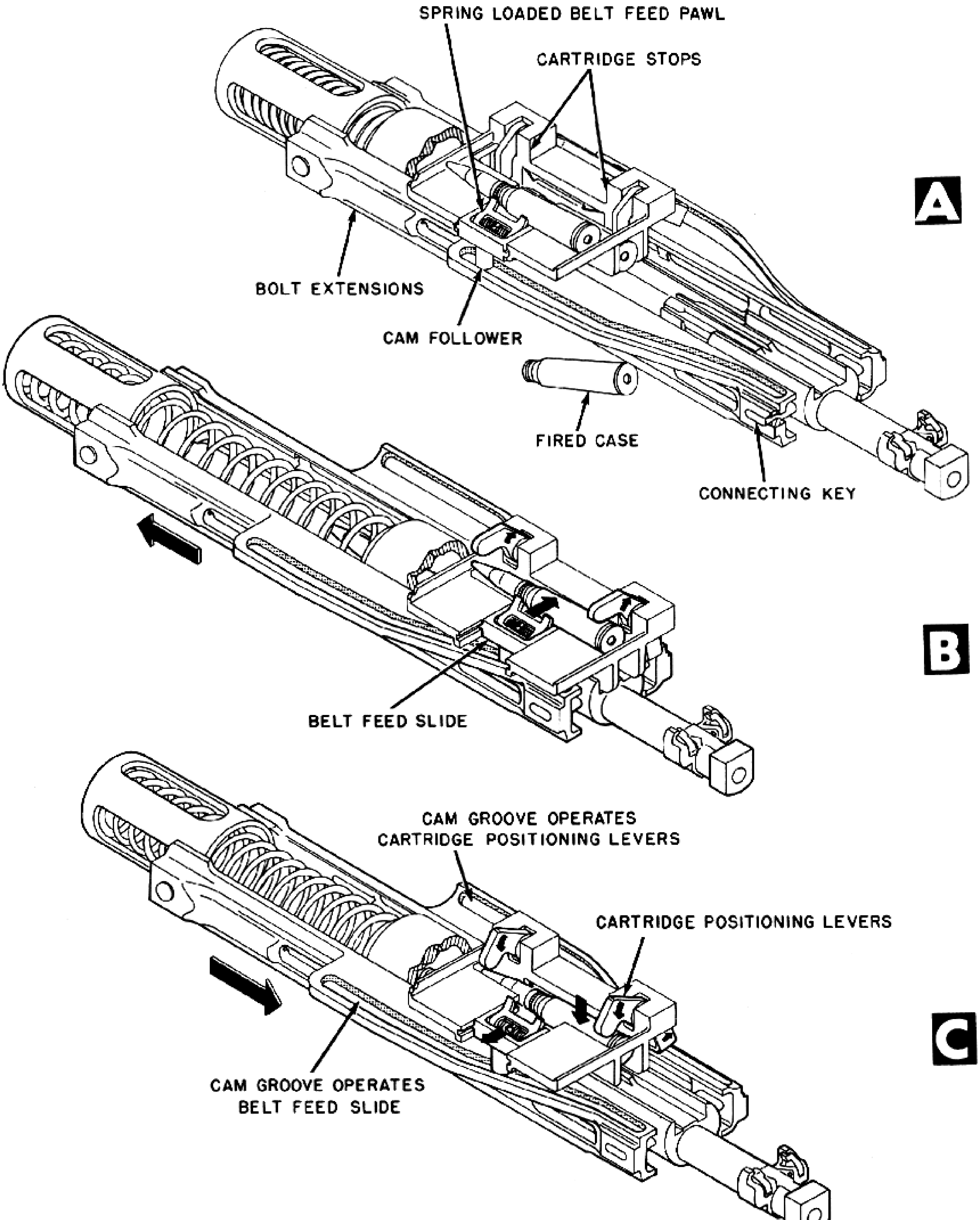


Figure 5–19. Cam Grooves in Bolt Extension Actuate Belt Feed Slide and Cartridge Positioning Lever.

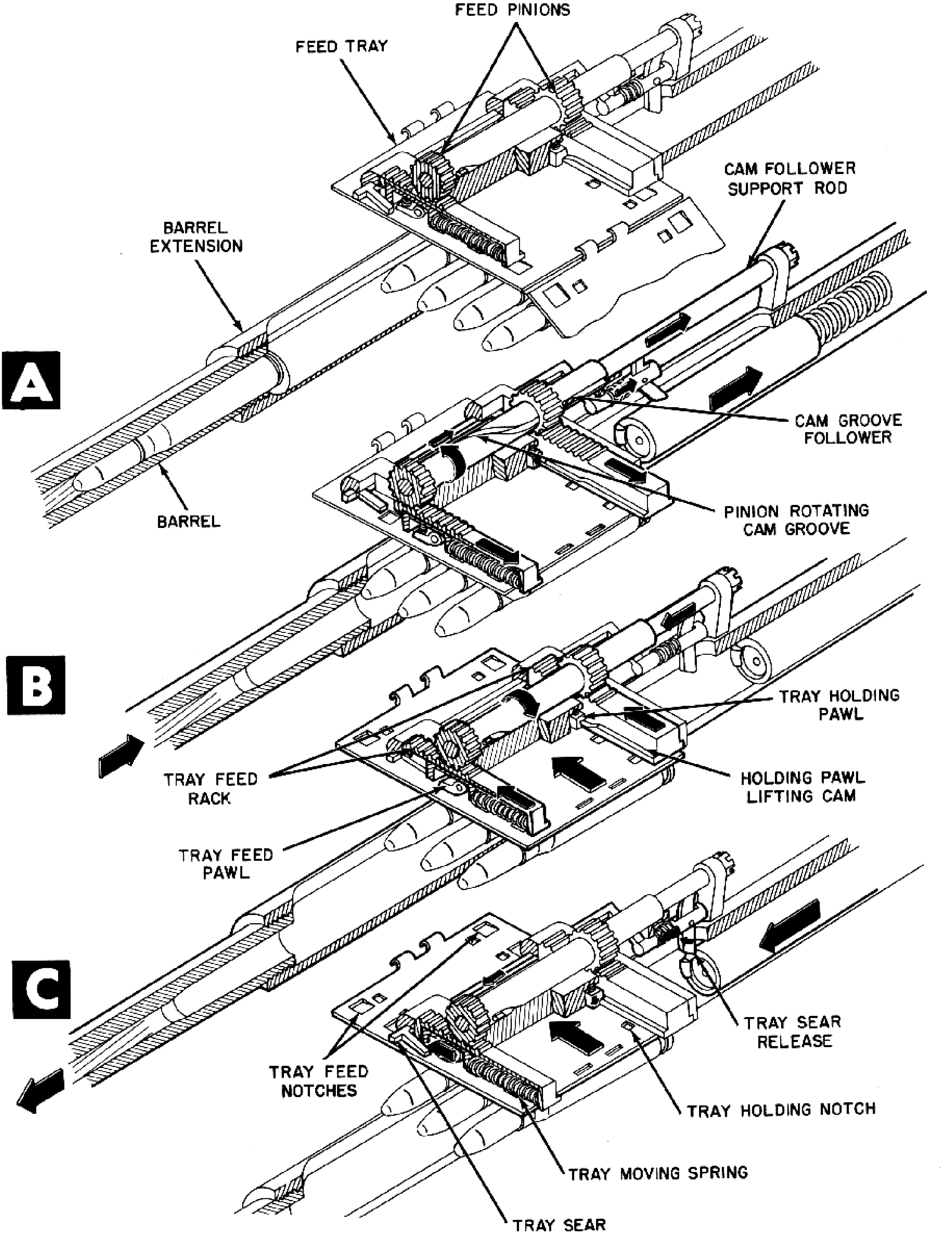


Figure 5-20. Recoiling Barrel Extension Operates Feed Pinions.

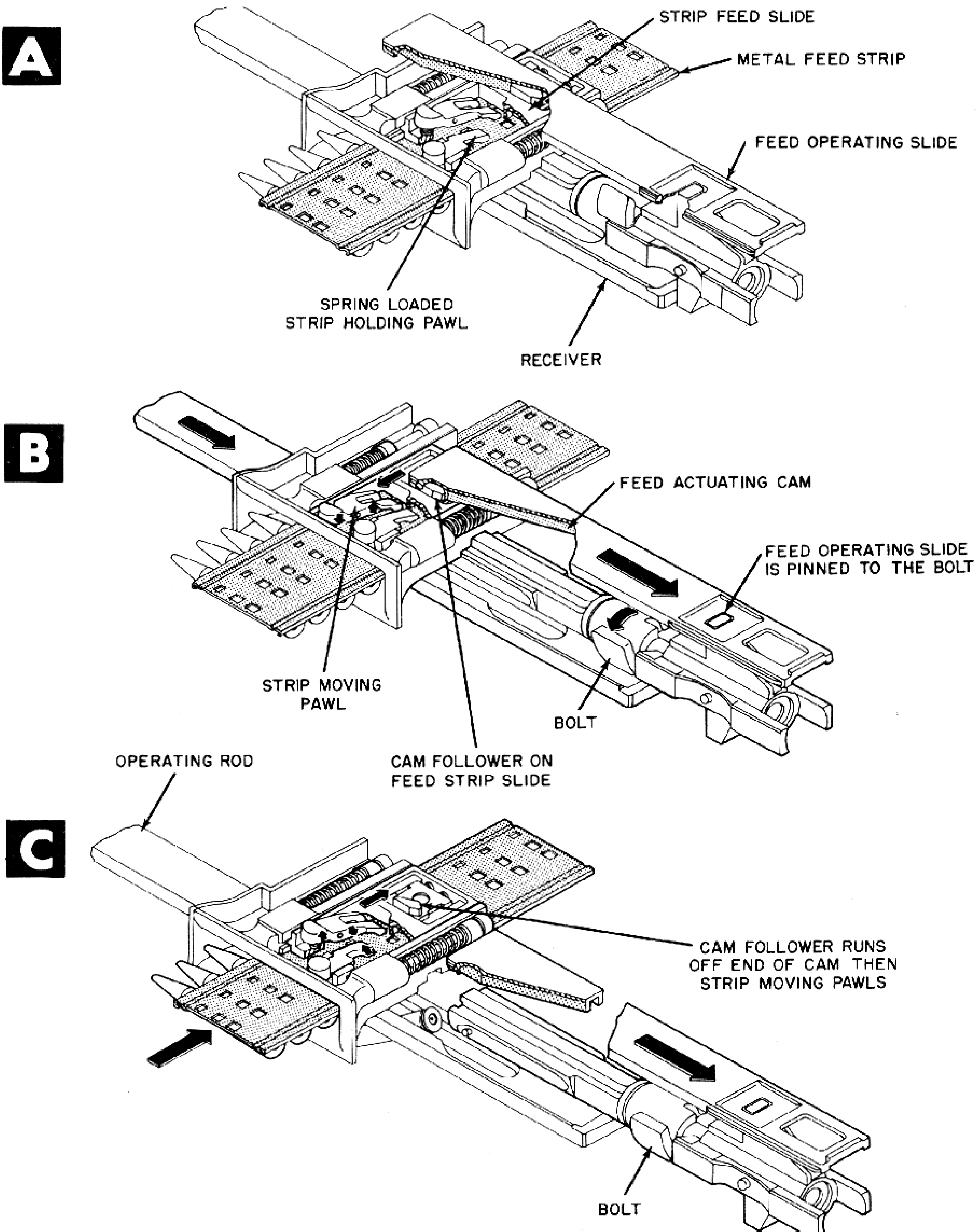


Figure 5–21. Feed Strip Slide Is Actuated by Recoiling Cam Plate and Springs.

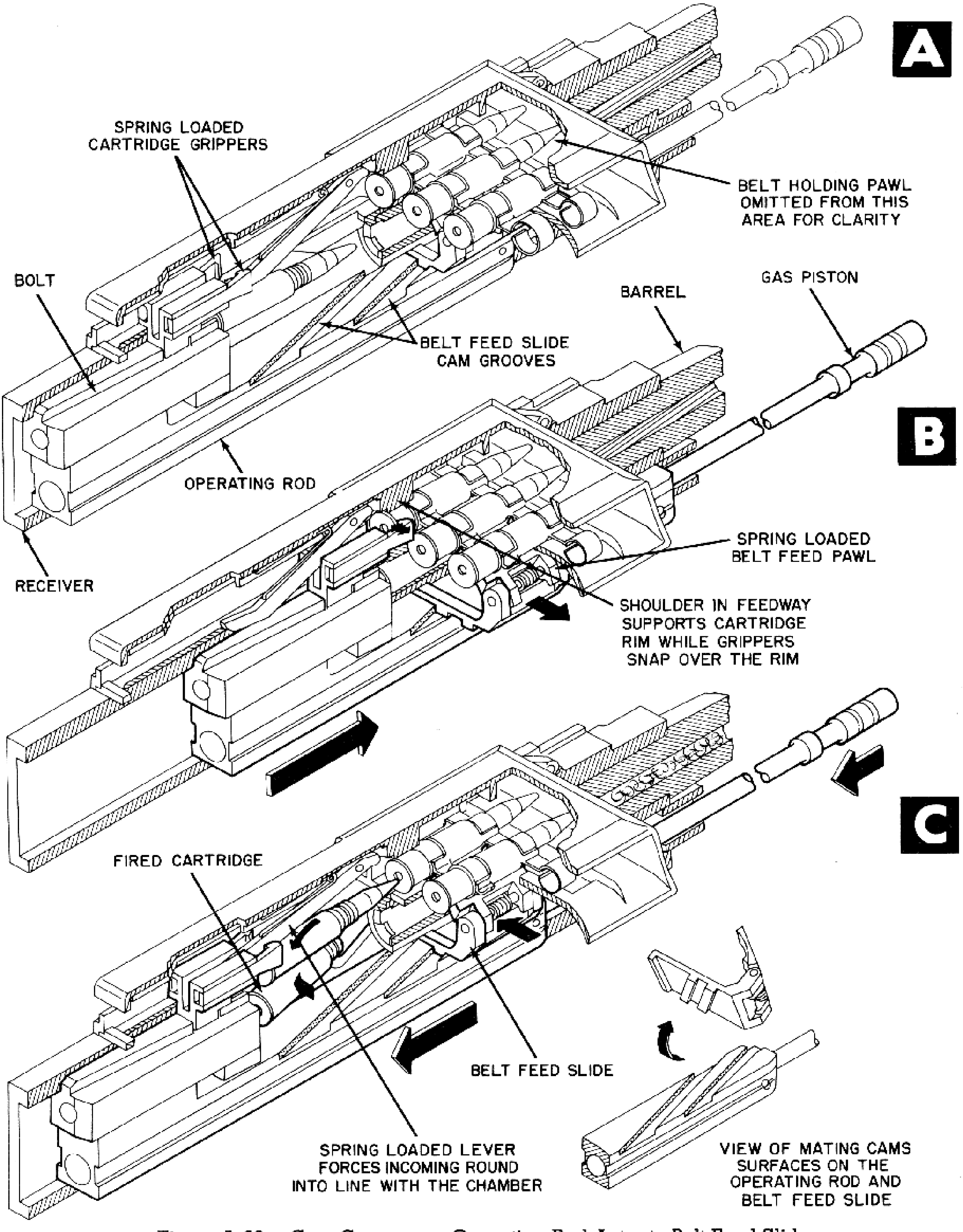


Figure 5–22. Cam Grooves on Operating Rod Actuate Belt Feed Slide.

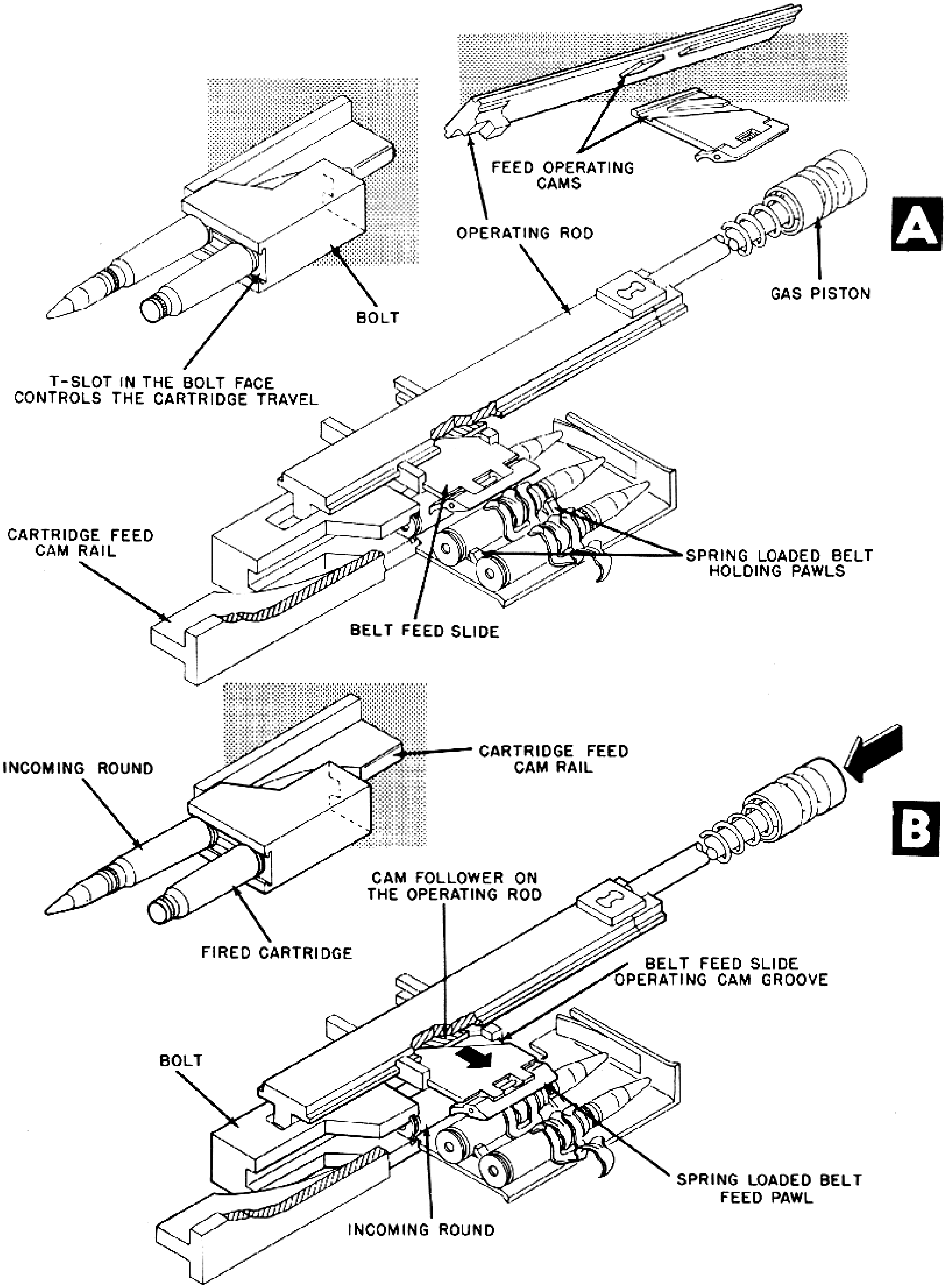
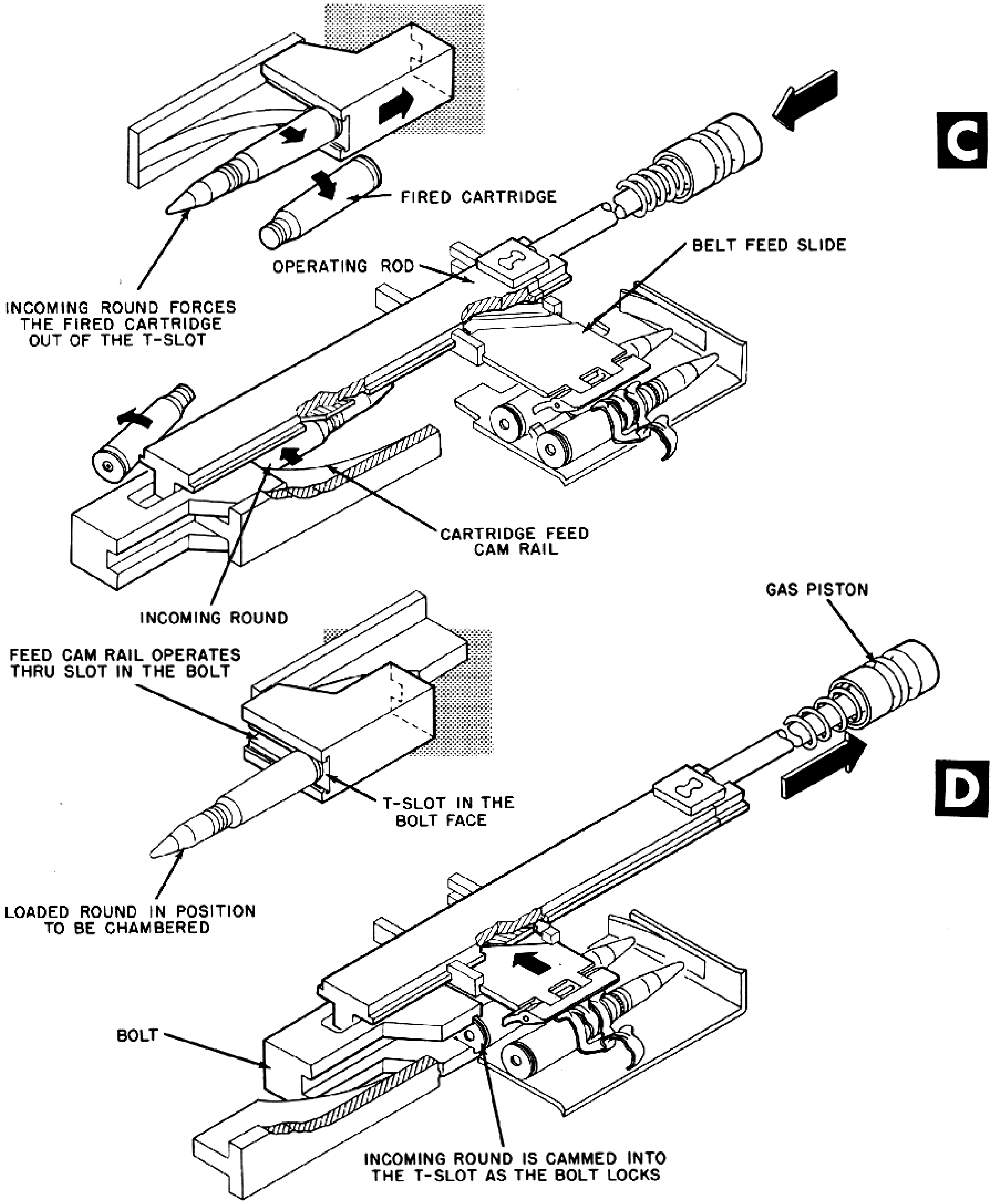


Figure 5–23. Cam on Operating Rod



Actuates Belt Feed Slide.

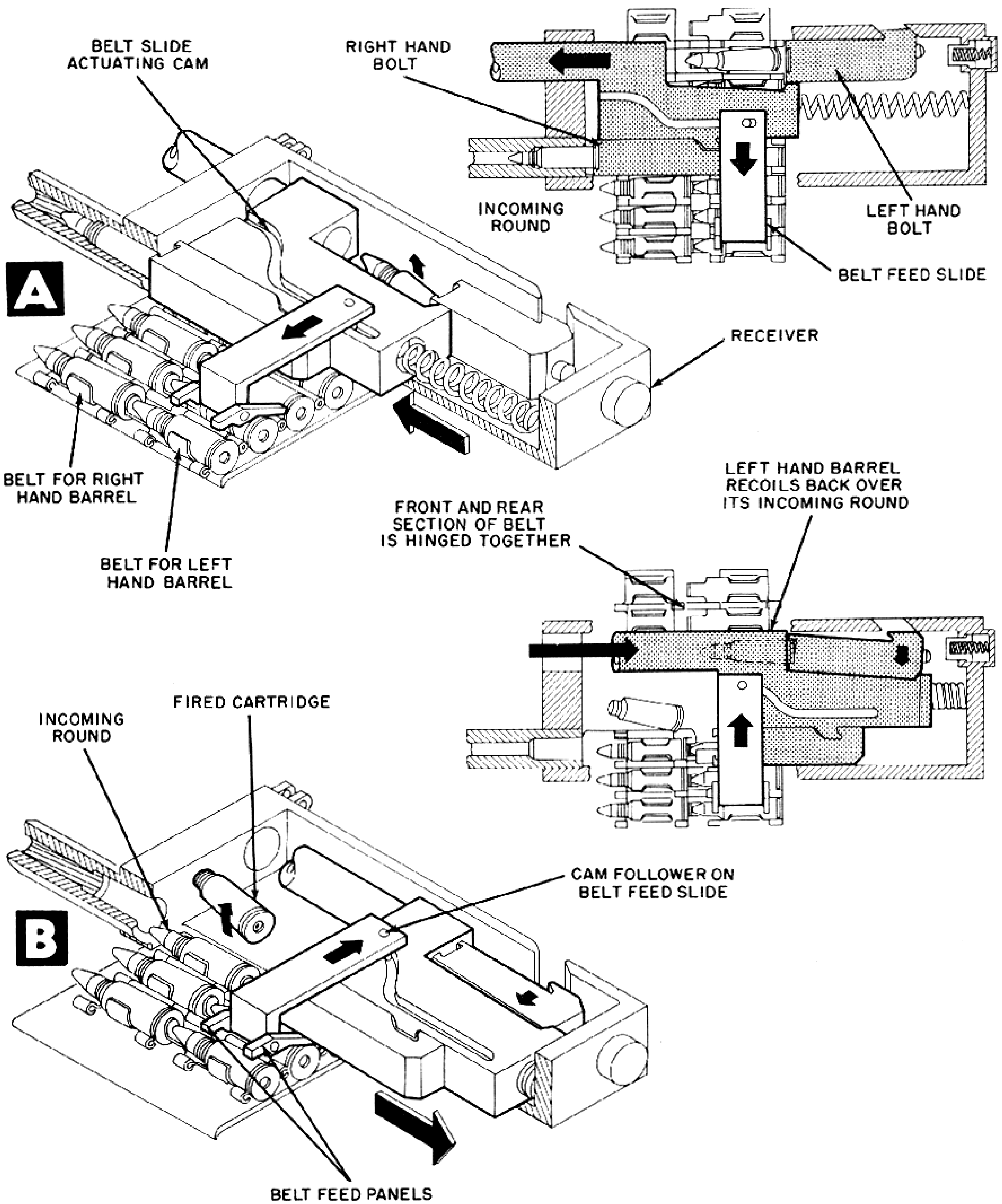


Figure 5–24. Recoiling Barrel Extension Actuates Belt Feed Slide.

C. Sprocket Type

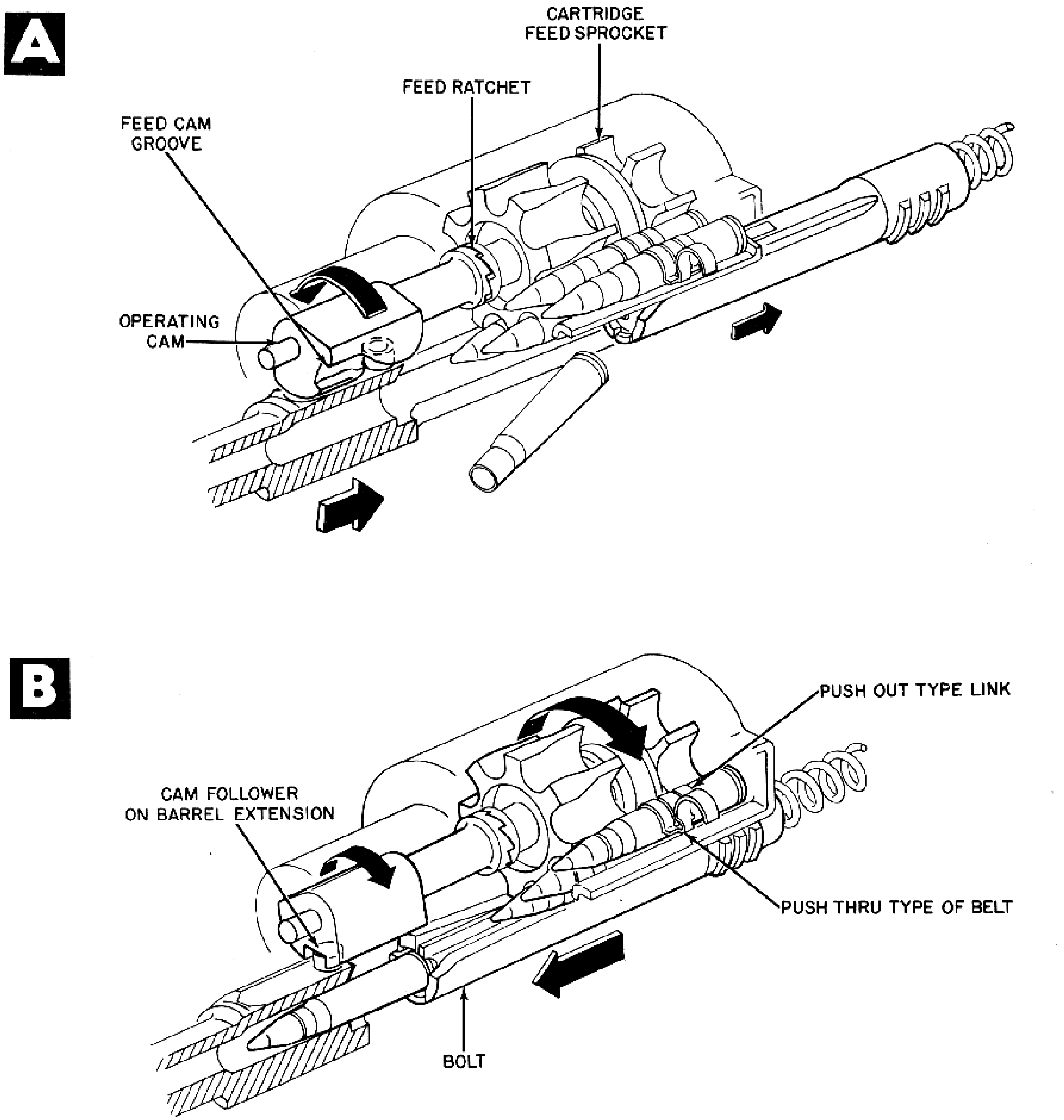


Figure 5–25. Recoiling Barrel Extension Rotates Feed Sprocket.

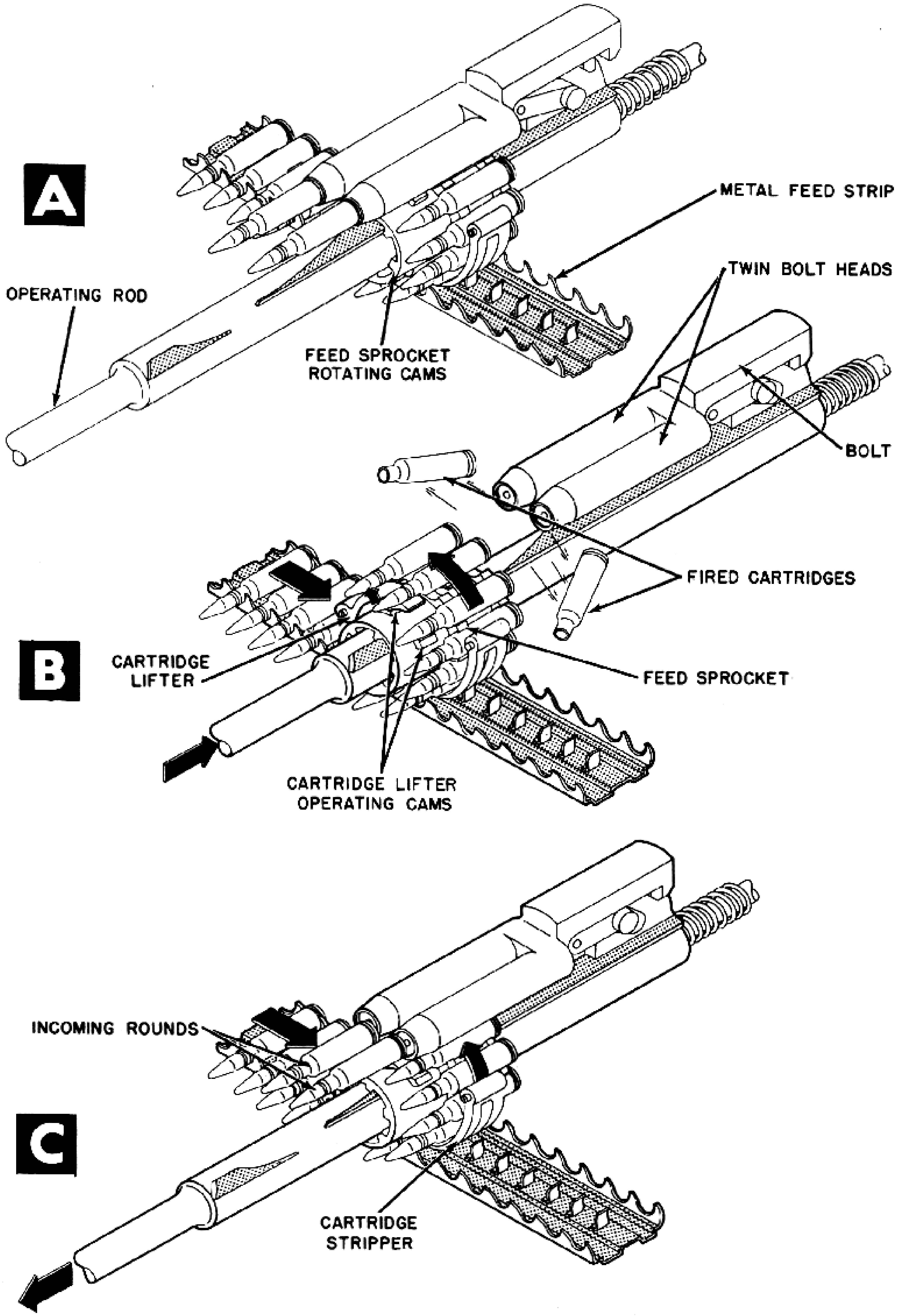


Figure 5–26. Cams on Operating Rod Rotate Feed Sprocket.

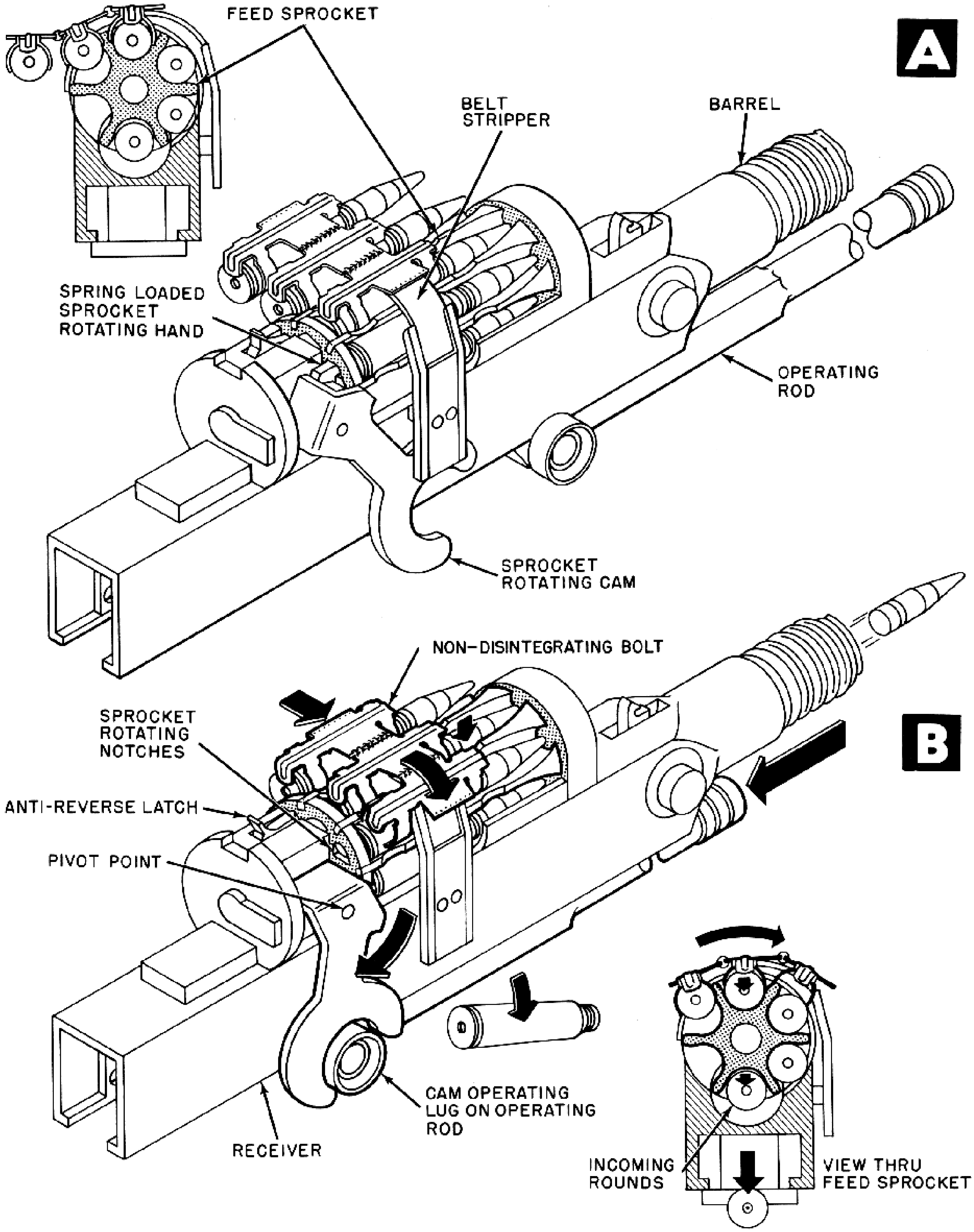


Figure 5-27. Lug on Operating Rod Actuates Sprocket Rotating Cam.

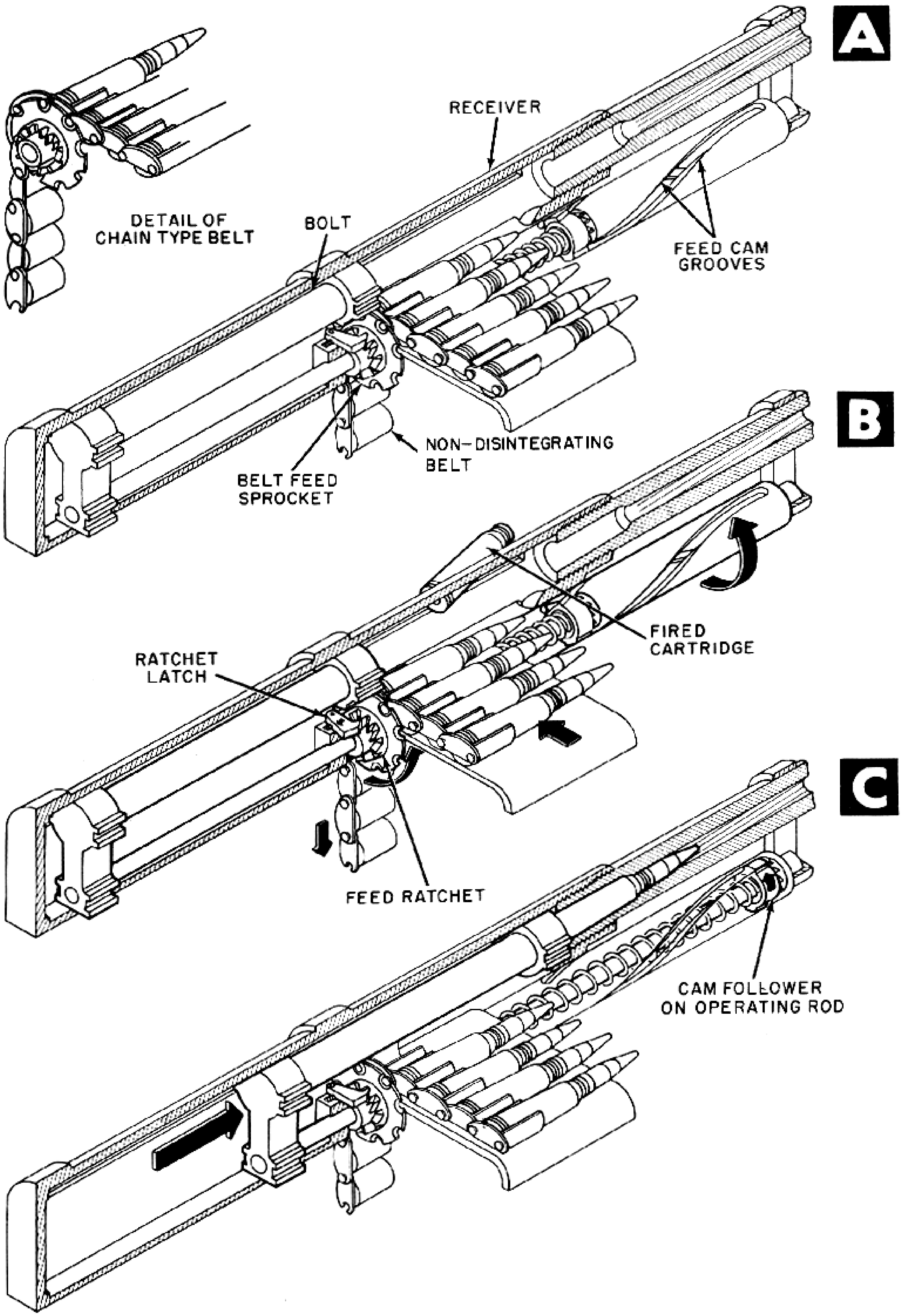


Figure 5–28. Rotating Sprocket Actuates Bicycle Type Chain Ammunition Belt.

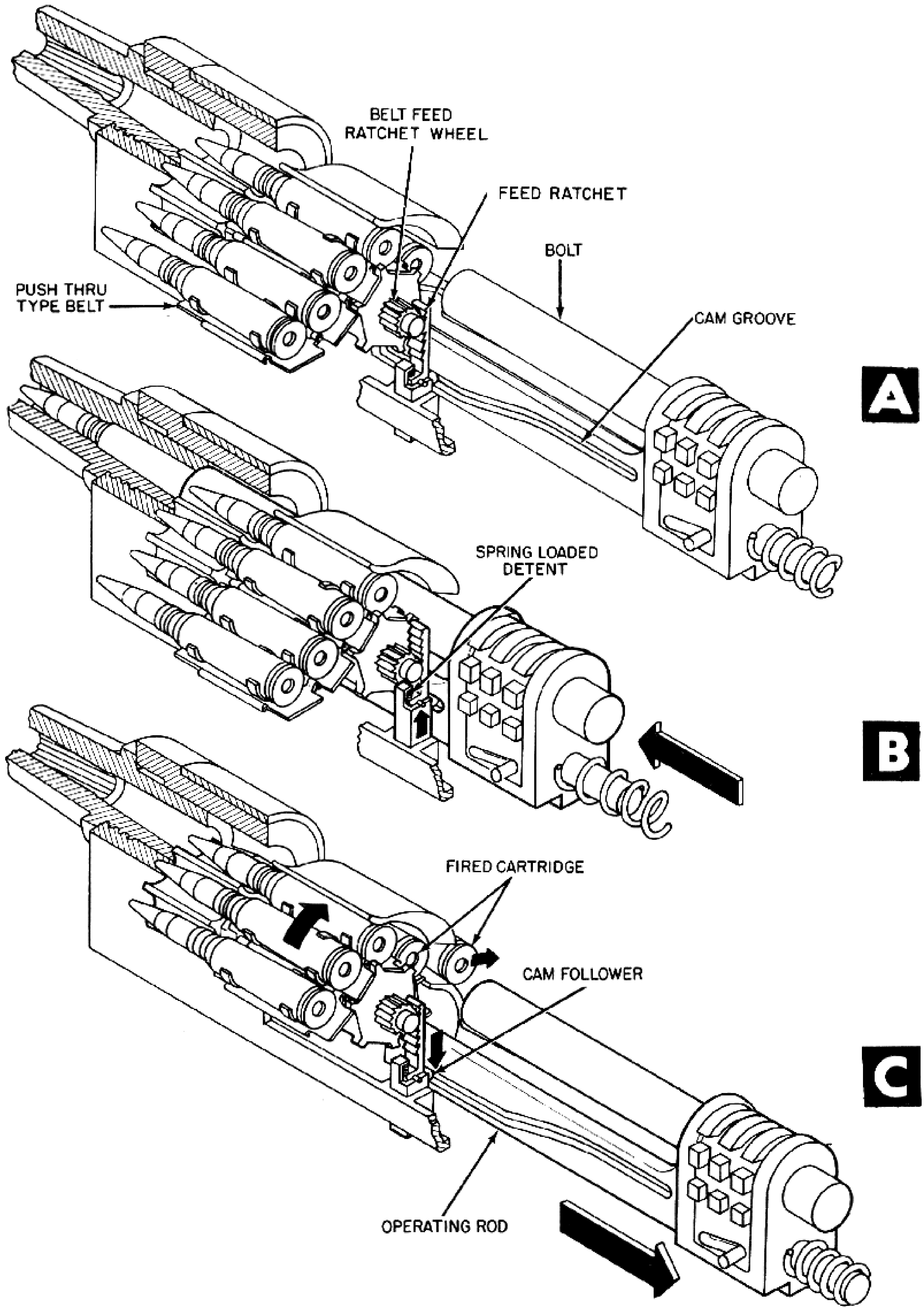


Figure 5–29. Cam Groove in Operating Rod Actuates Feed Sprocket Ratchet.

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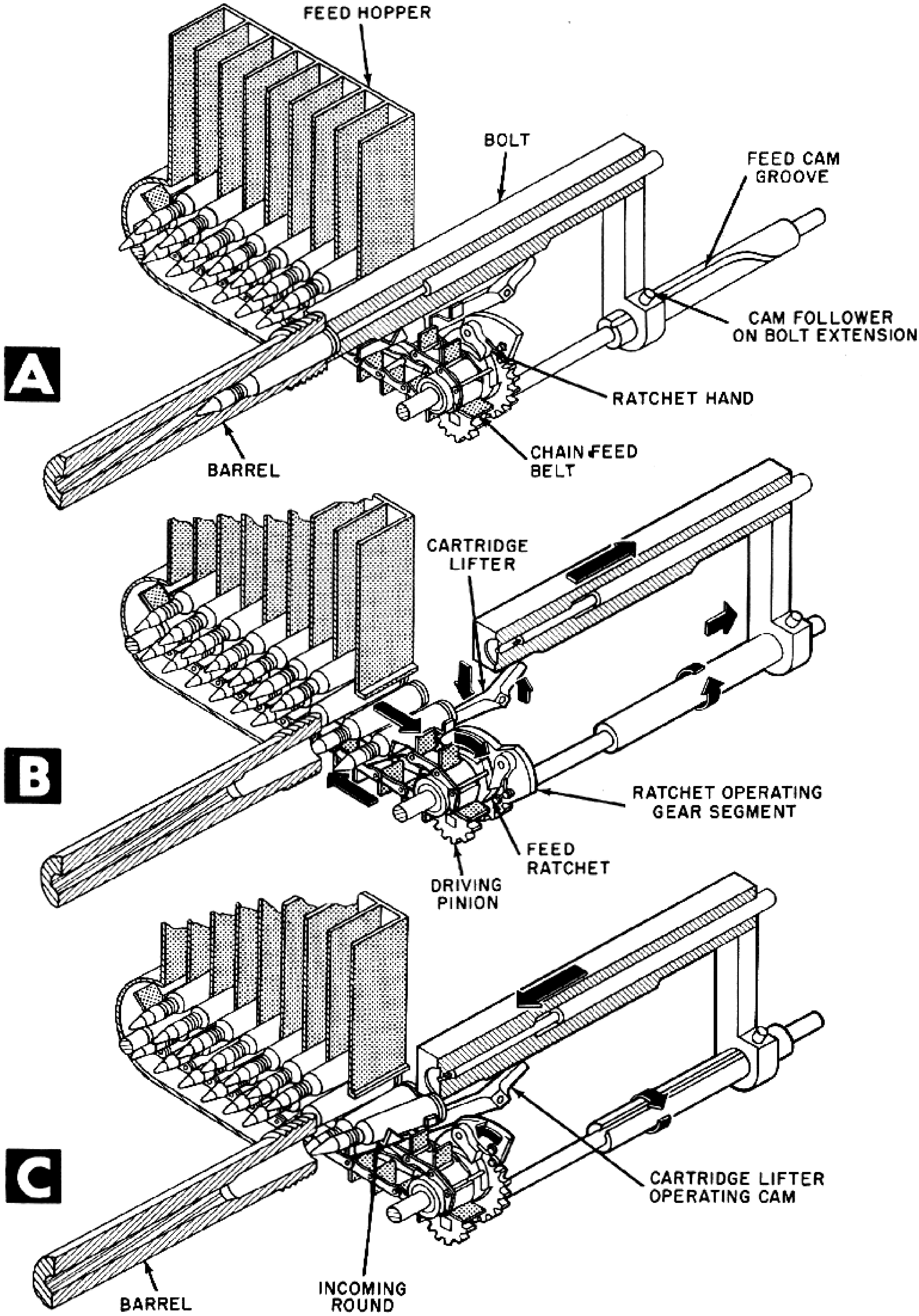


Figure 5–30. Recoiling Bolt Actuates Conveyor Pinions.

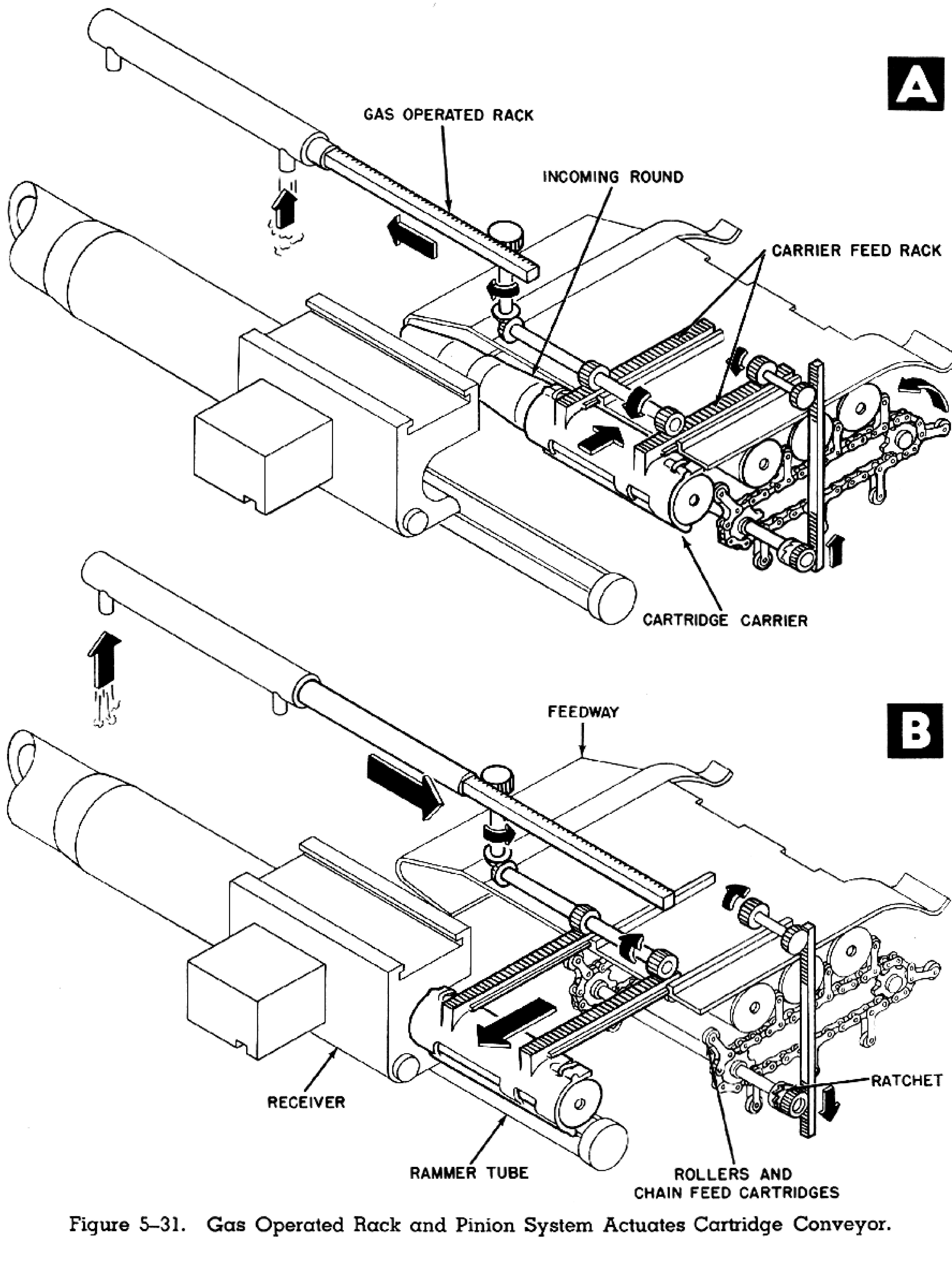


Figure 5–31. Gas Operated Rack and Pinion System Actuates Cartridge Conveyor.

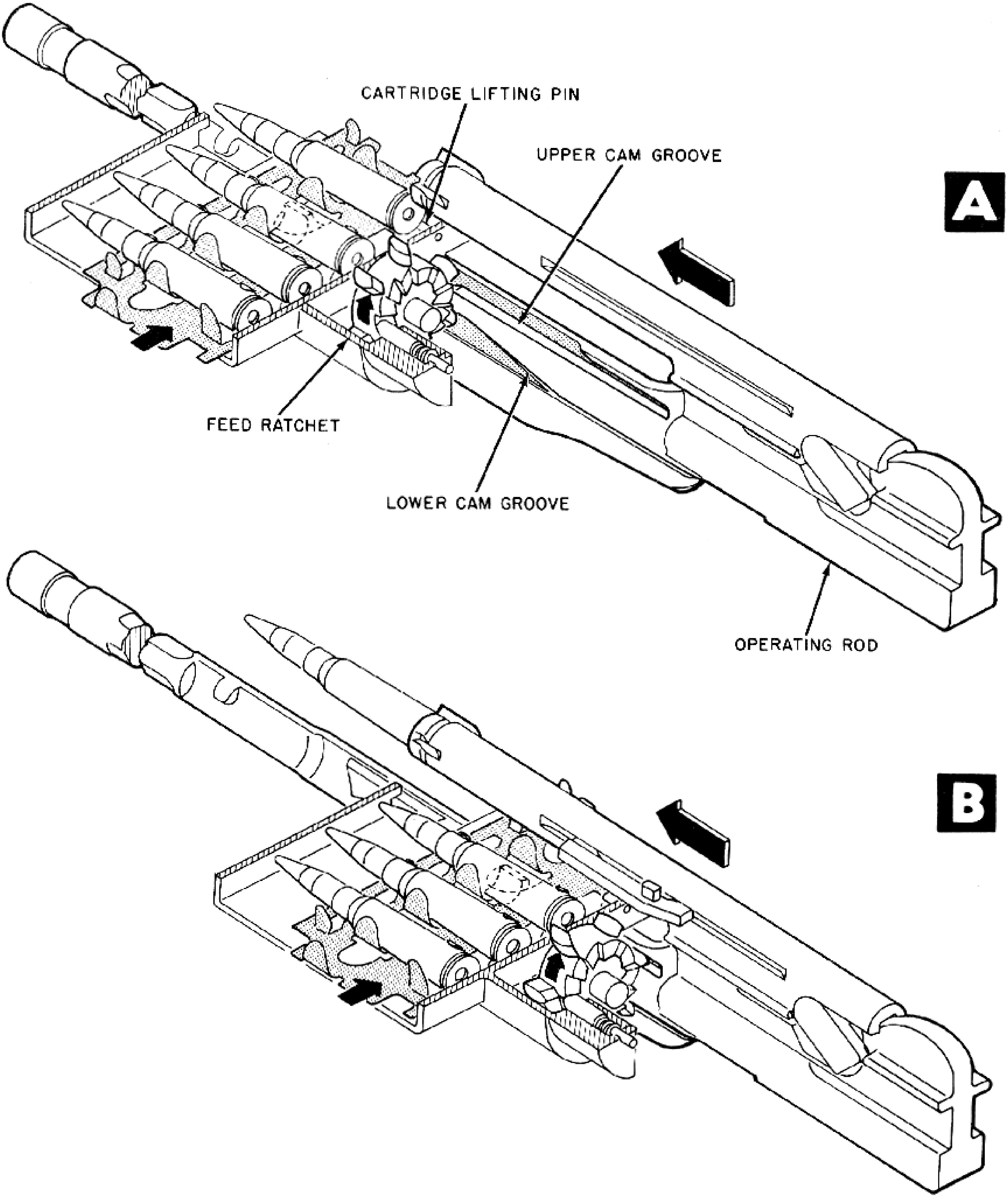
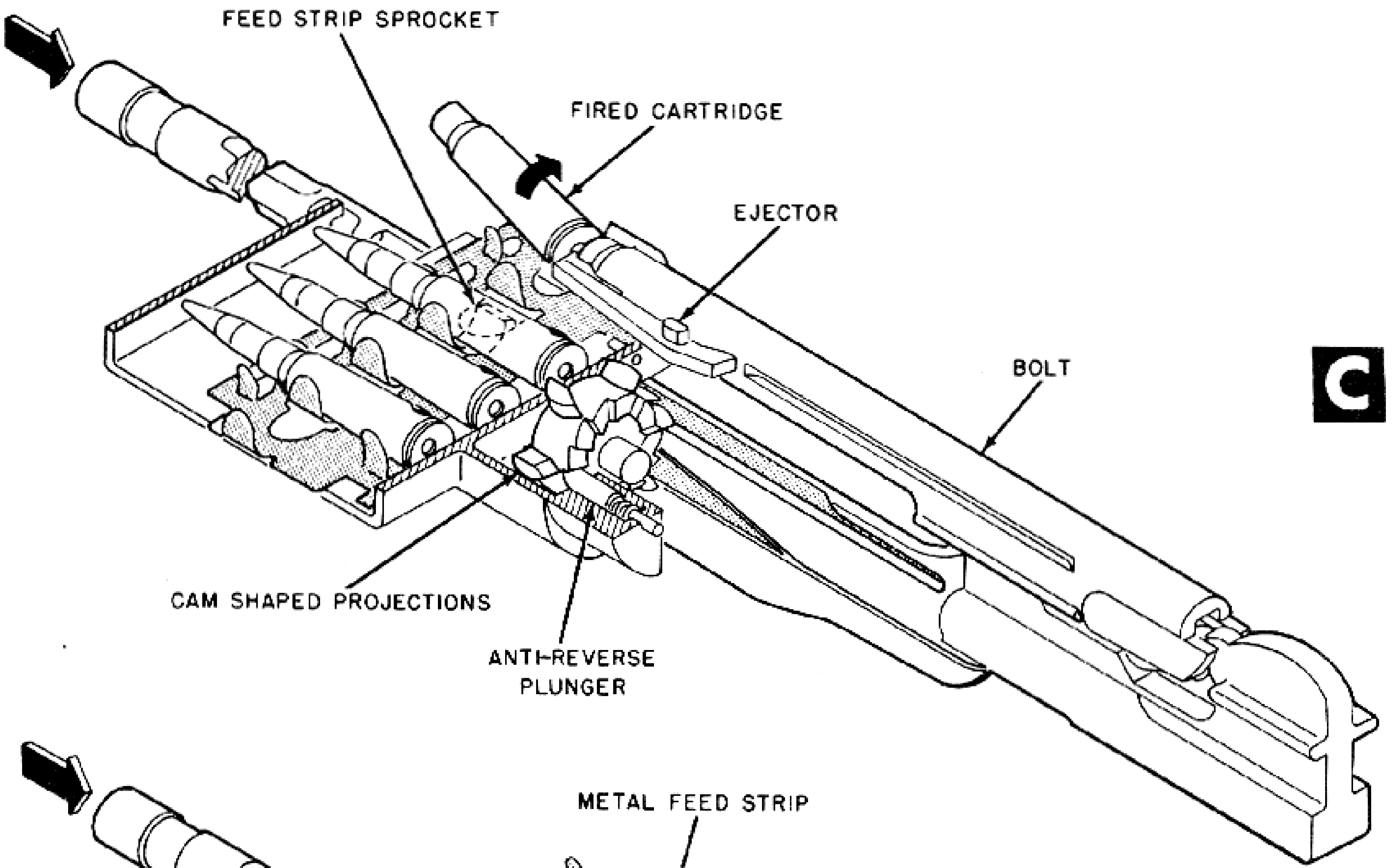
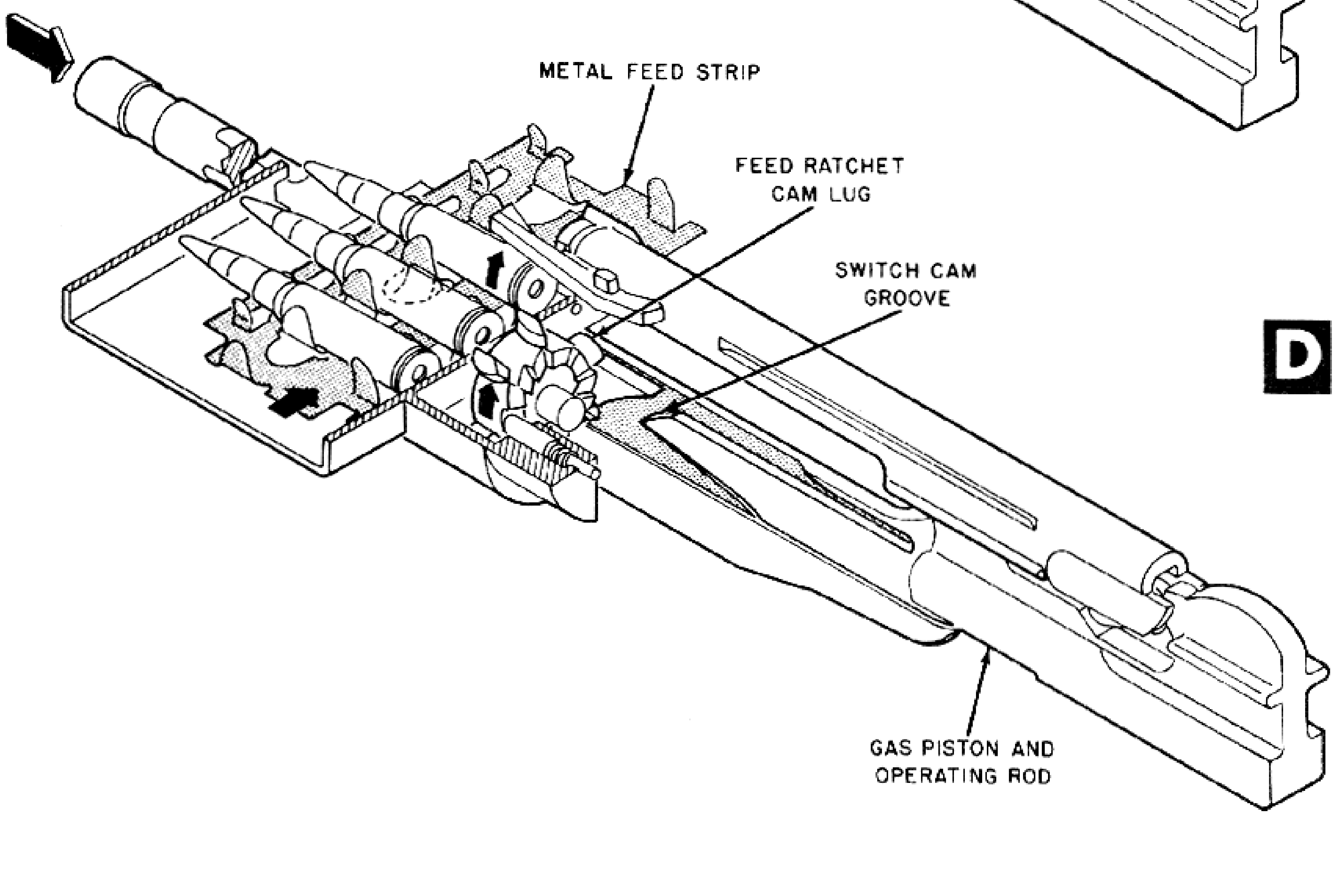


Figure 5–32. Cam Grooves in Operating Rod Actuate





Cam Followers on Feed Sprocket Surface.

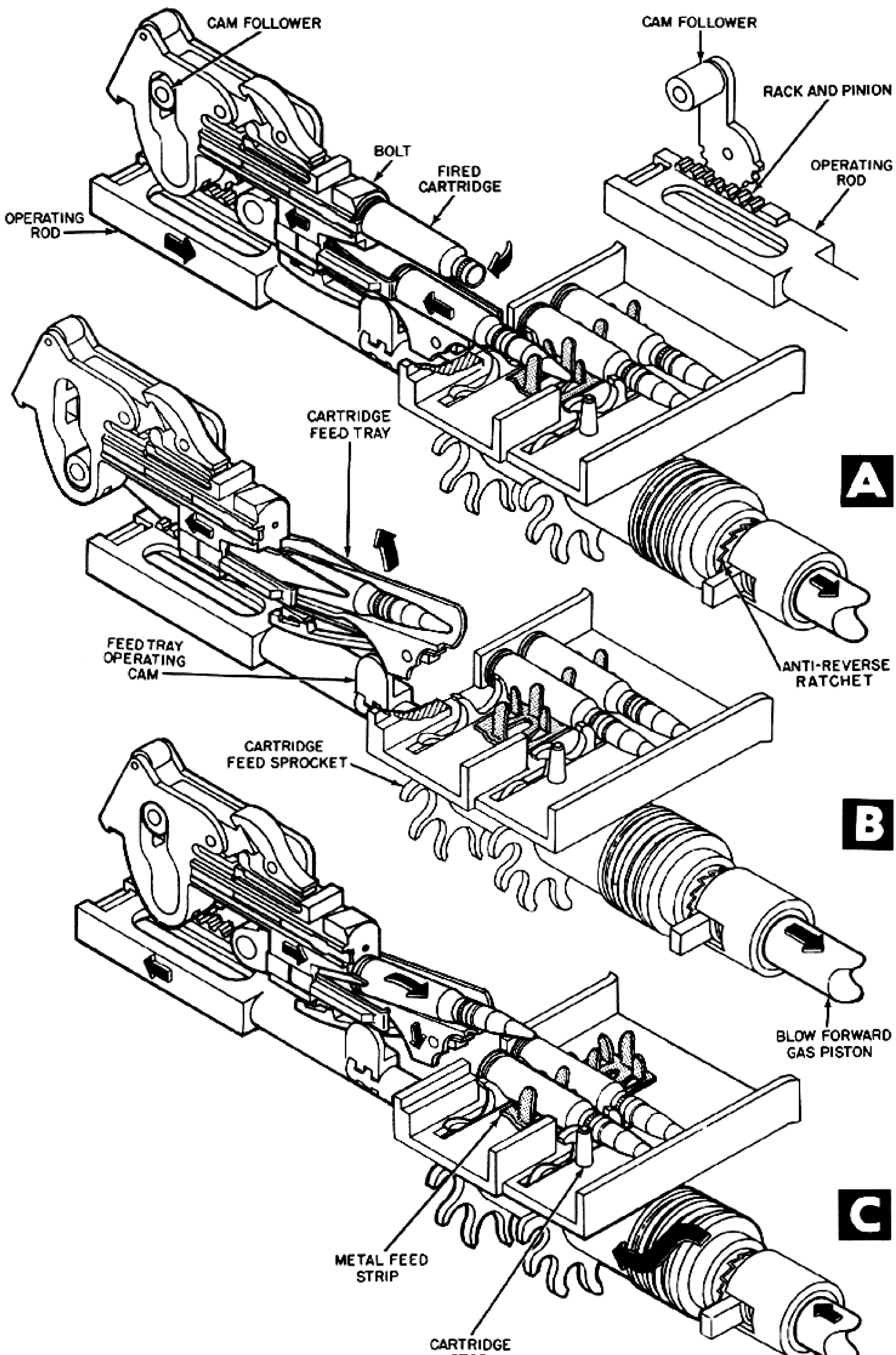


Figure 5–33. Blow-forward Operating Rod Lifts Cartridge Feed Tray and Rotates Sprocket.

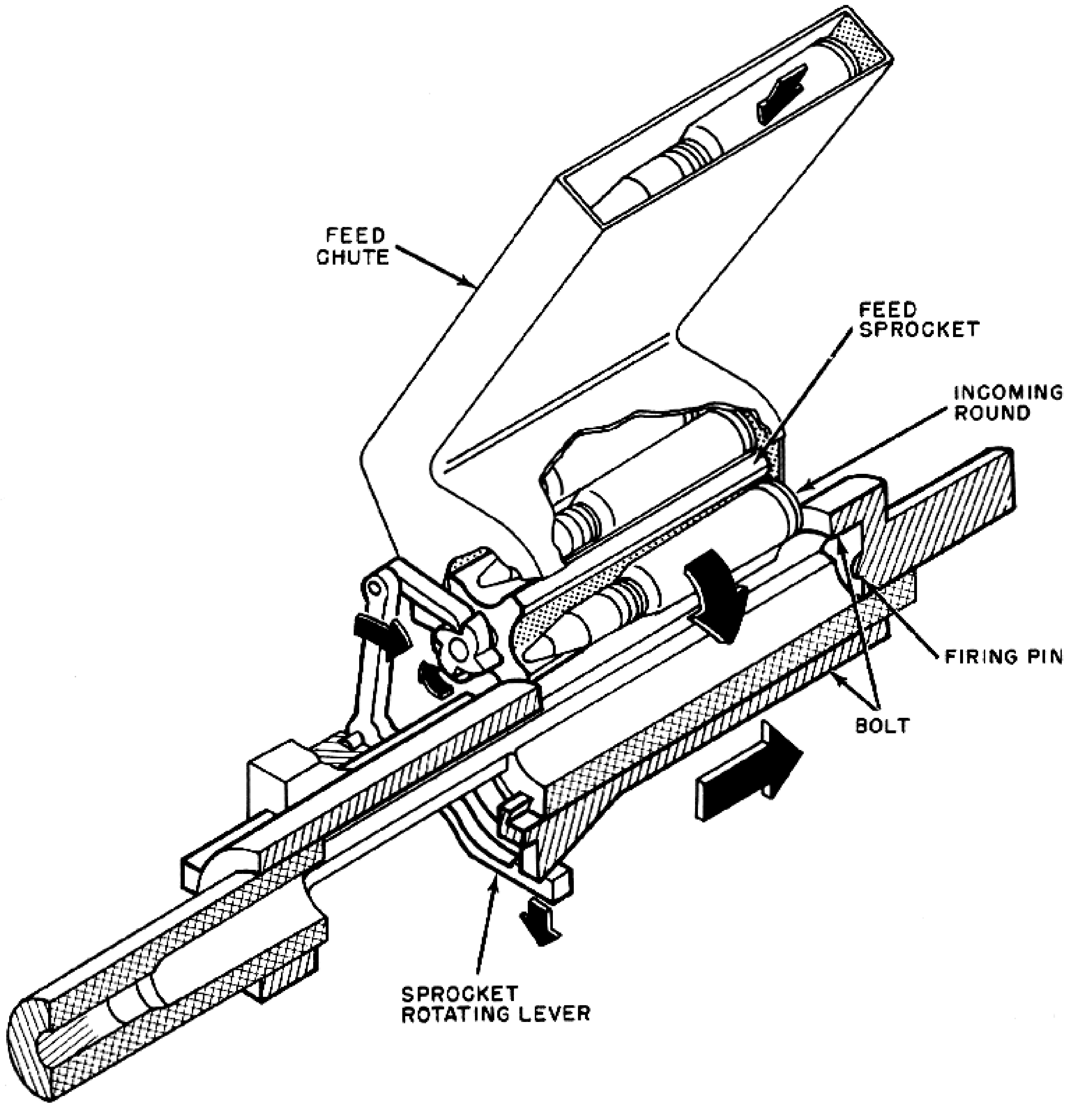


Figure 5–34. Recoiling Bolt Actuates Feed Sprocket.

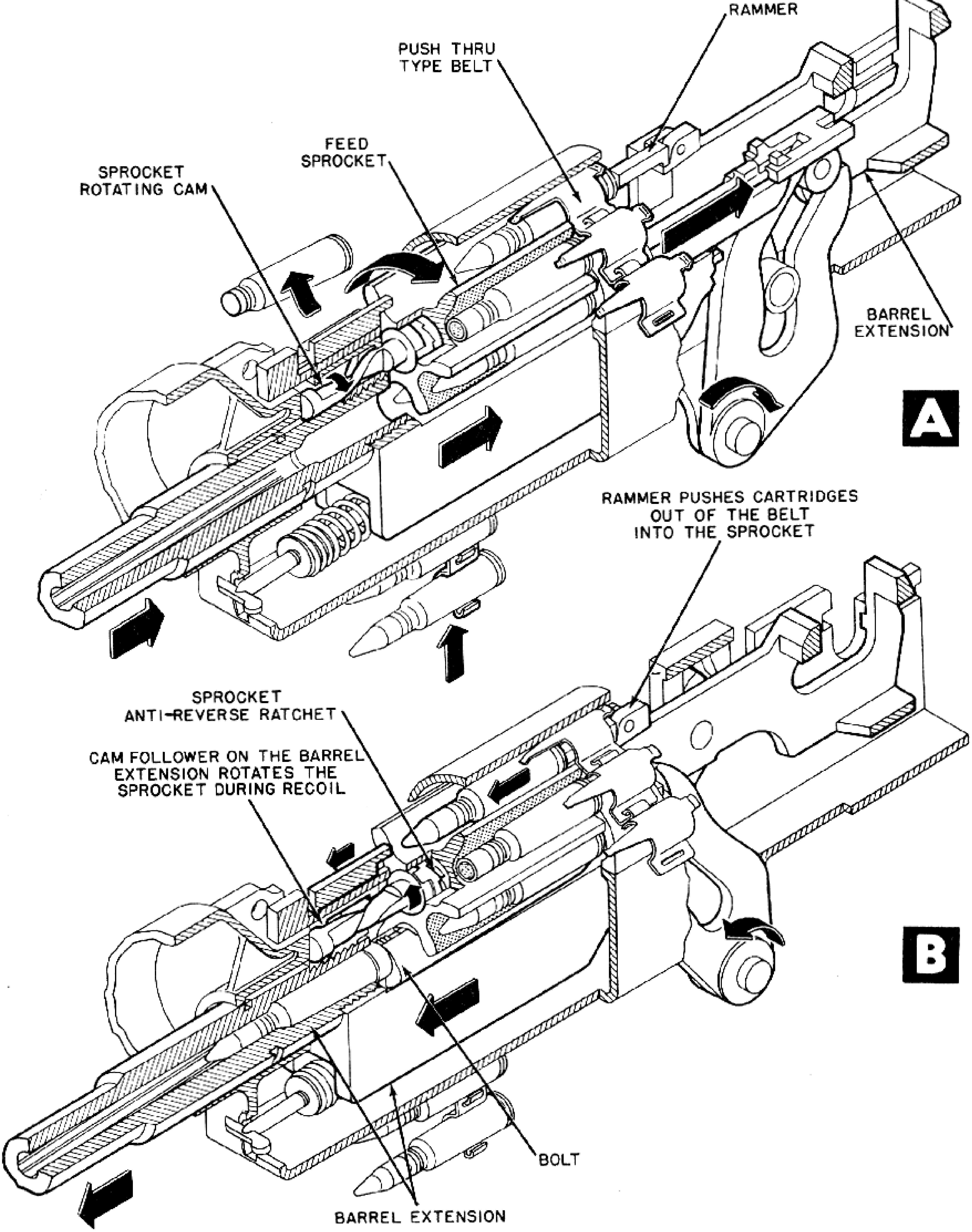


Figure 5–35. Cam Follower on Barrel Extension Rotates Feed Sprocket.

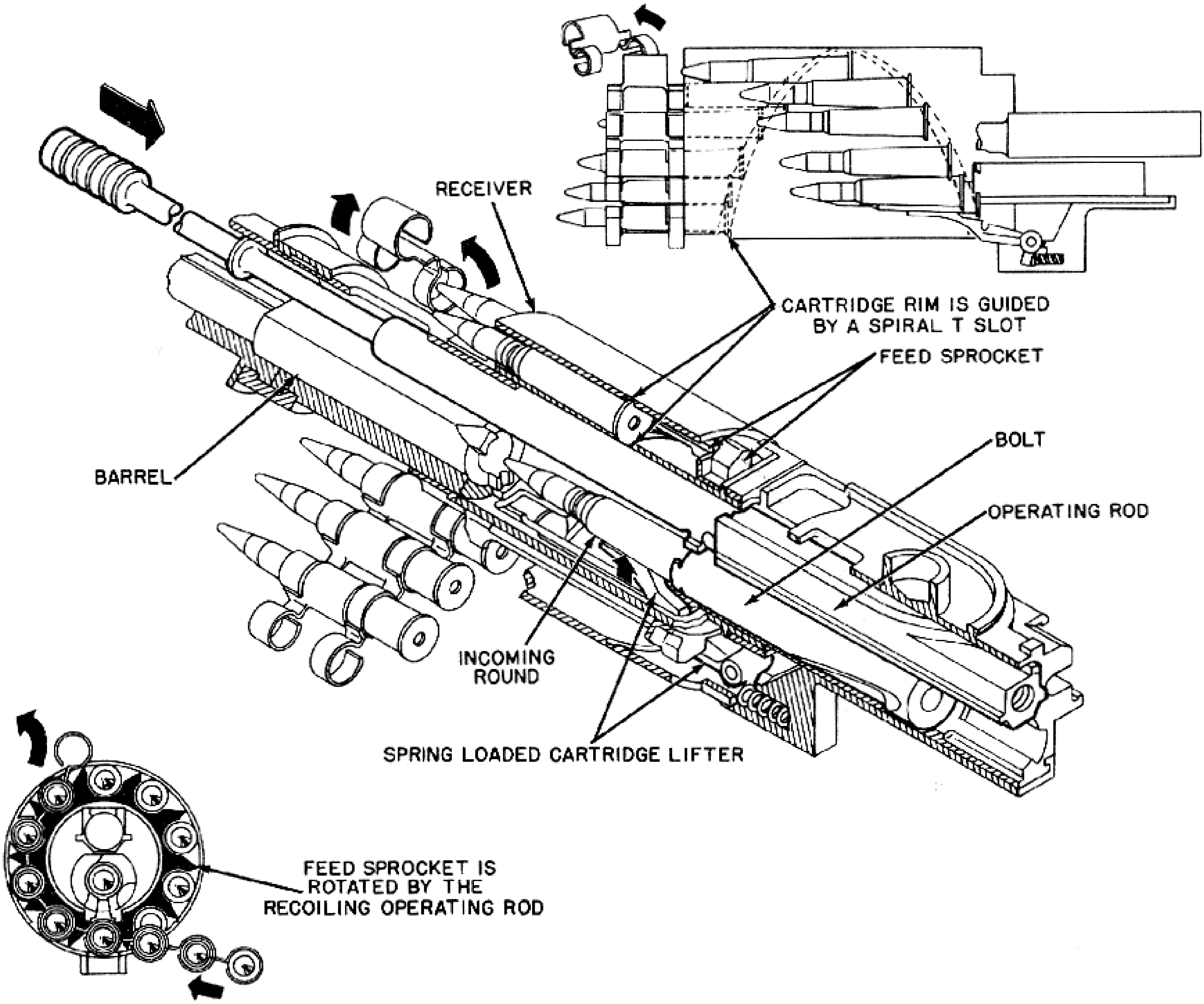


Figure 5–36. Spiral Cam Withdraws Rimmed Ammunition From Belt.

D. Cartridge Lifter

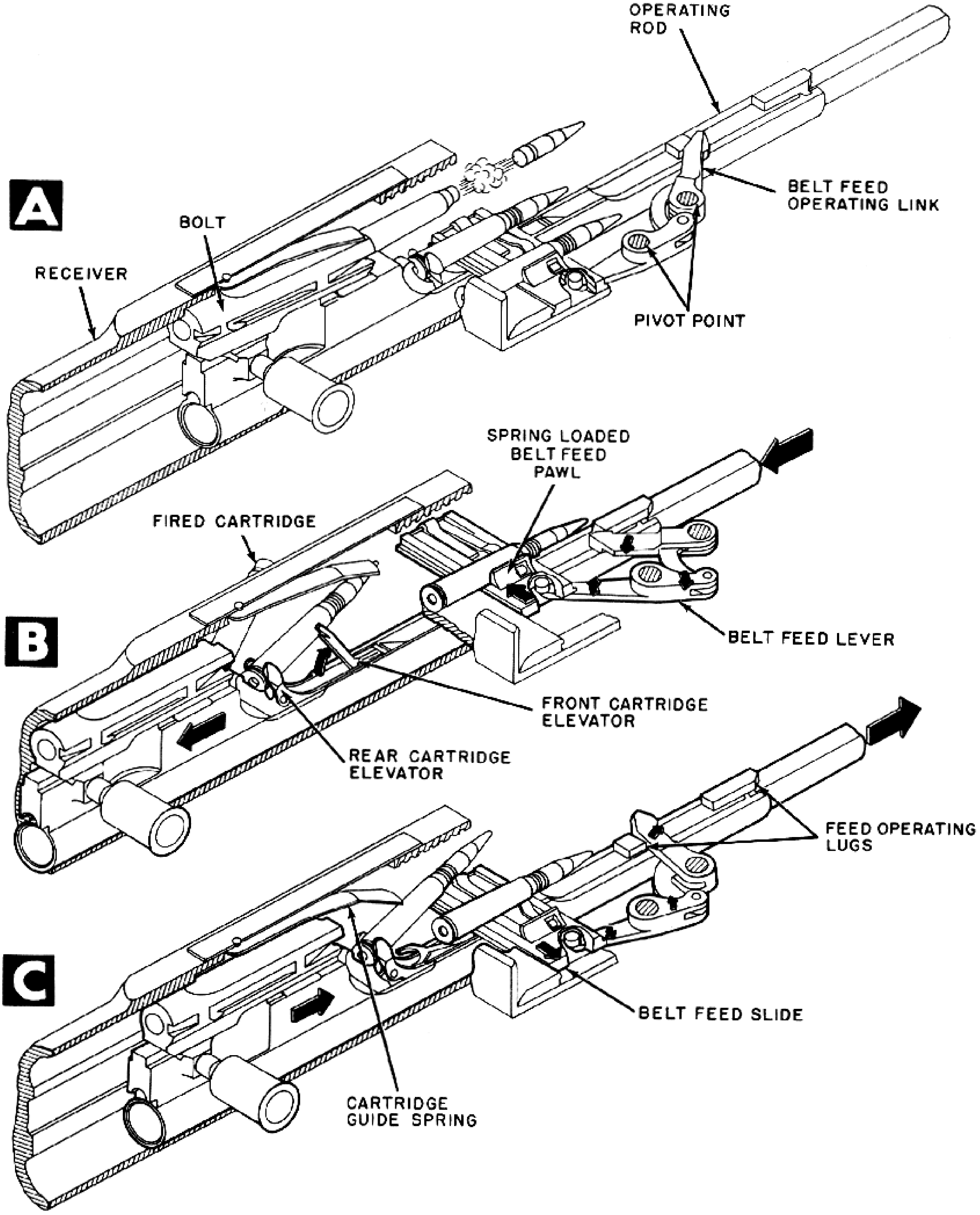


Figure 5–37. Cam on Operating Rod Actuates Belt Feed Levers and Cartridge Elevators.

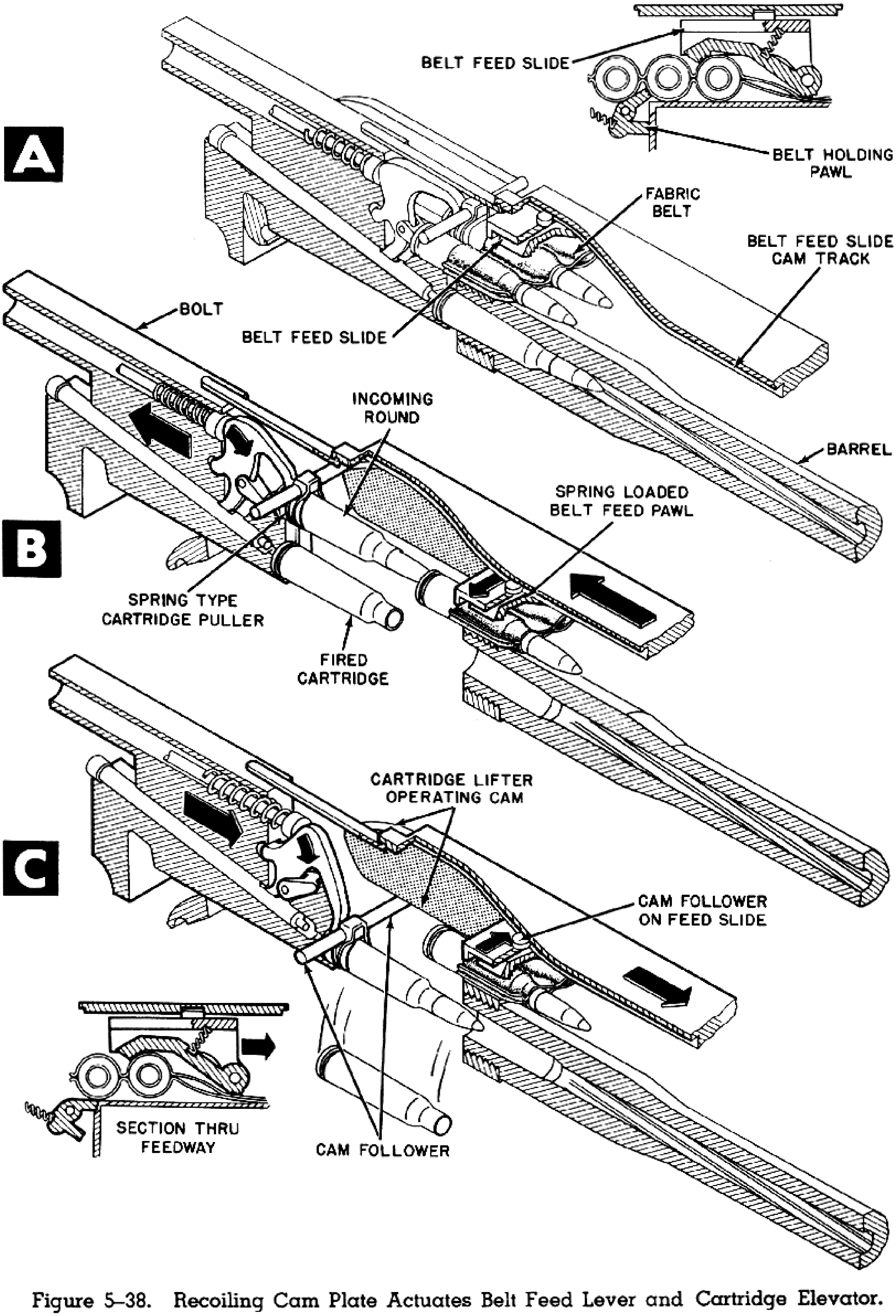


Figure 5–38. Recoiling Cam Plate Actuates Belt Feed Lever and Cartridge Elevator.

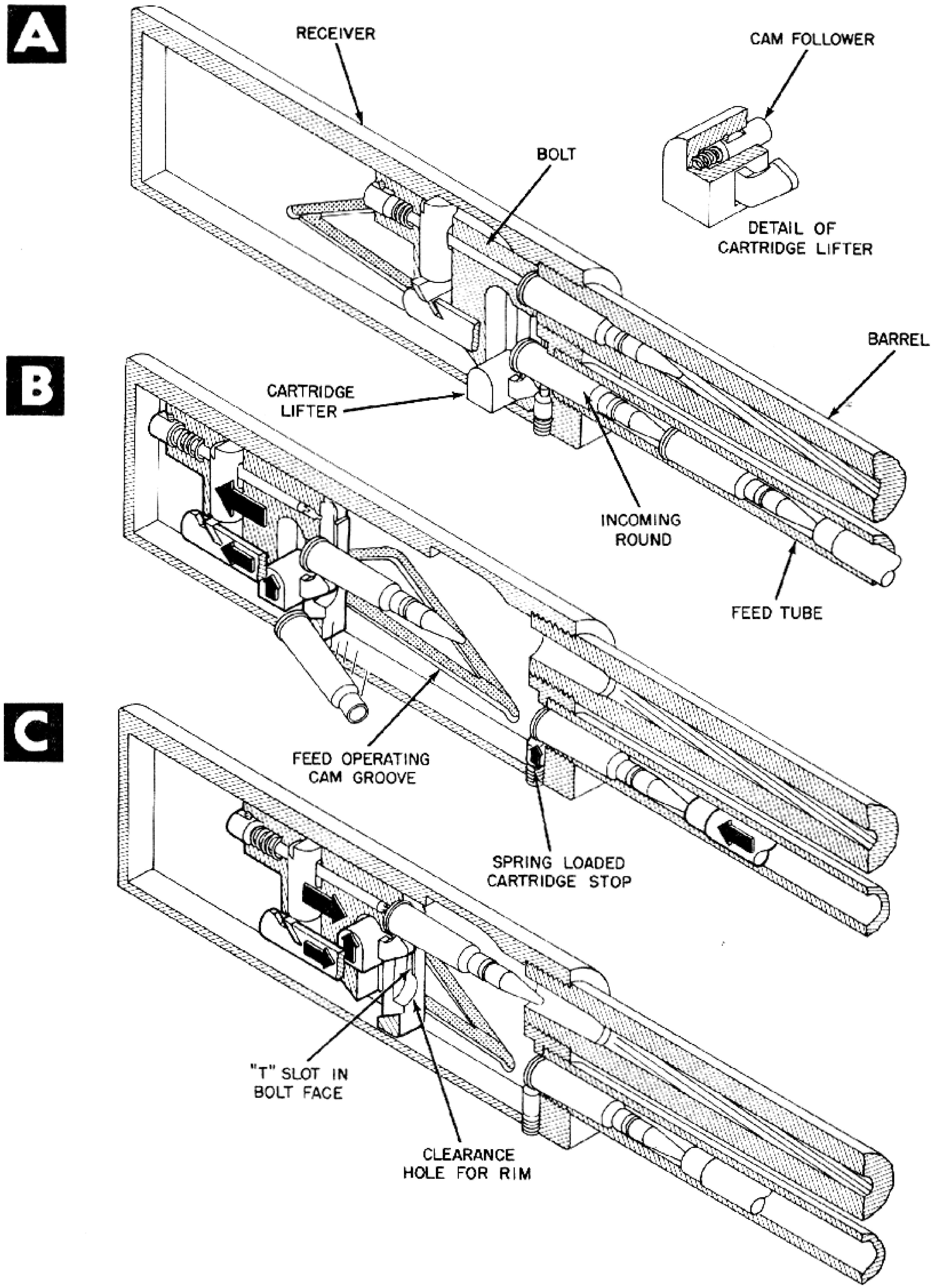


Figure 5–39. Cartridge Lifter Is Actuated by Cams in Receiver Wall.

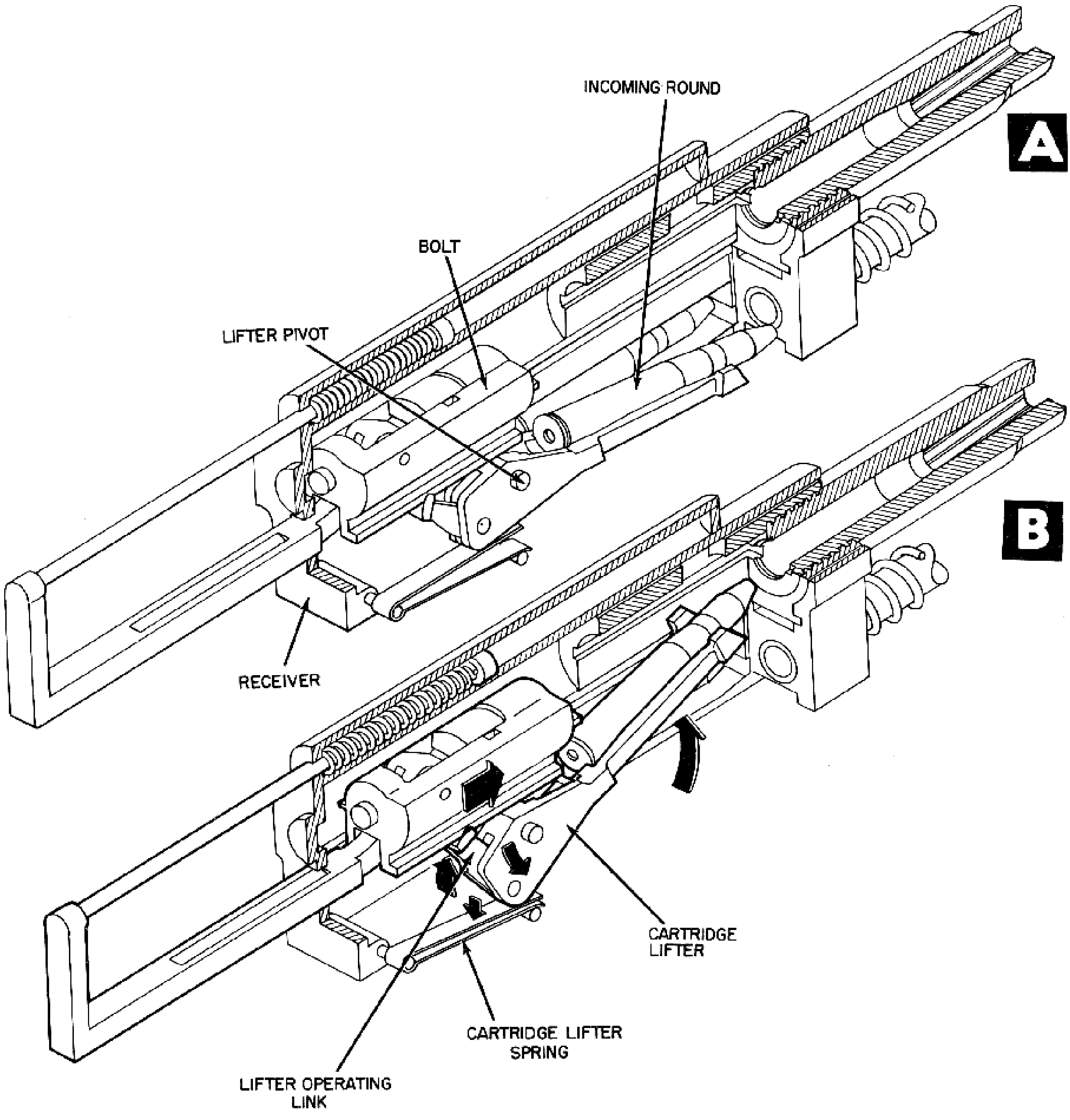


Figure 5–40. Counter-Recoiling Bolt Actuates Cartridge Lifter.

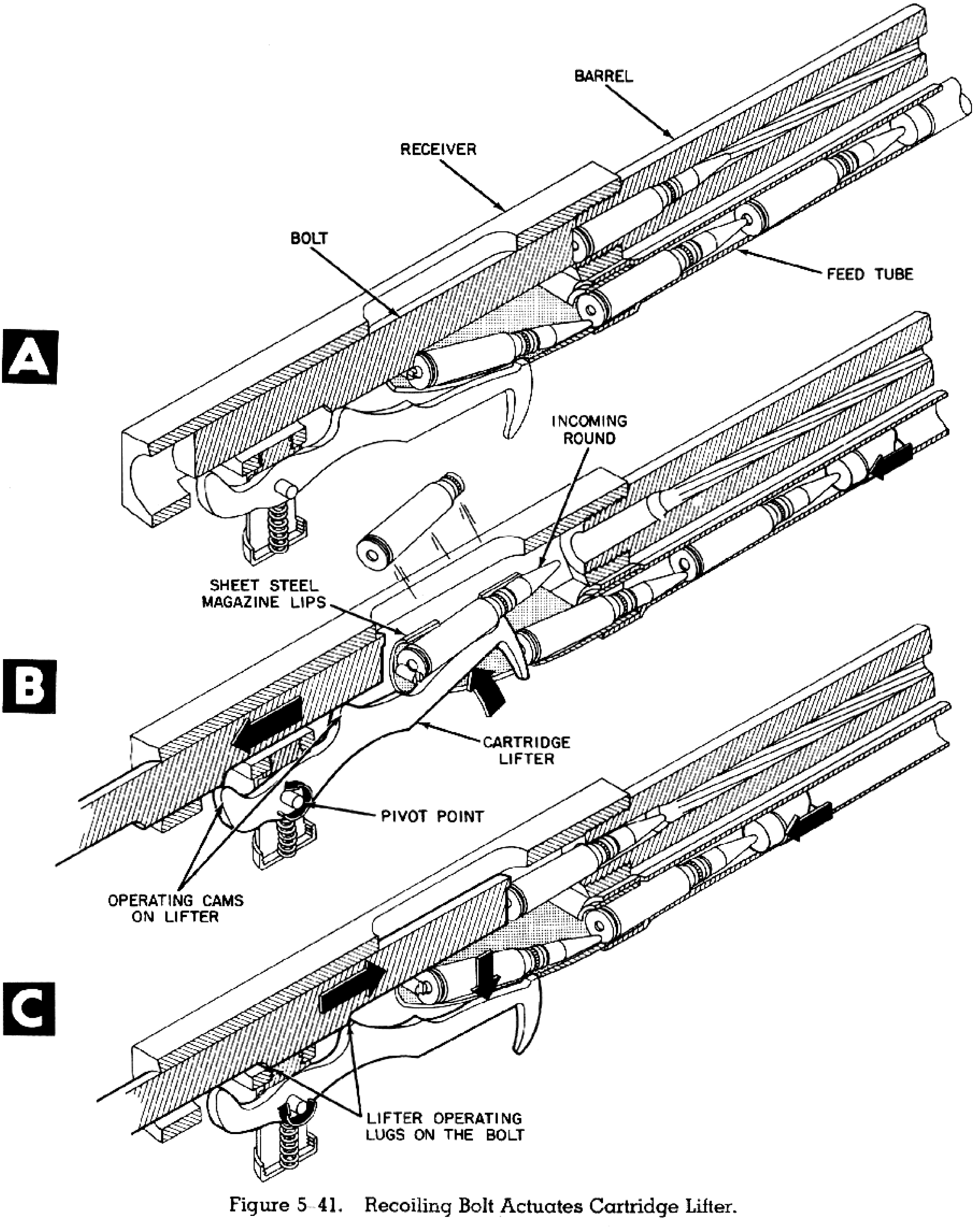


Figure 5-41. Recoiling Bolt Actuates Cartridge Lifter.

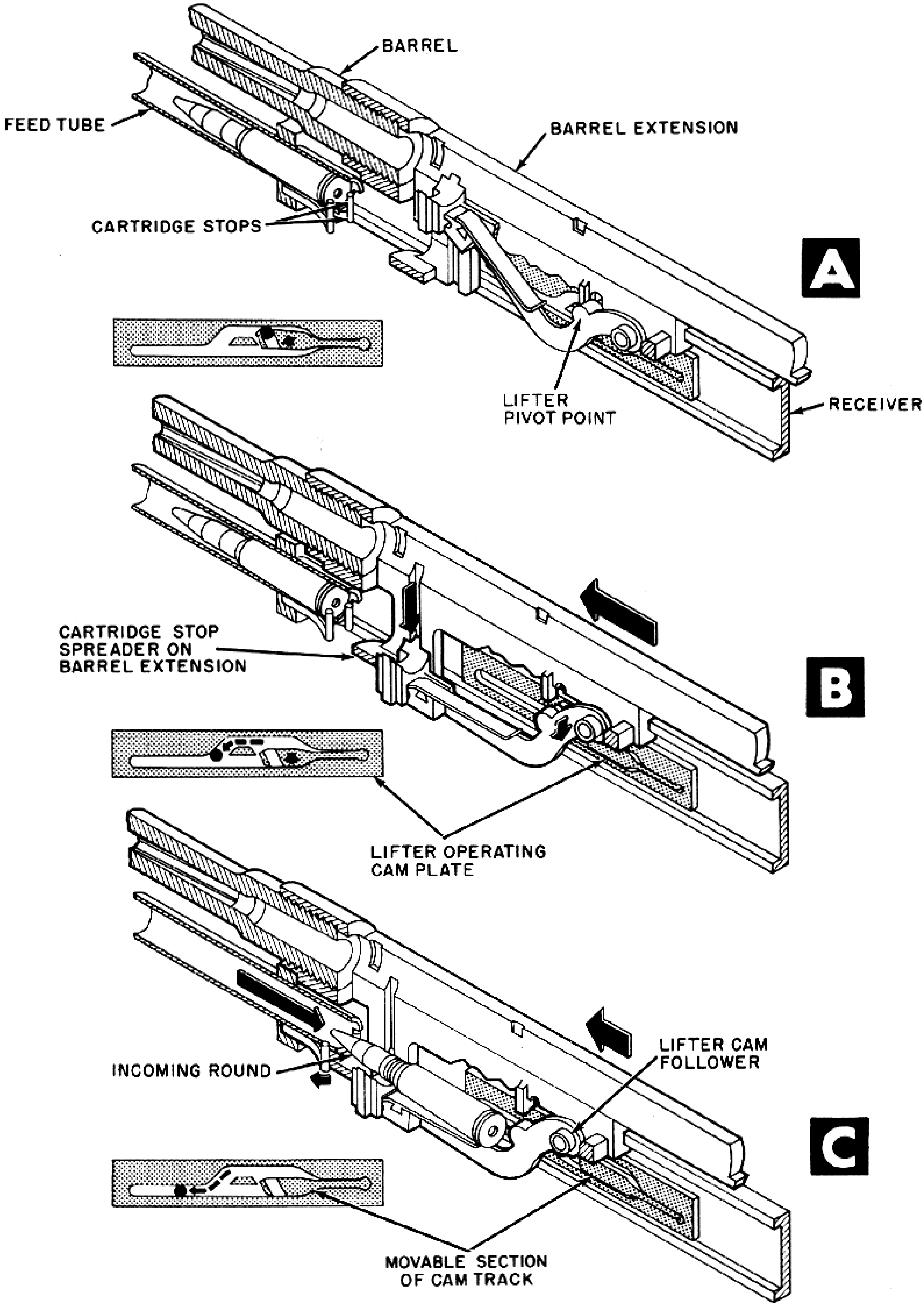


Figure 5–42. Cam Track on Receiver Actuates Cartridge Lifter.

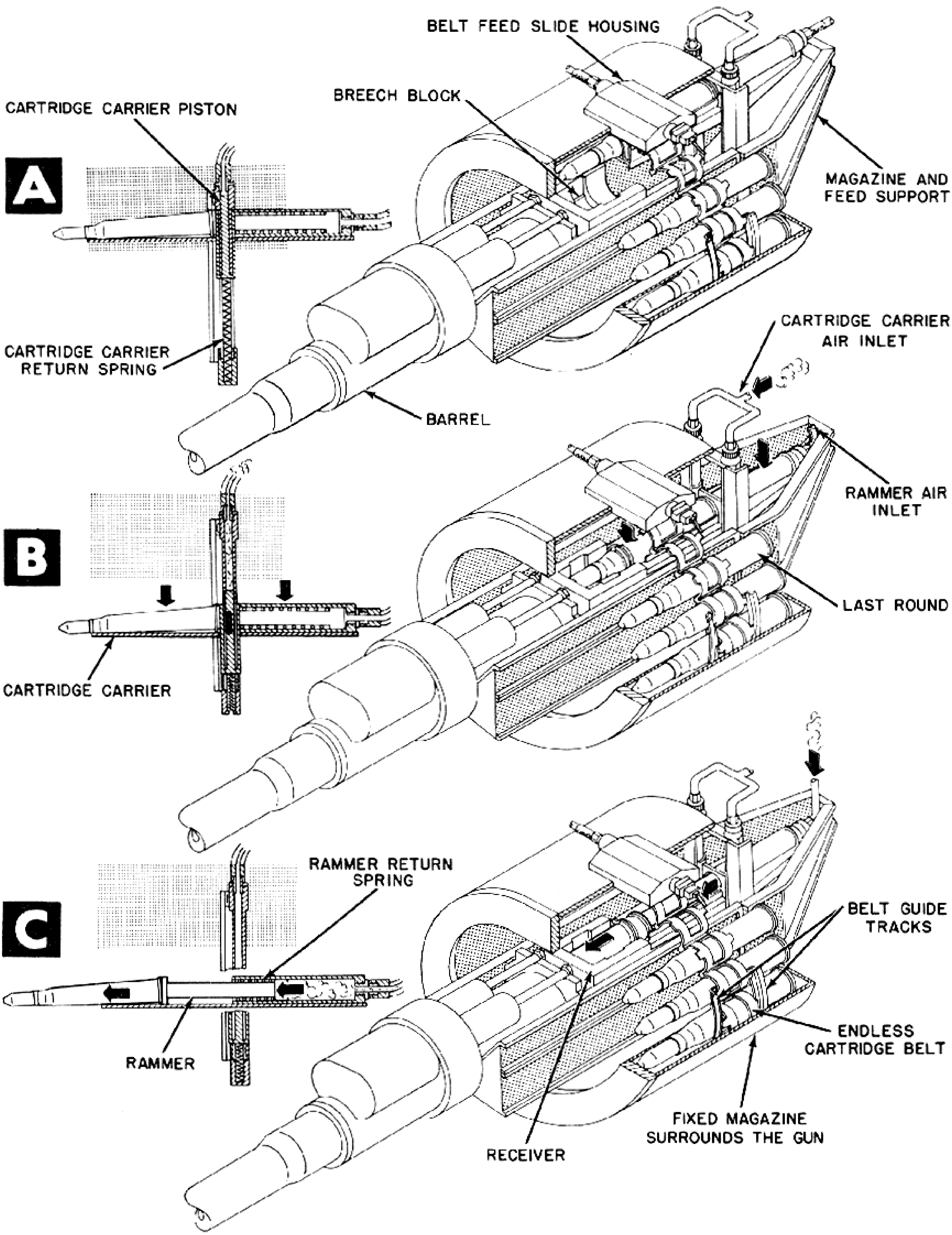


Figure 5–43. Gas Actuated Cartridge Lifter and Rammer.

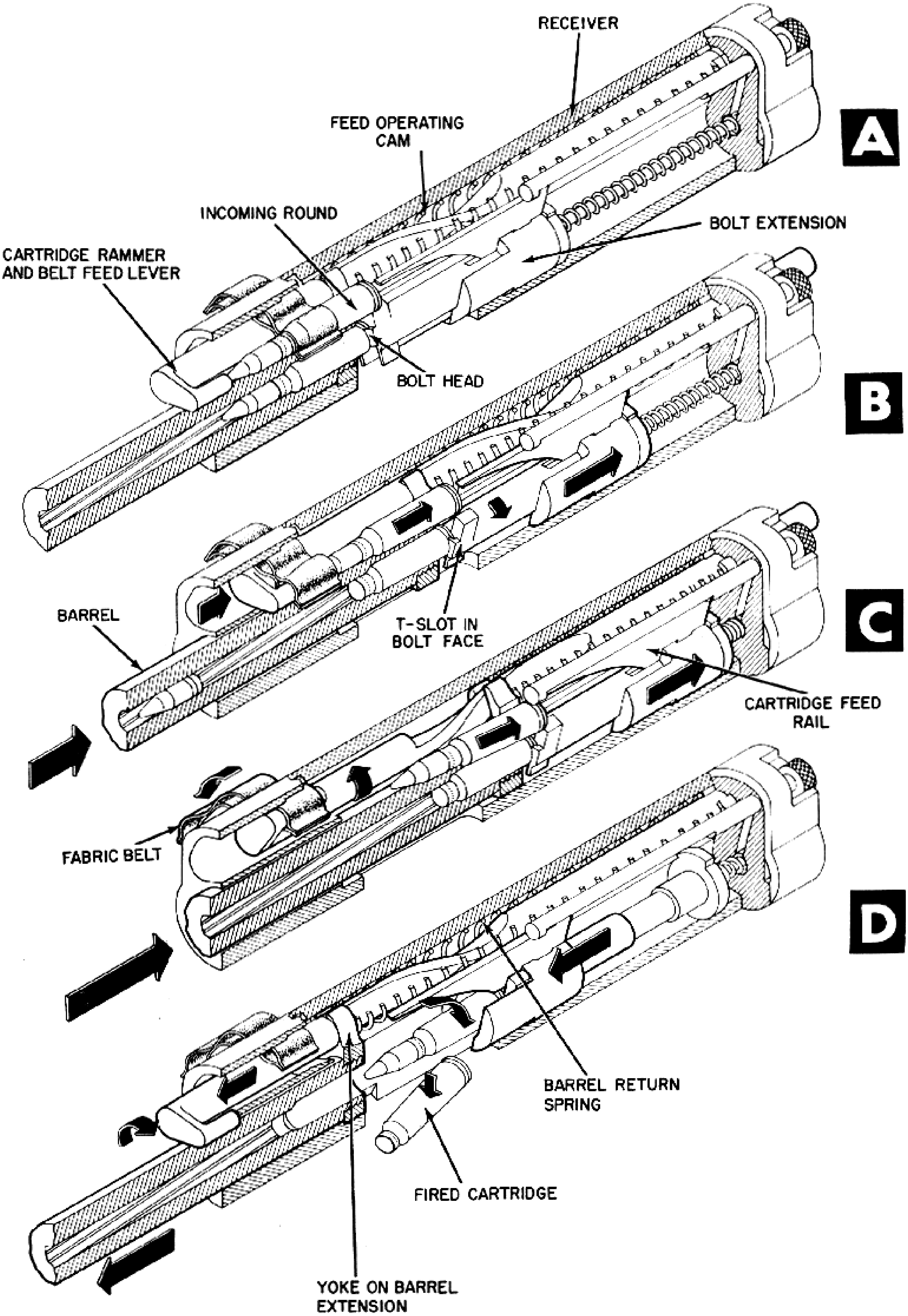


Figure 5-44. Cam on Barrel Extension Actuates Belt Feed Lever.

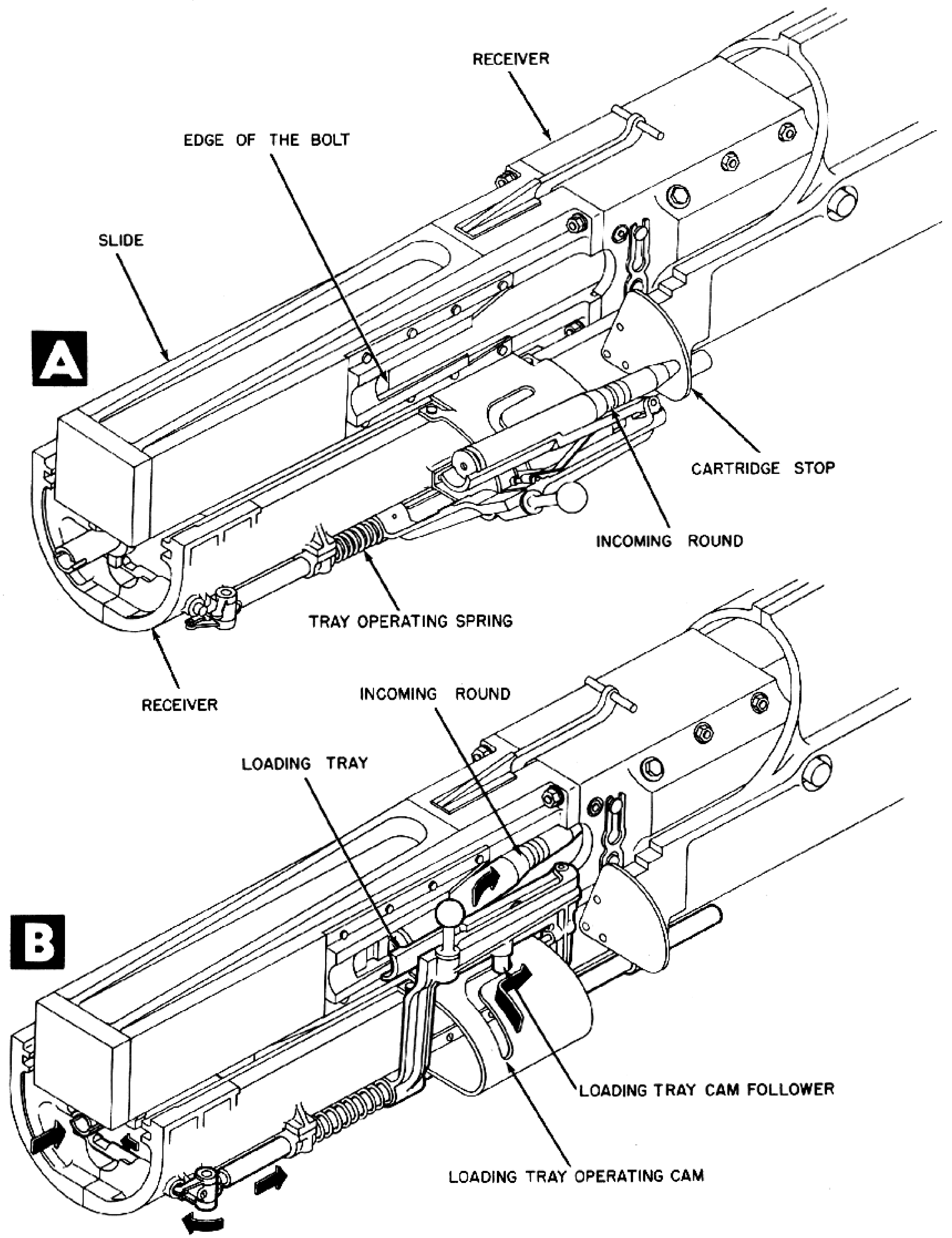


Figure 5–45. Cam on Receiver Guides Spring-Powered Loading Tray.

E. Rammer

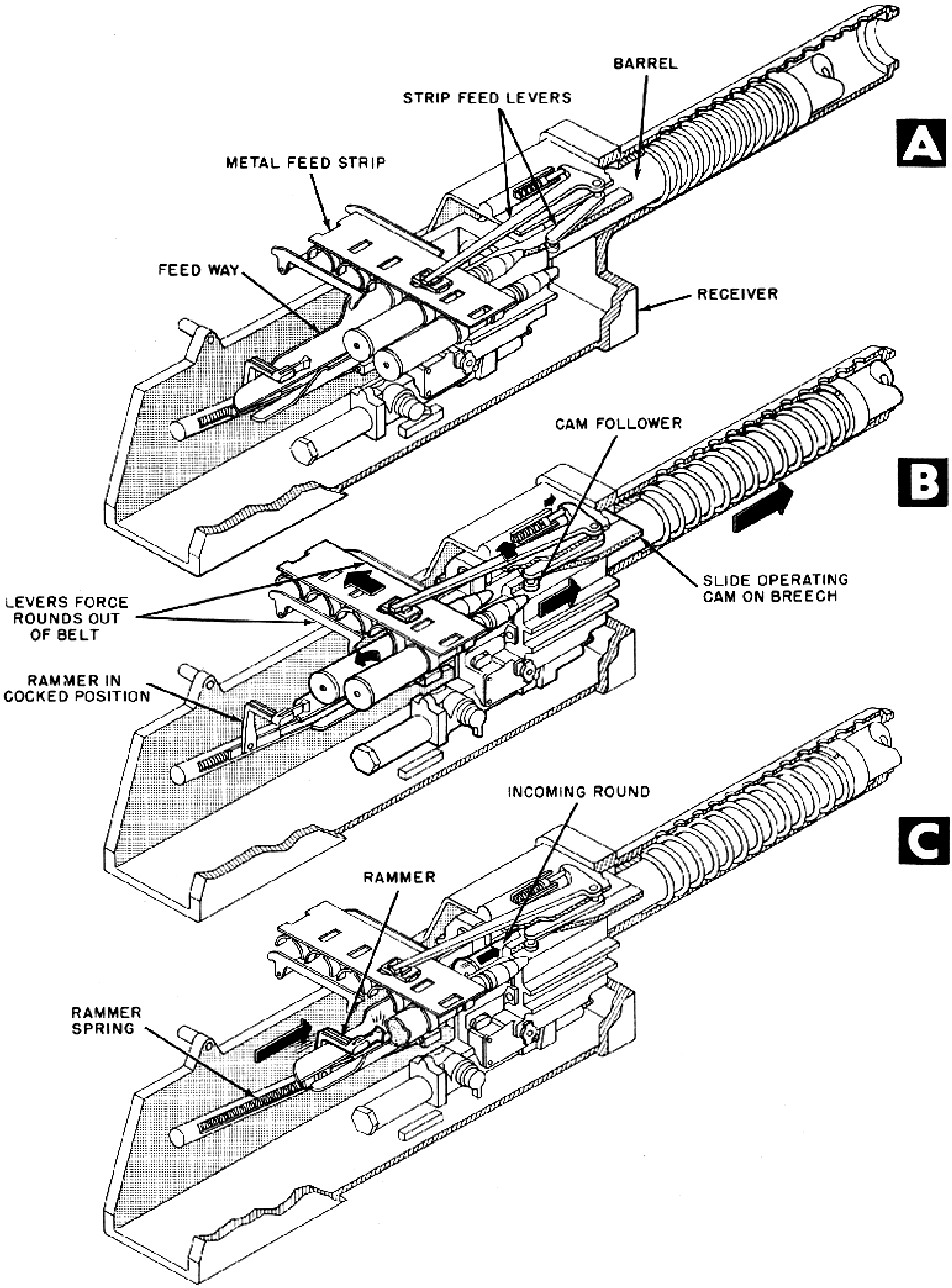


Figure 5-46. Cam on Recoiling Breech Actuates Feed Strip.

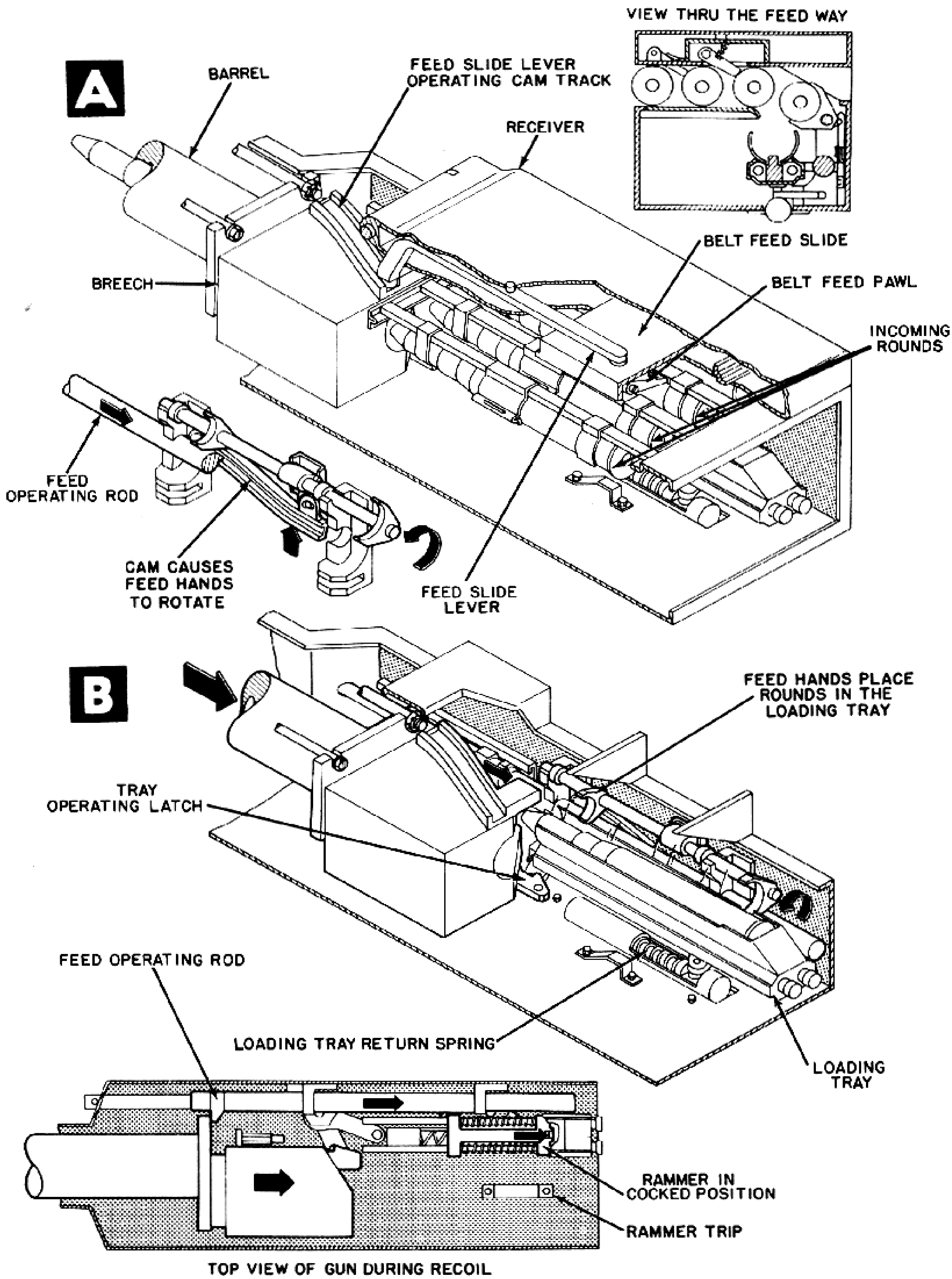
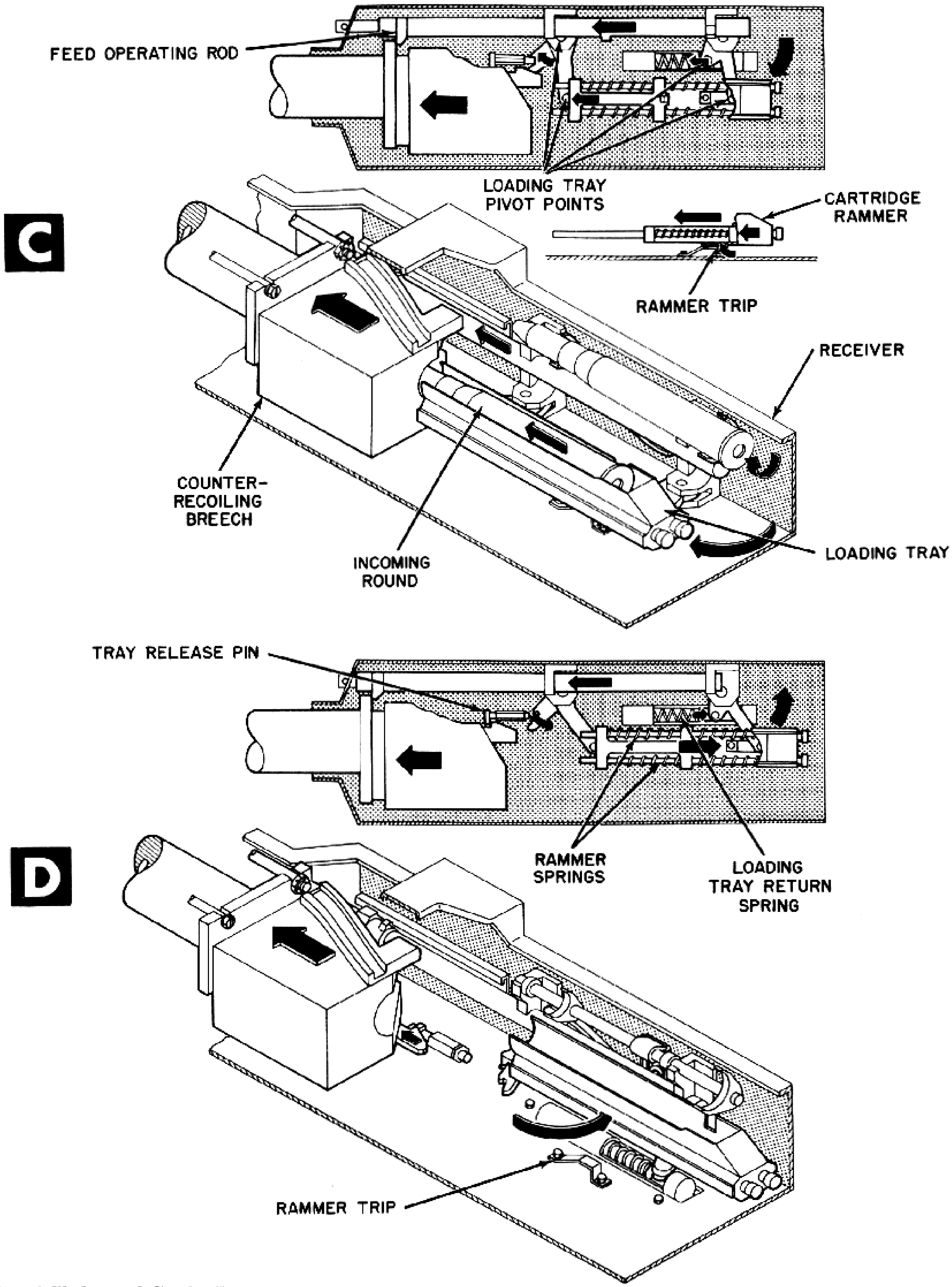


Figure 5-47. Recoiling Breech Block Actuates



Belt Feed Slide and Cocks Rammer.

F. Linkless

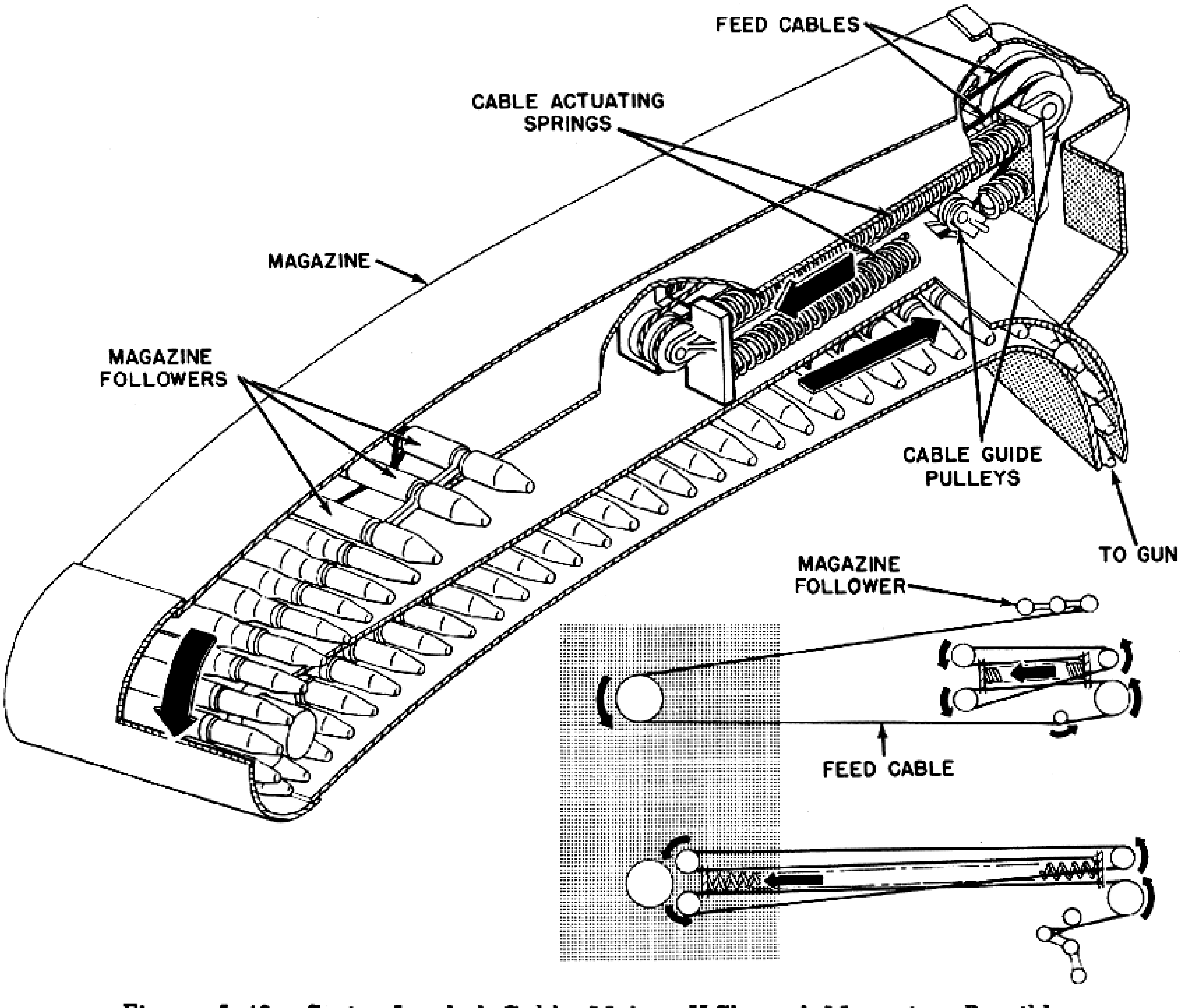


Figure 5–48. Spring-Loaded Cable Makes U-Shaped Magazine Possible.

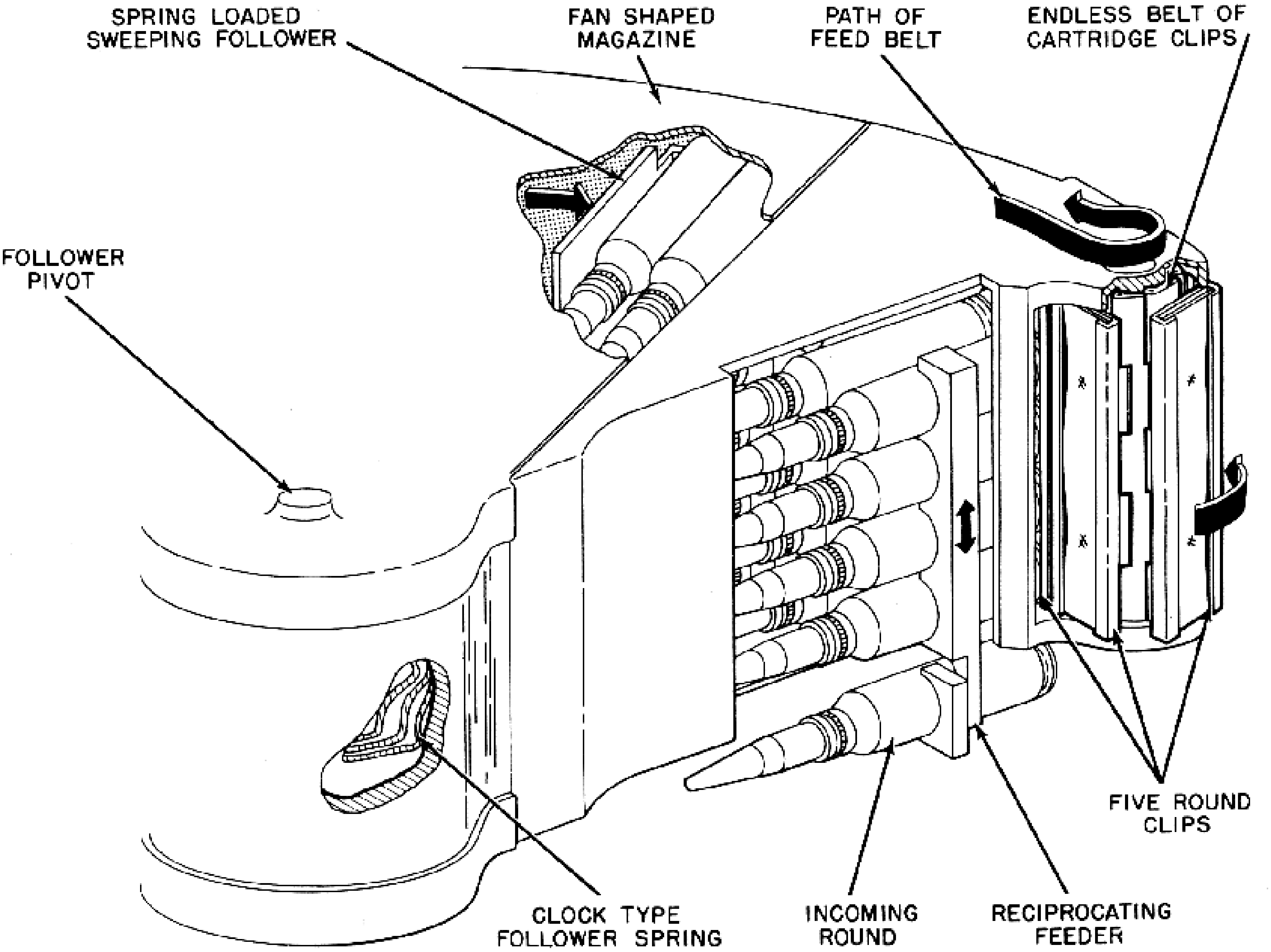


Figure 5–49. Fan-Shaped Magazine Stores Ammunition on Endless Belt of Clips.

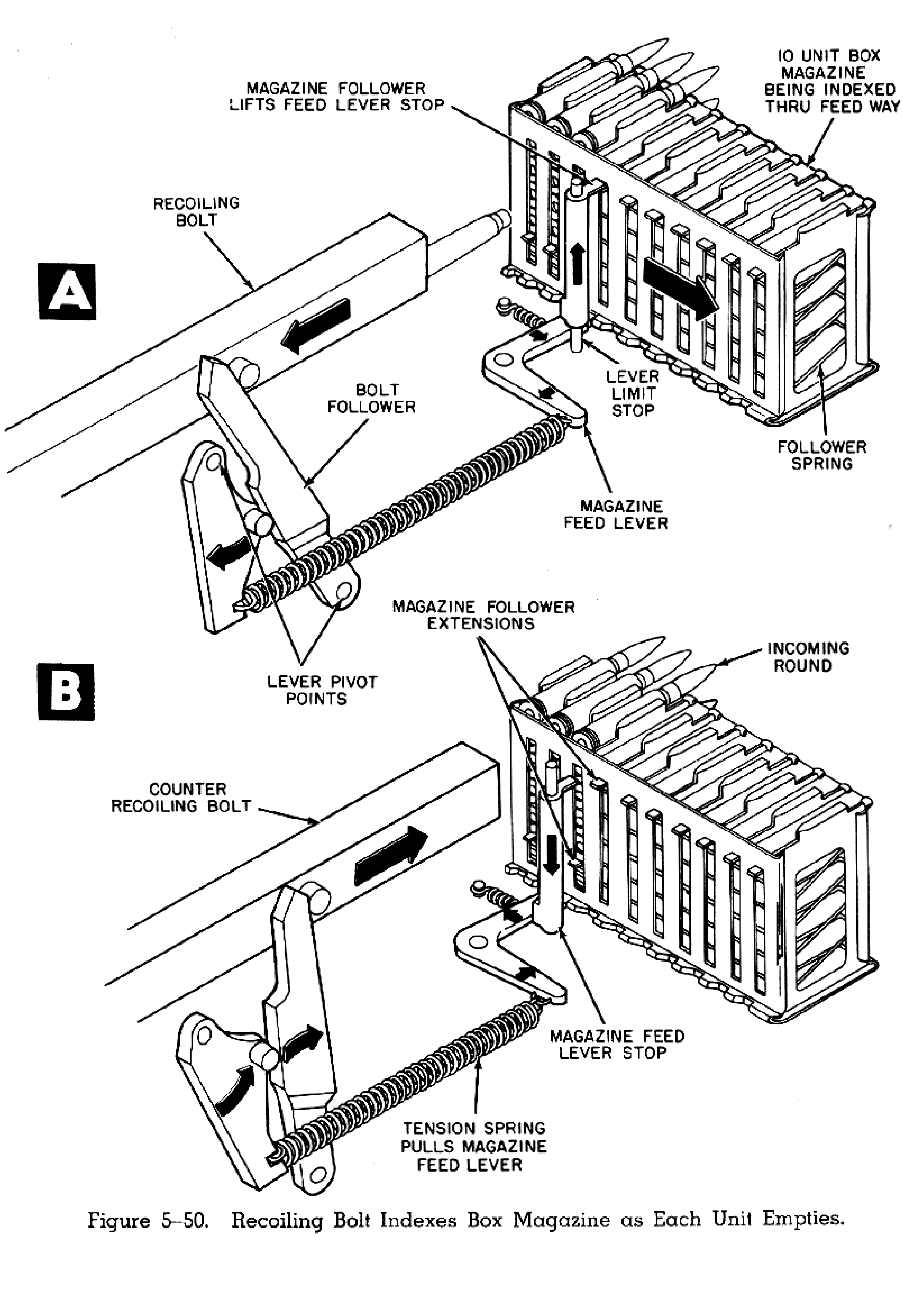


Figure 5–50. Recoiling Bolt Indexes Box Magazine as Each Unit Empties.

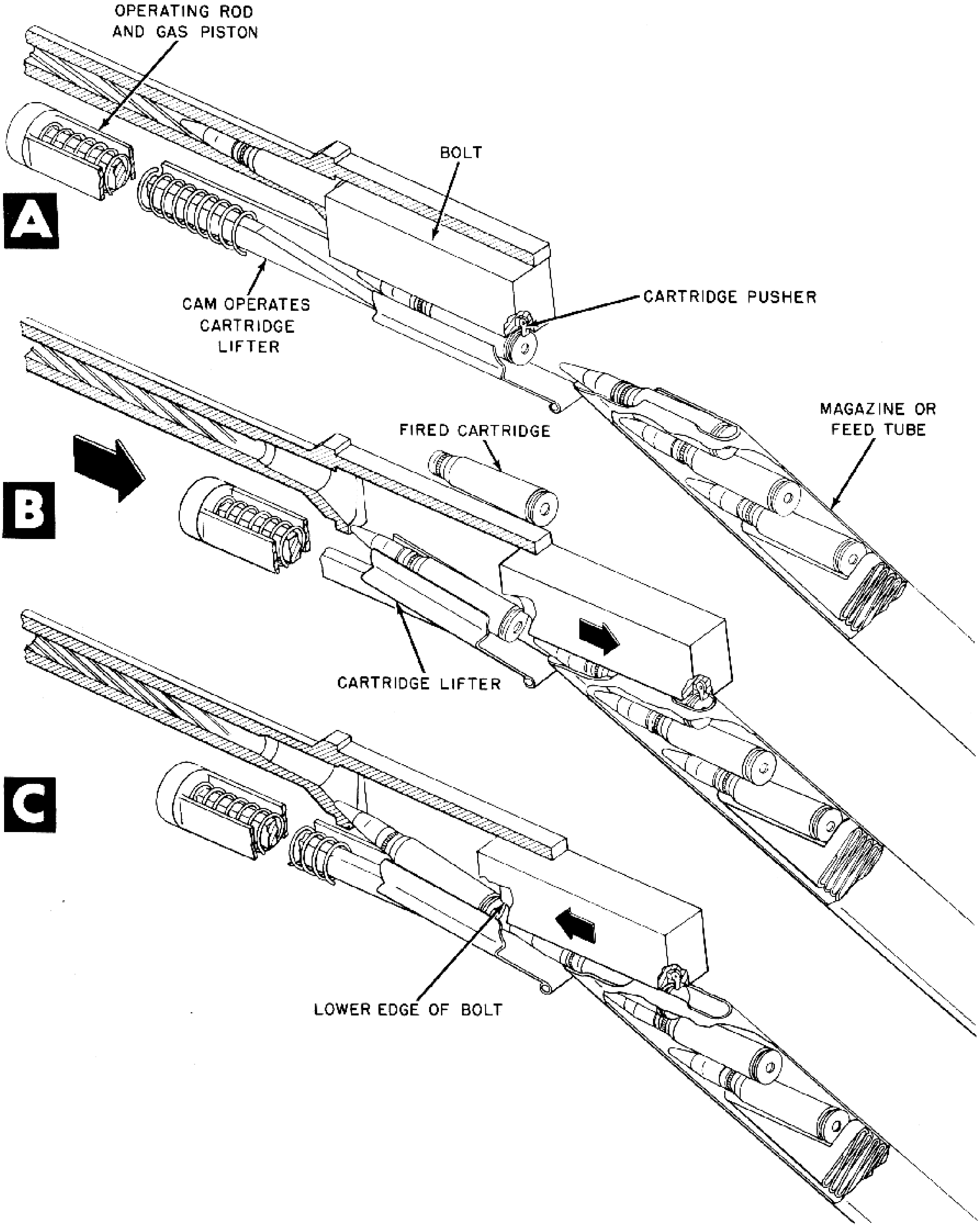


Figure 5–51. Cam on Operating Rod Actuates Cartridge Lifter.

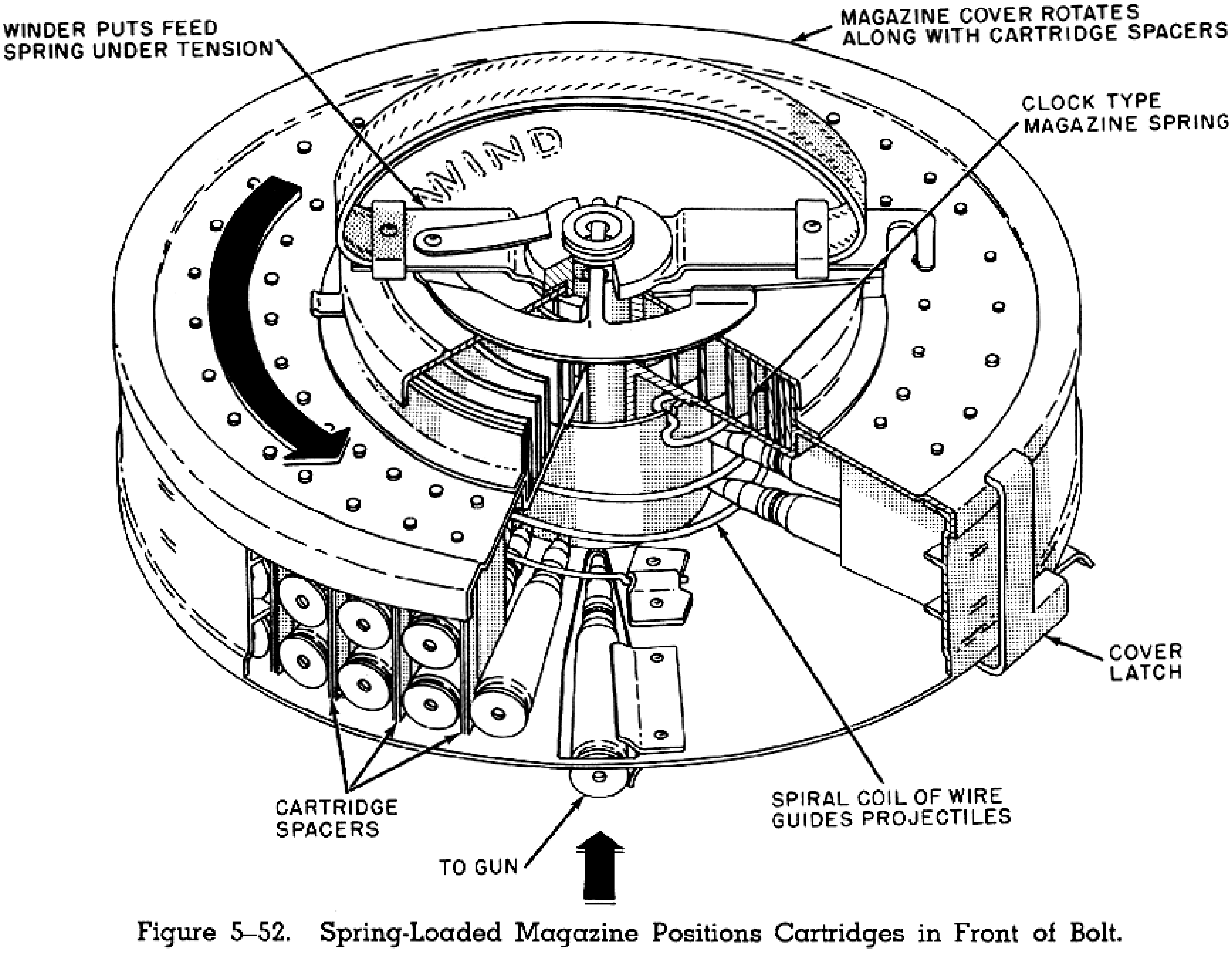


Figure 5–52. Spring-Loaded Magazine Positions Cartridges in Front of Bolt.

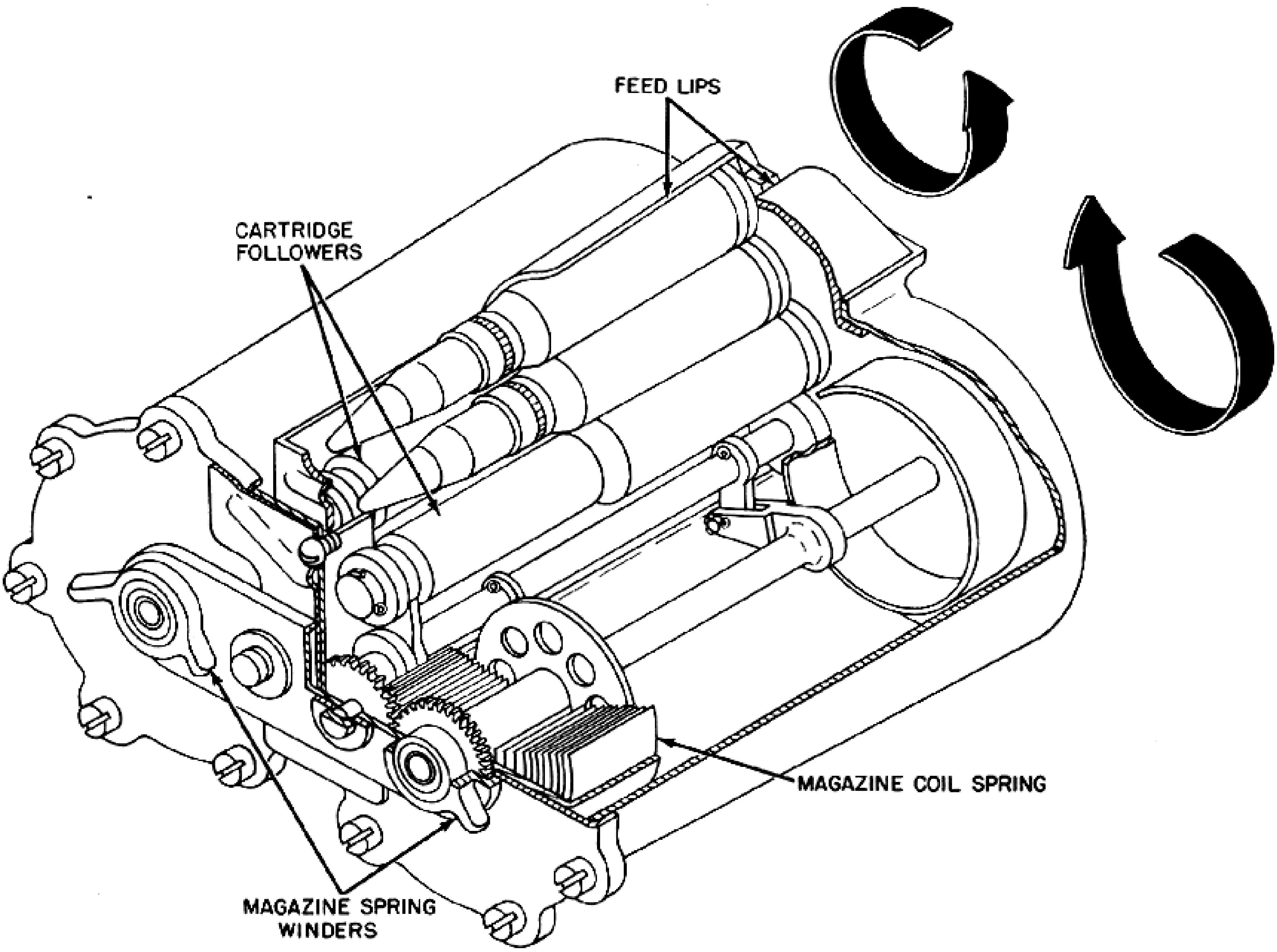


Figure 5–53. Twin-Drum Magazine Feeds Cartridges Alternately to the Guns.

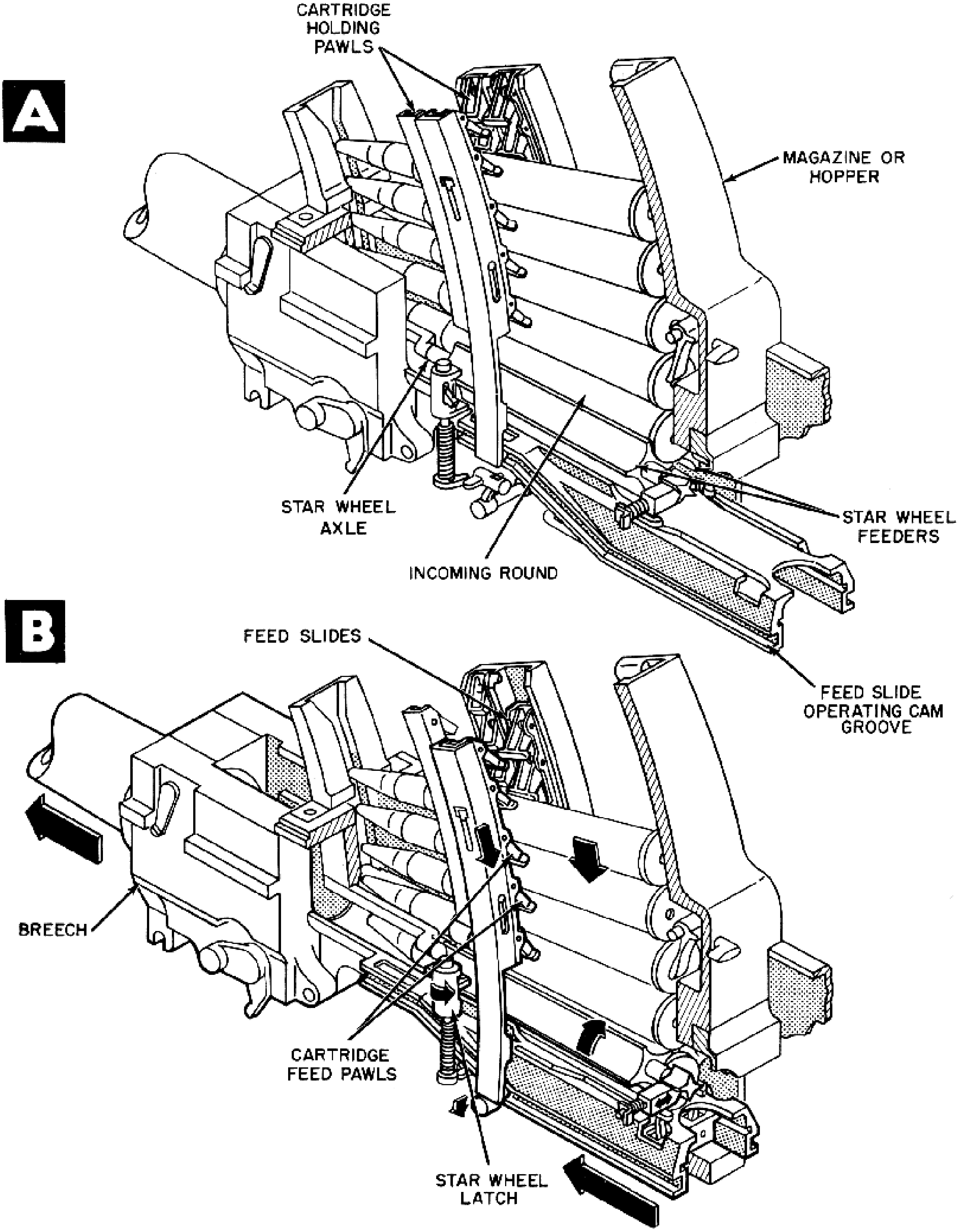
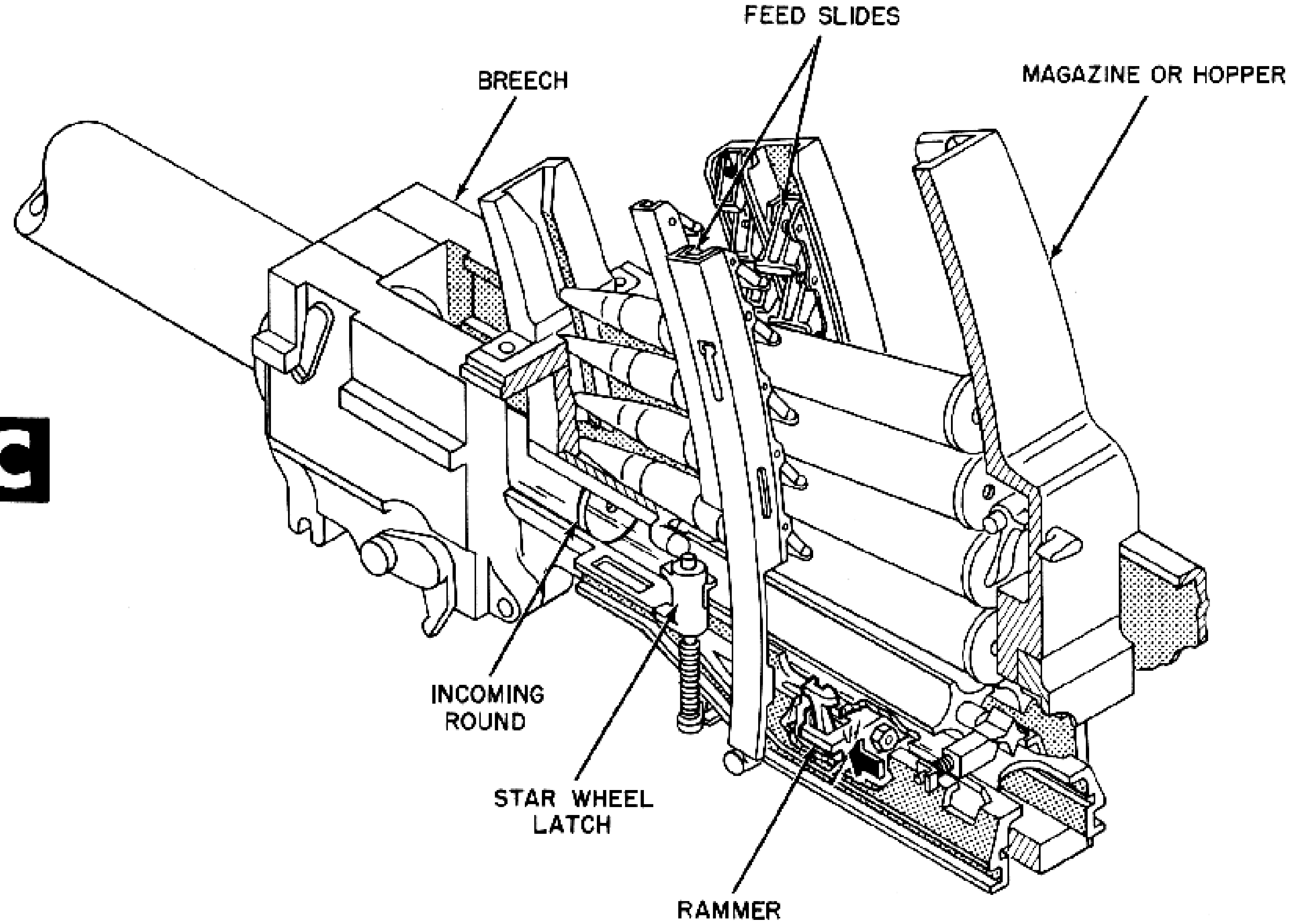


Figure 5–54. Recoiling Breech Actuates

C



Feed Slide and Rammer.

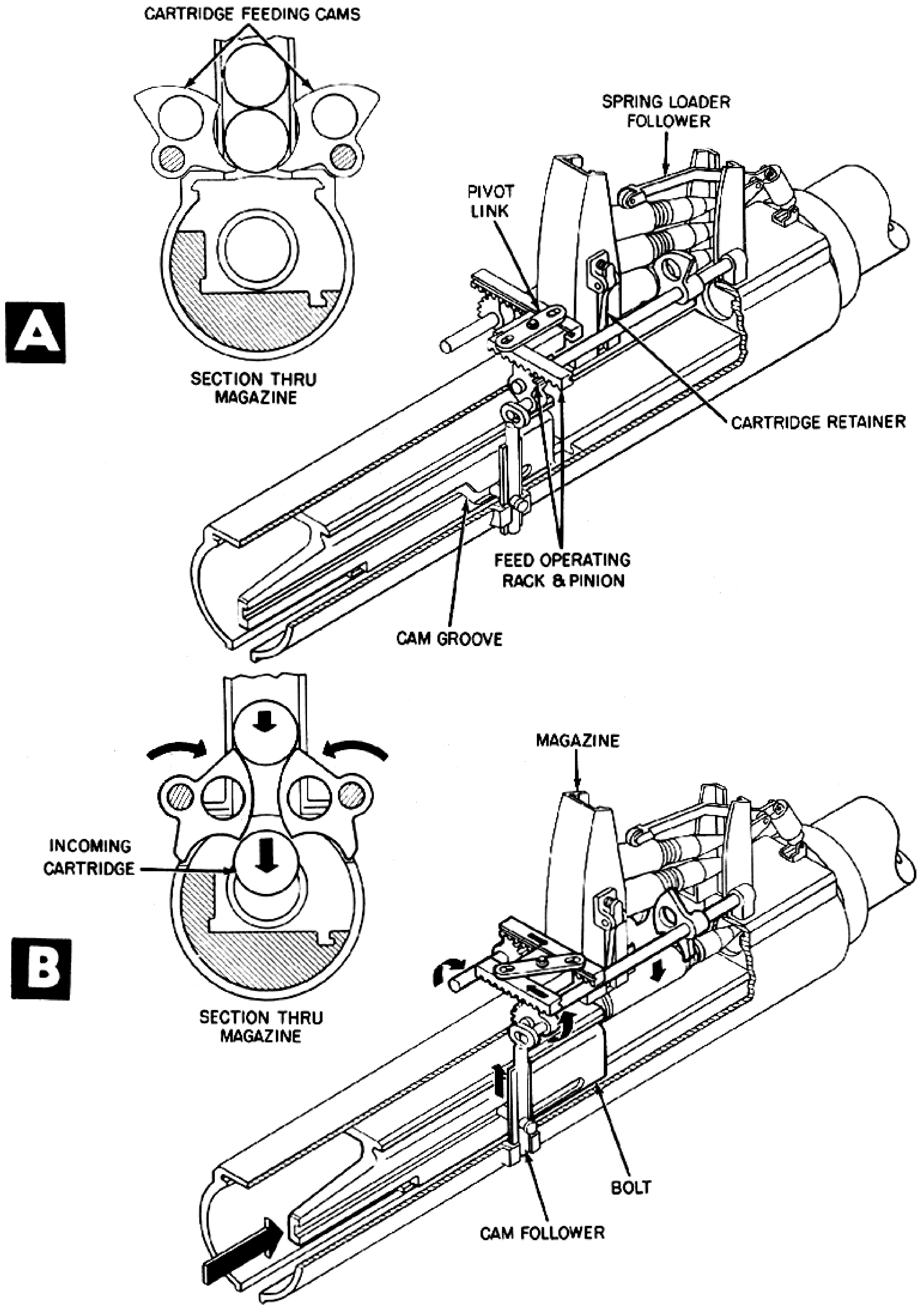


Figure 5–55. Recoiling Bolt Actuates Cartridge Feeding Cams.

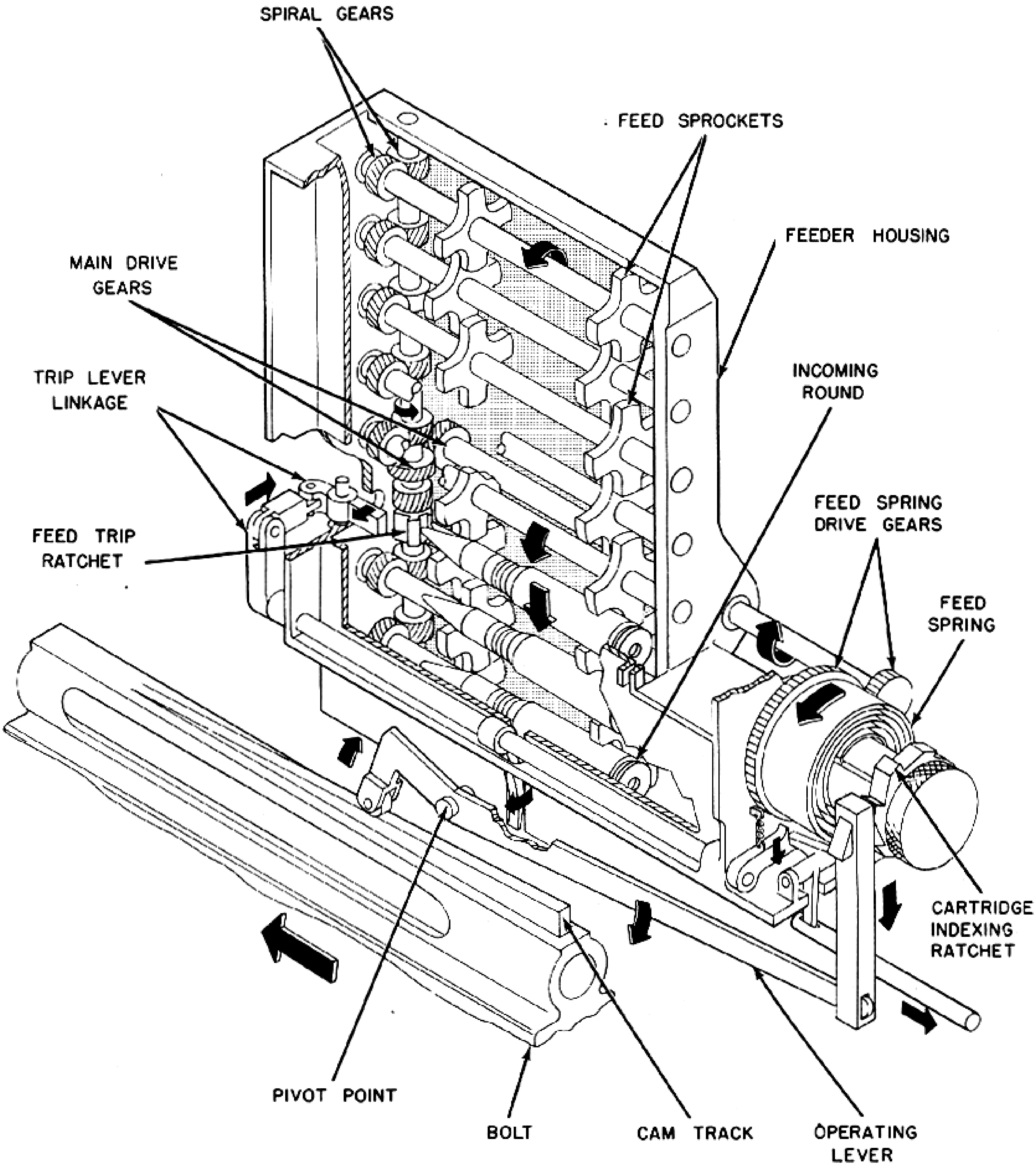


Figure 5–56. Cam Track on Bolt Actuates Spring-Loaded Feeder.

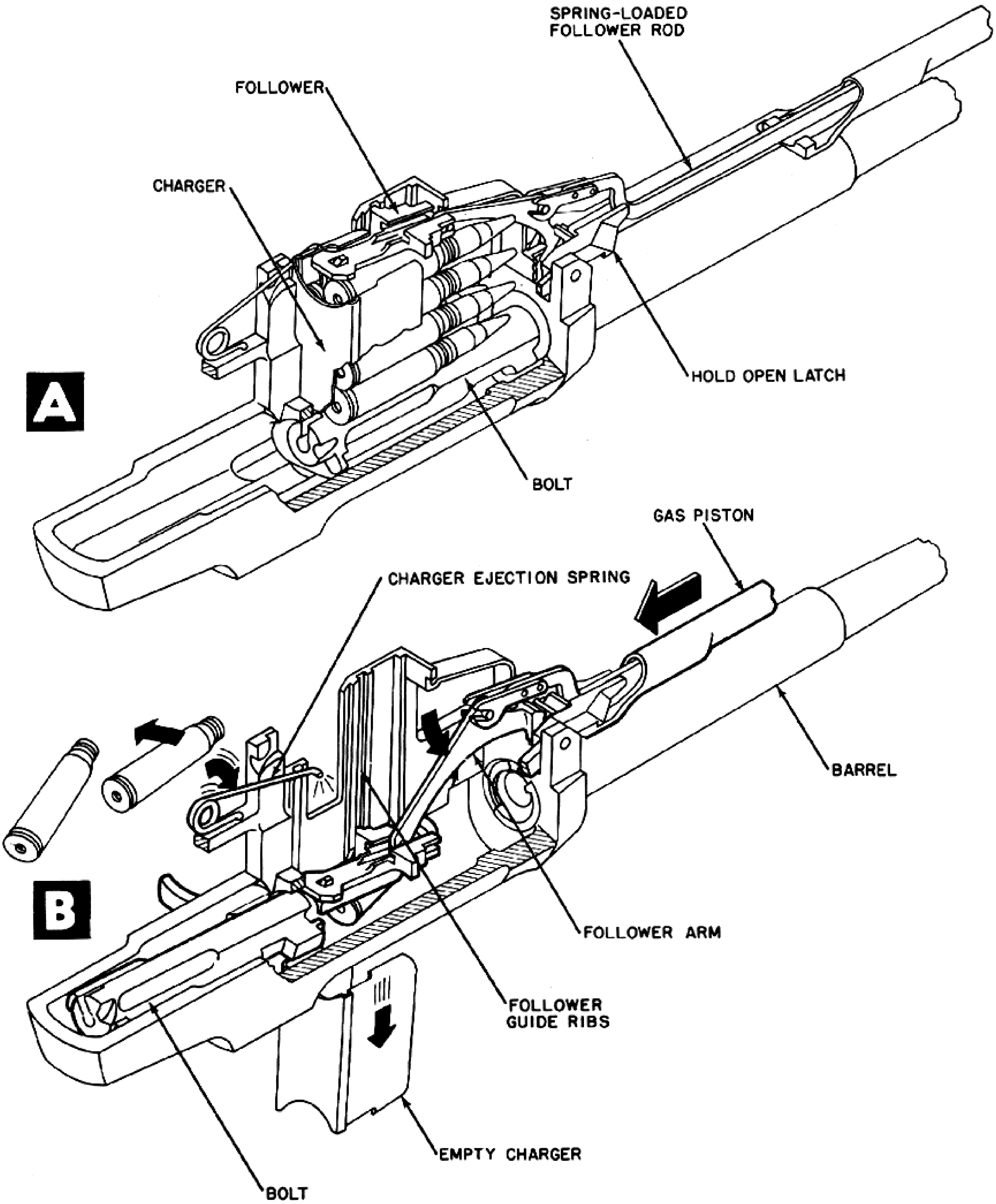


Figure 5–57. Method of Feeding Ammunition From a Charger.

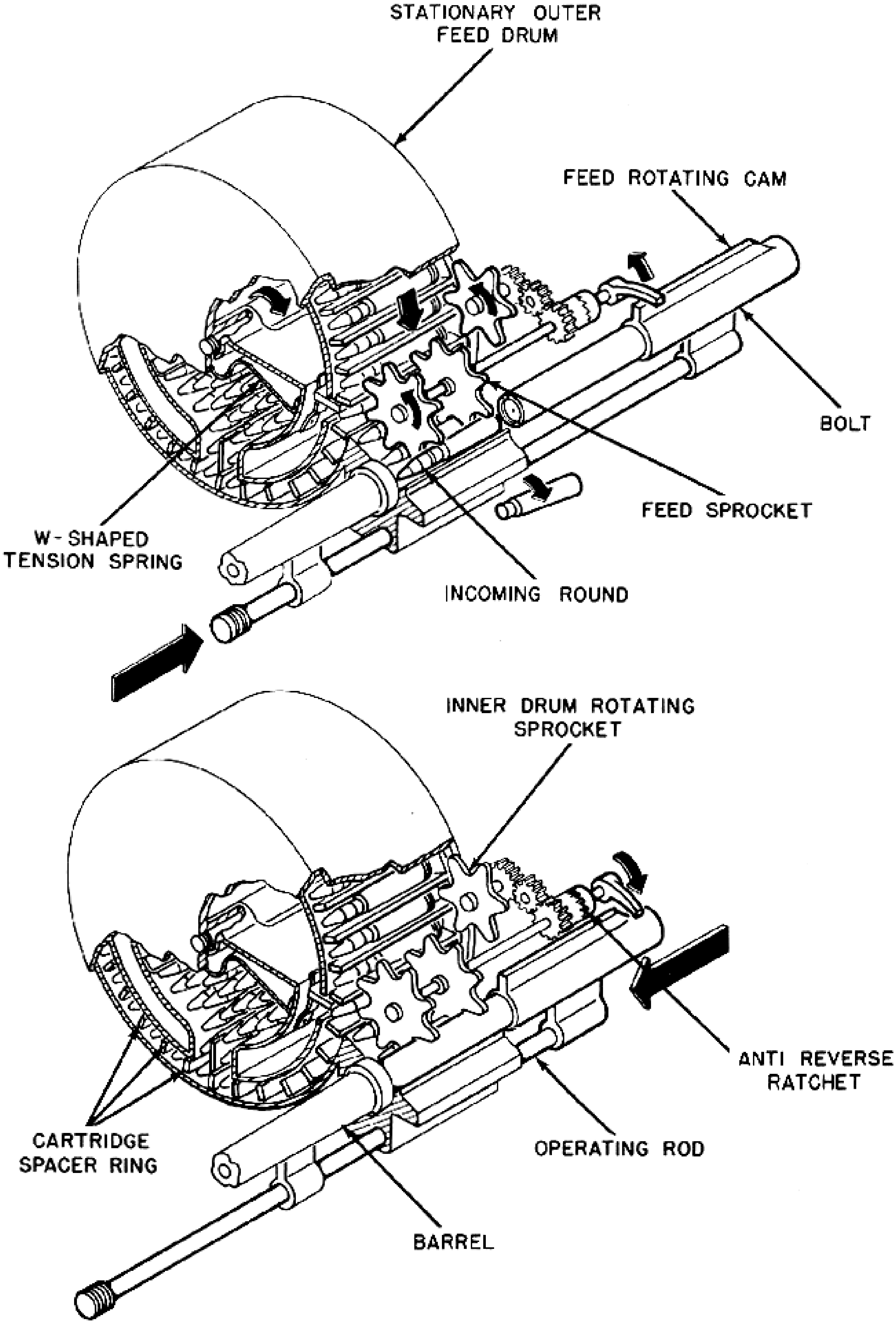


Figure 5–58. Cam on Bolt Rotates Feed Drum and Feed Sprocket.

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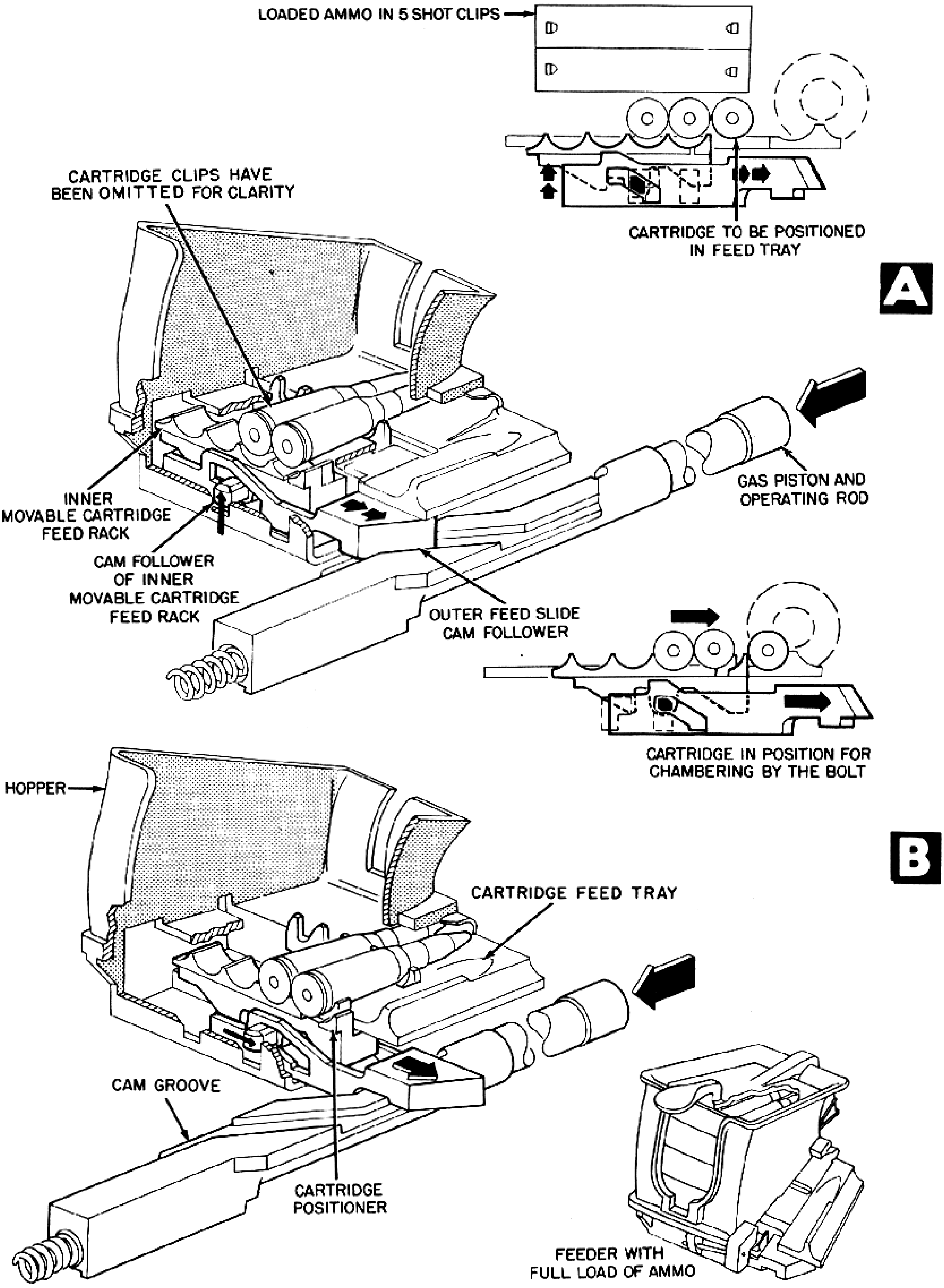
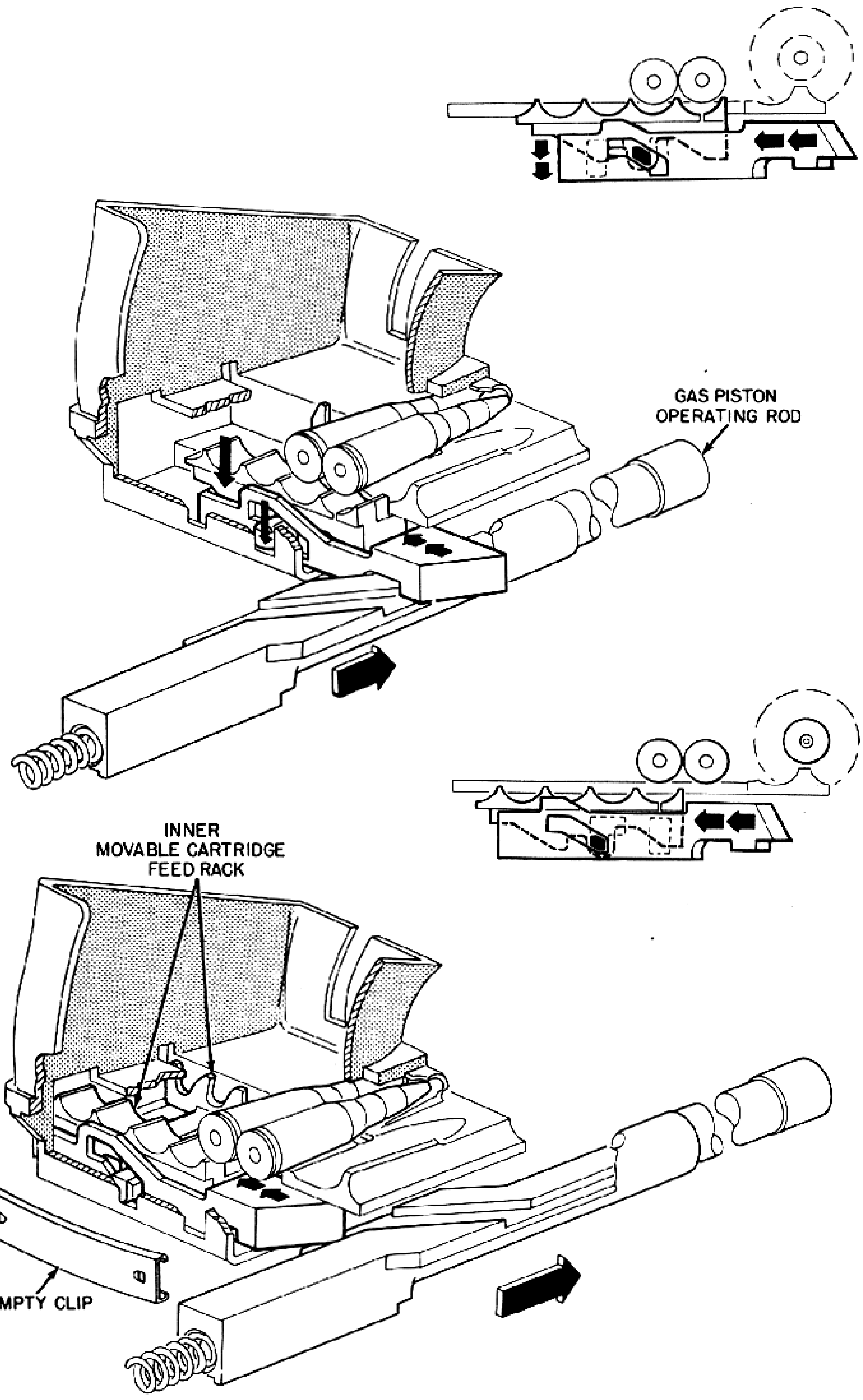


Figure 5–59. Cam-Operated Feed Rack Strips and

C

D



Positions Cartridges From 5-Round Clips.

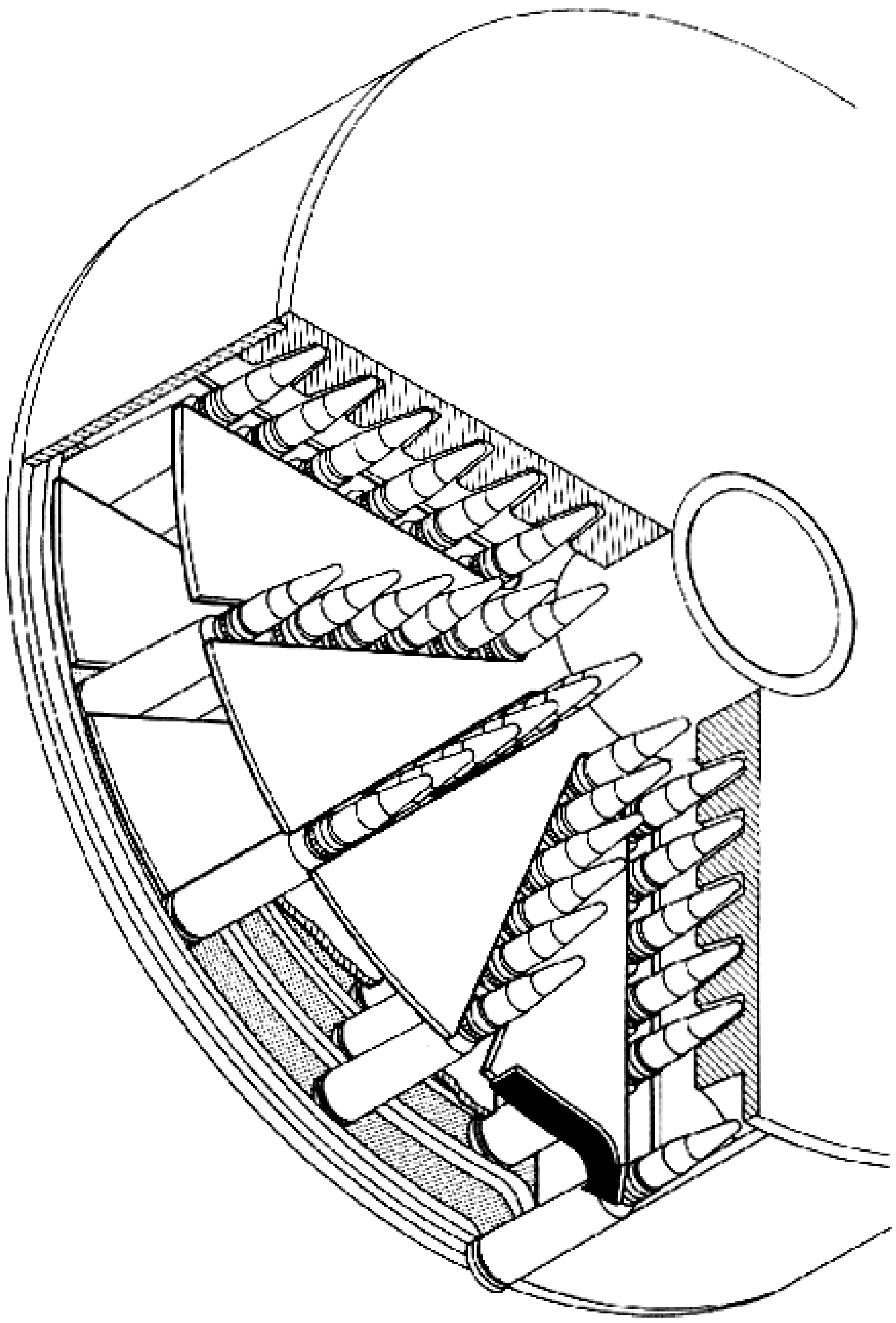


Figure 5–60. Rotating Sprocket Feeds Ammunition.

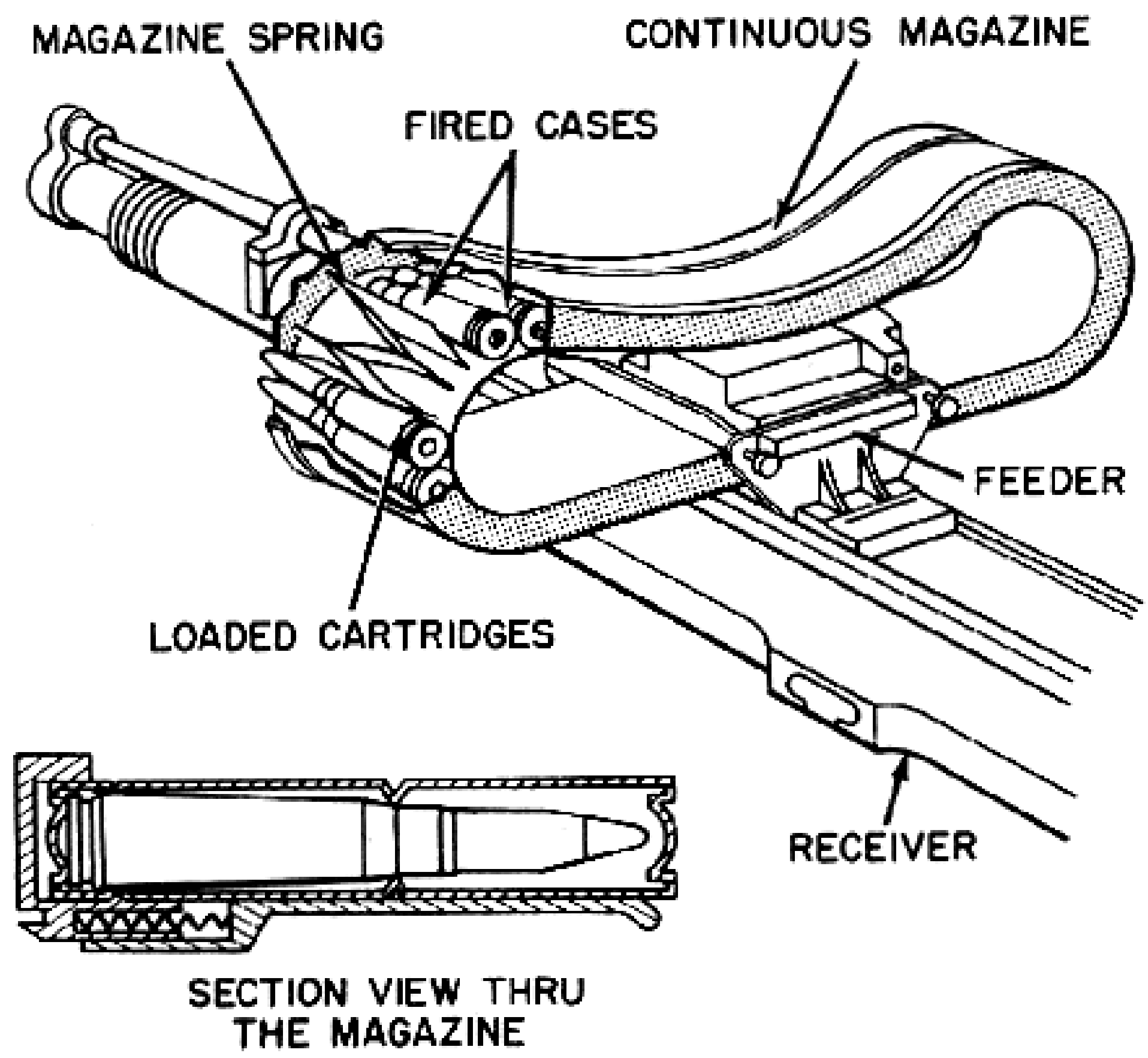


Figure 5–61. Continuous Magazine Retains Empty Cases.

G. Feed Accessories

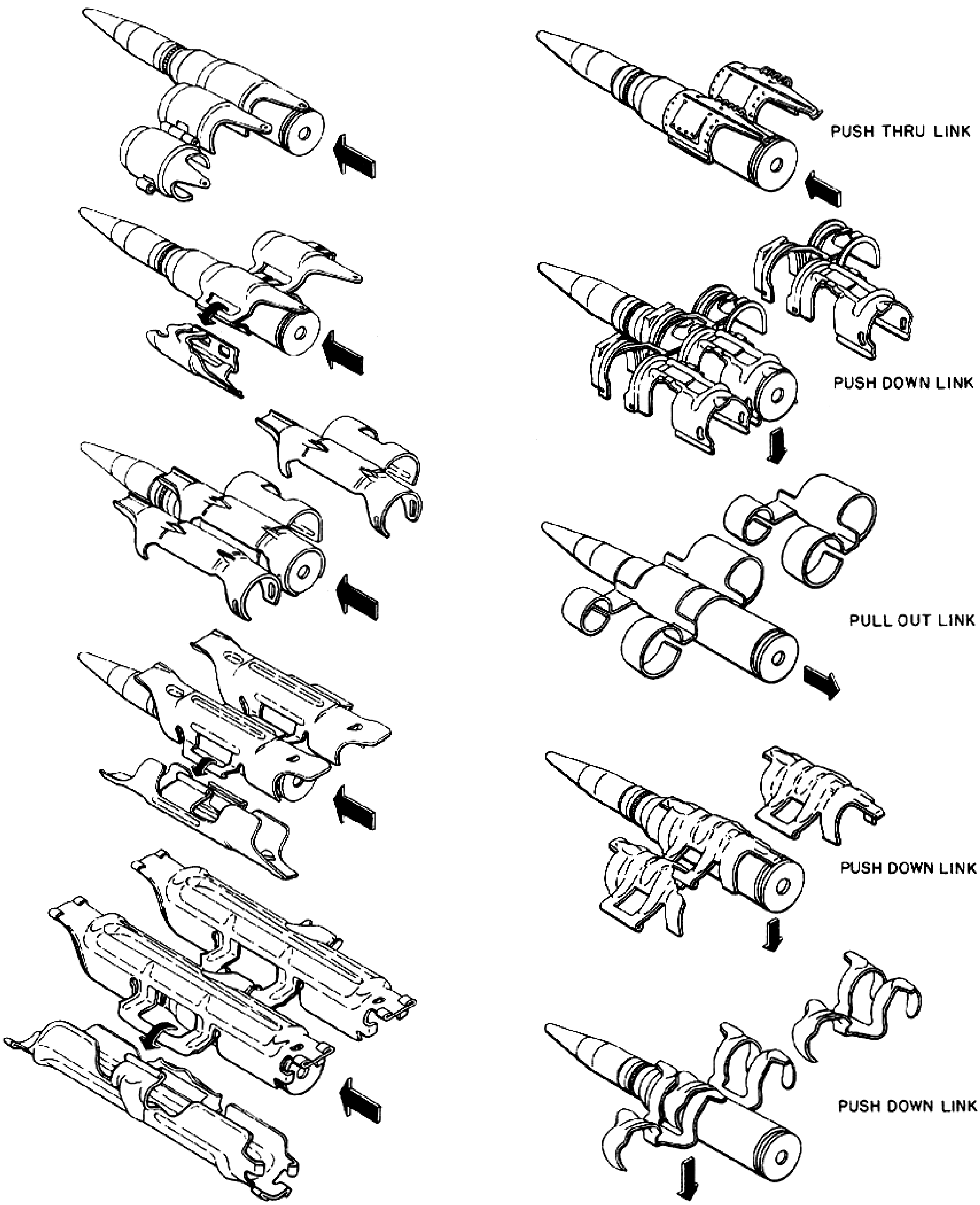


Figure 5–62. Types of Links.

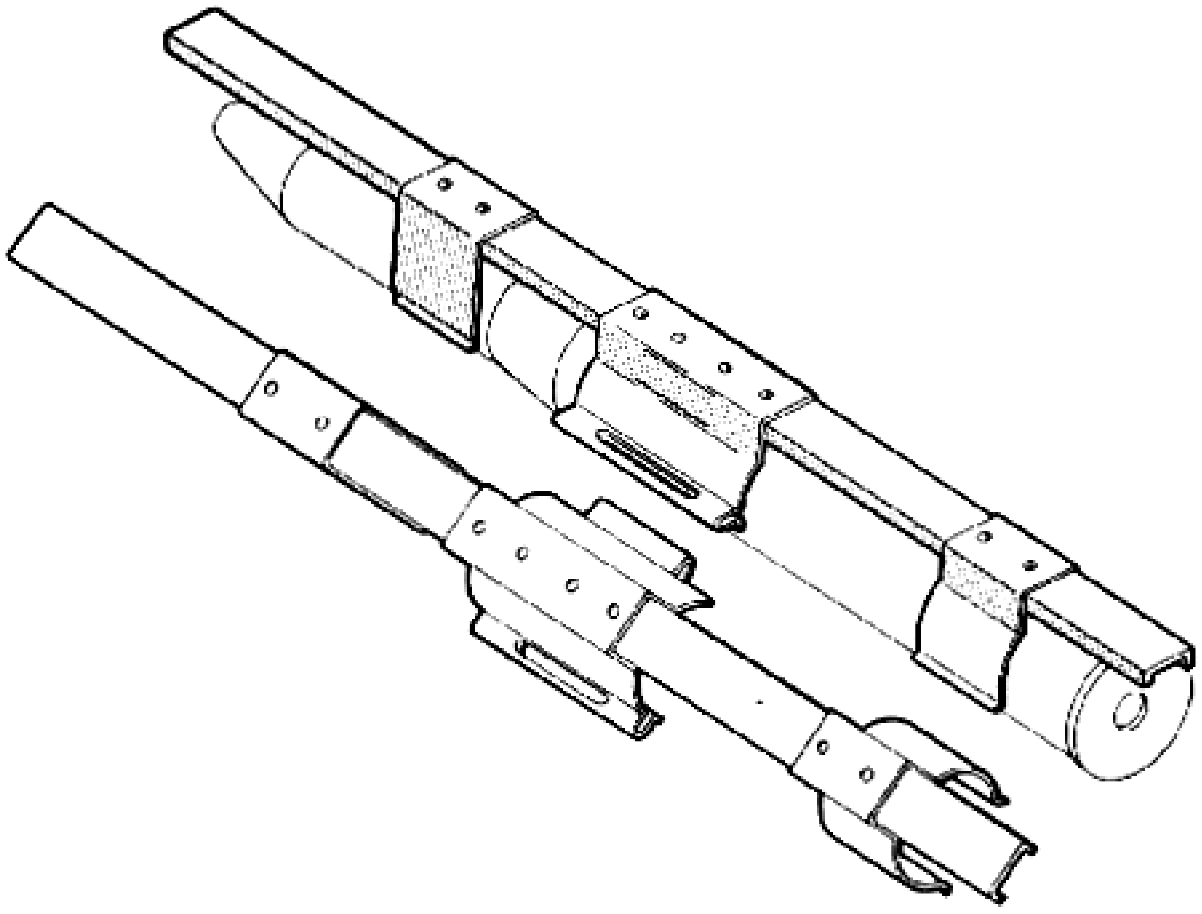


Figure 5–63. Example of Link for Large-Caliber Ammunition.

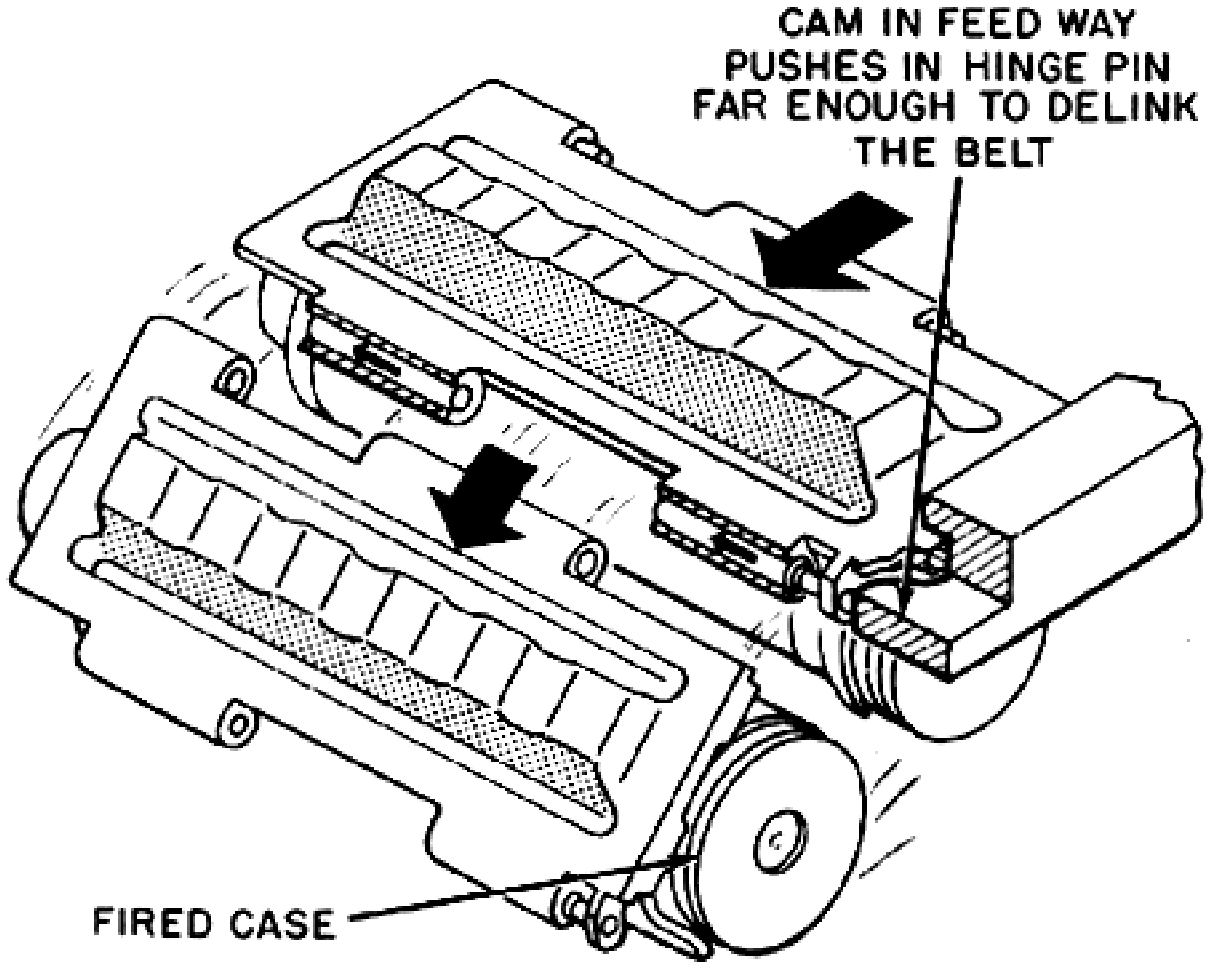


Figure 5–64. Belt Delinker.

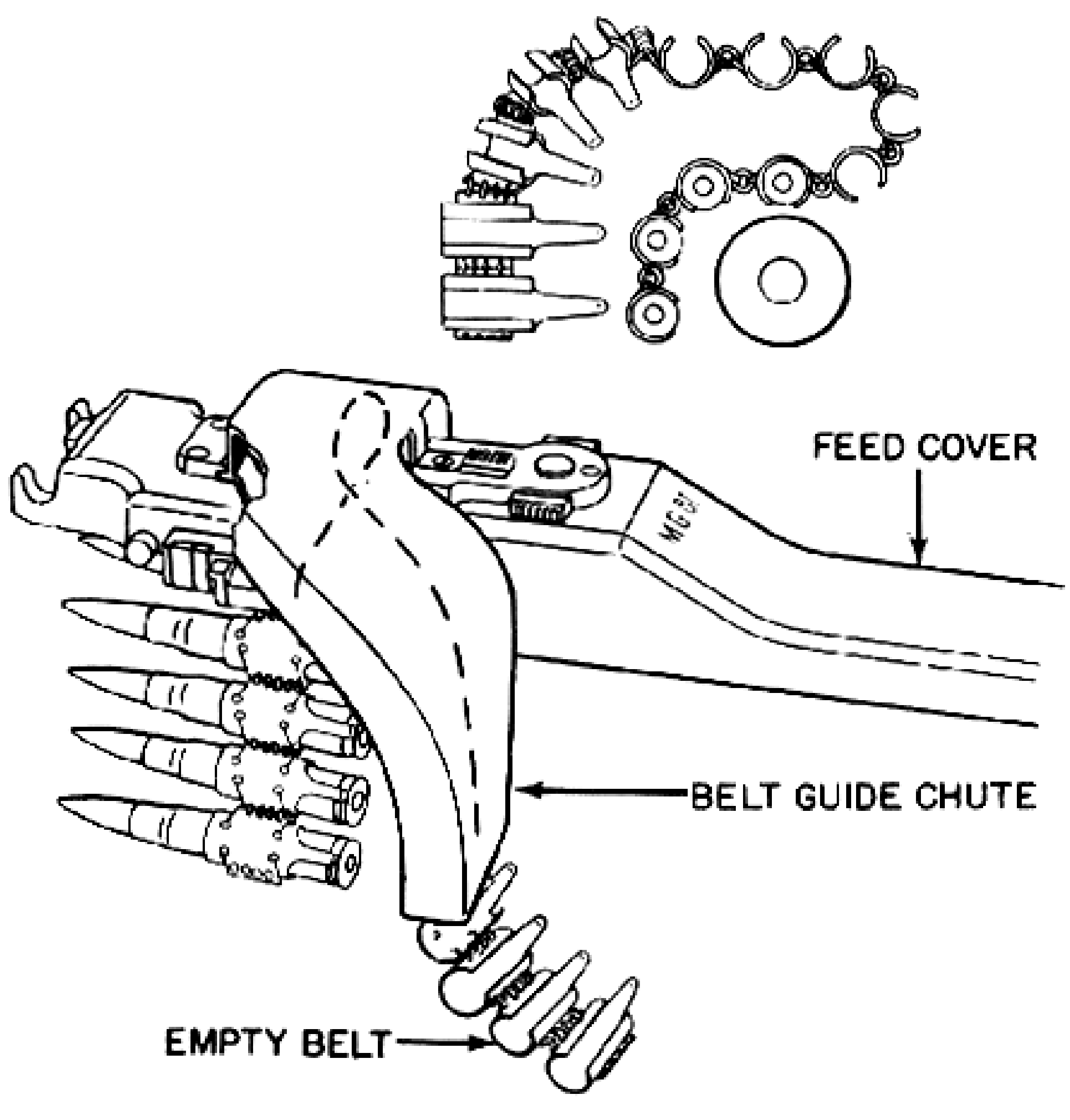


Figure 5–65. Belt Feed Guide Leads Belt Out on Same Side as It Enters.

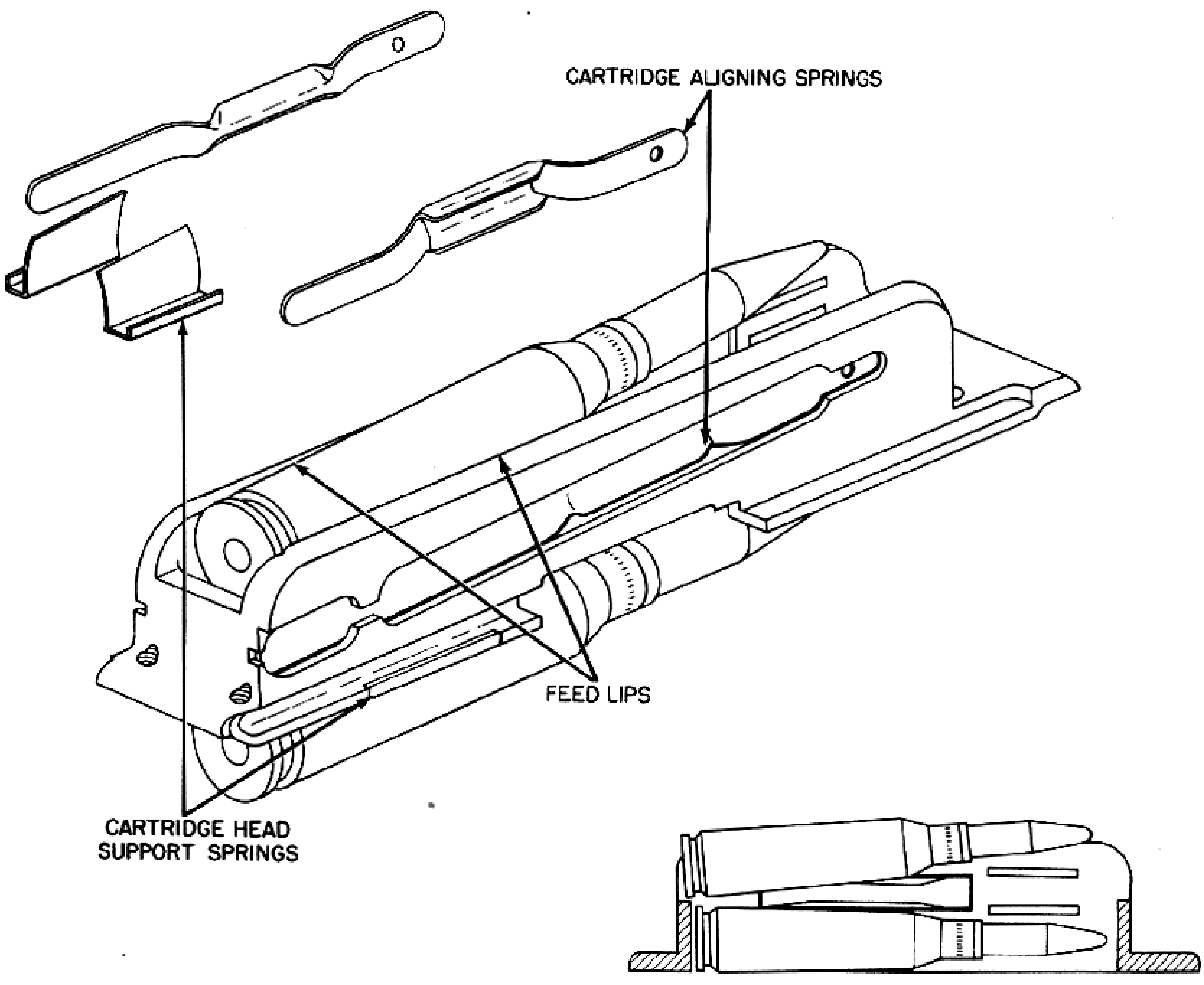


Figure 5–66. Cartridge Aligning Springs Support and Position the Round.

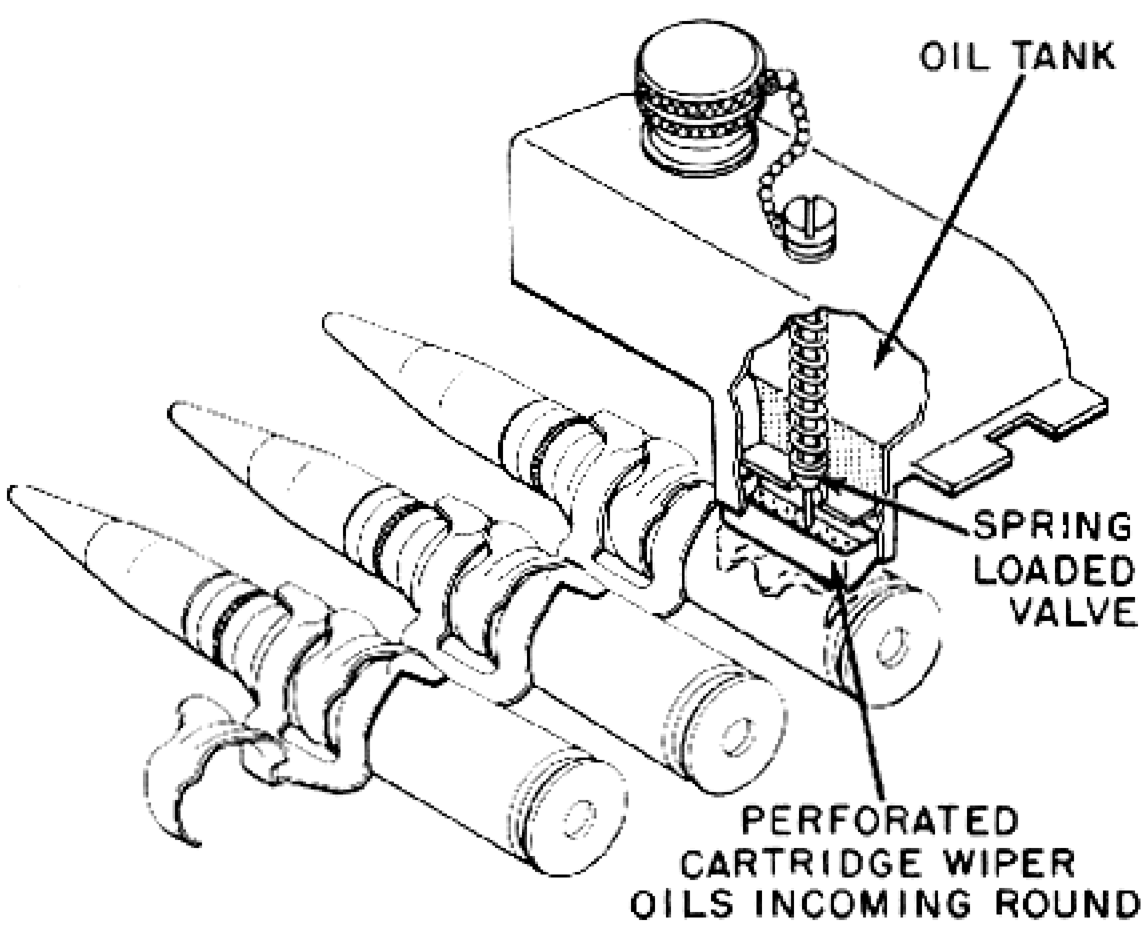


Figure 5–67. Oiler Valve Actuated by Movement of Cartridges Through Feedway.

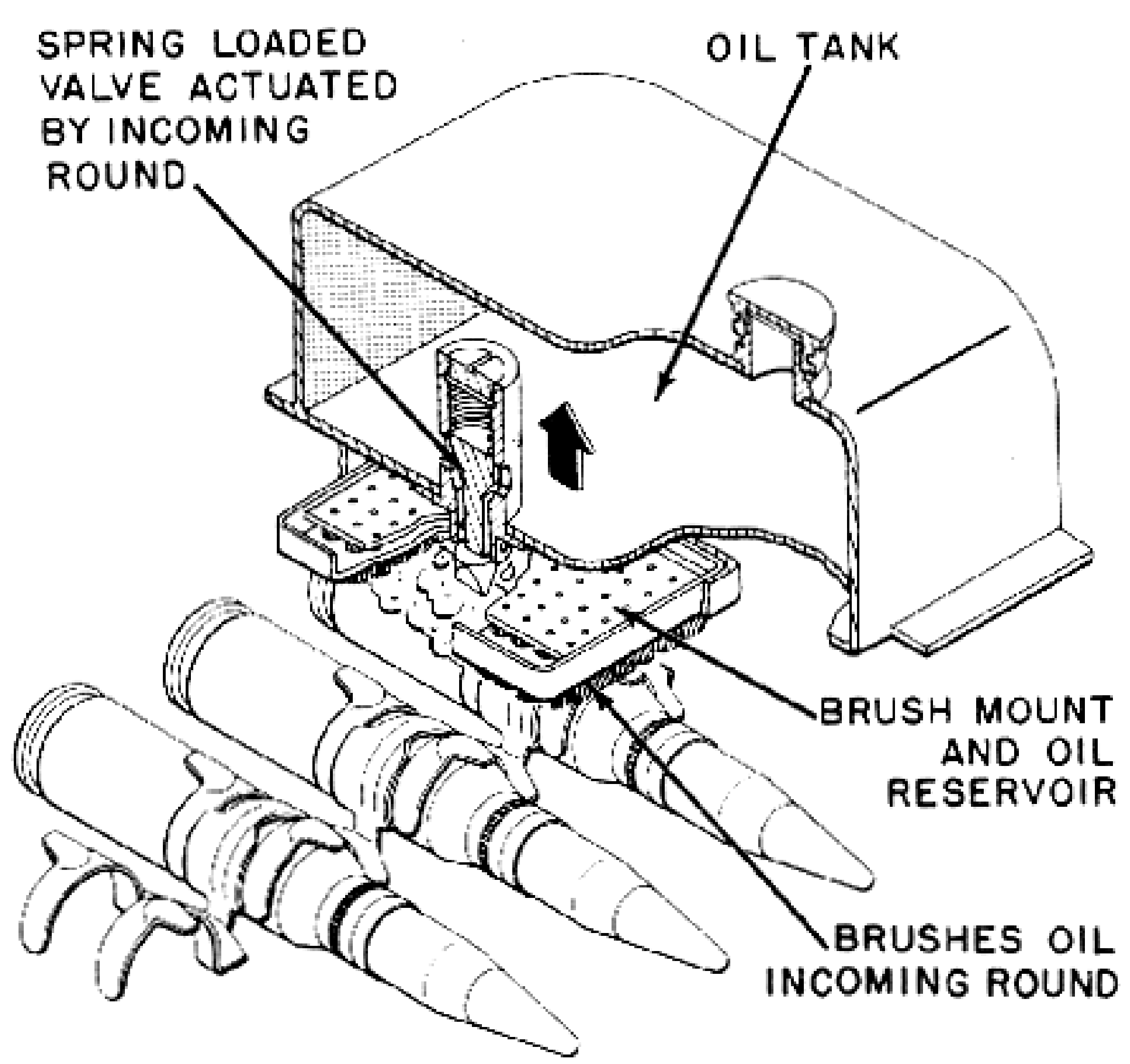


Figure 5–68. Oiler Valve Actuated by Movement of Cartridges Through Feedway, Wetting the Wiper Brushes.

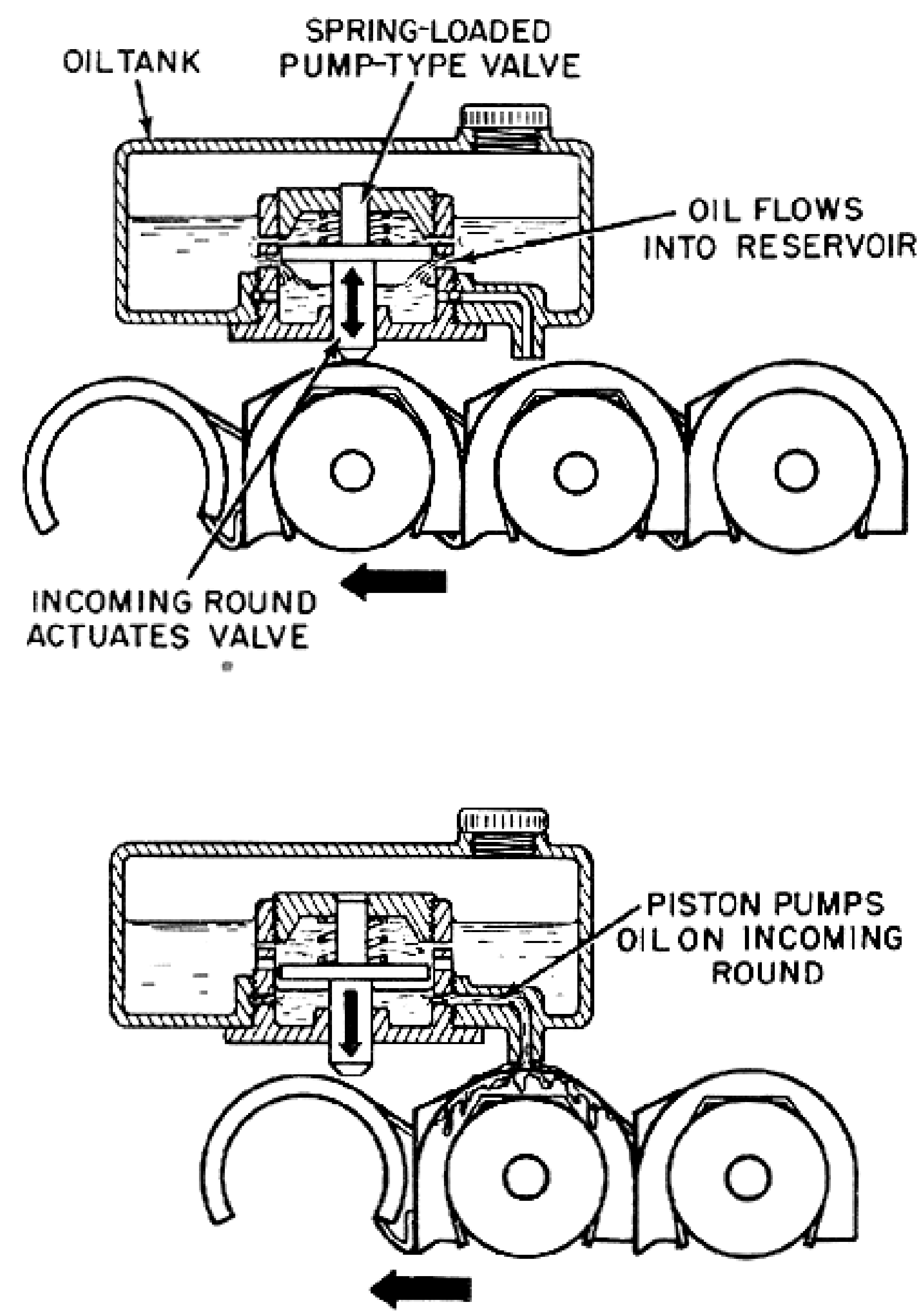


Figure 5–69. Oiler Valve Actuated by Incoming Round. Pump Oils Next Round as Belt Moves Out From Under Plunger.

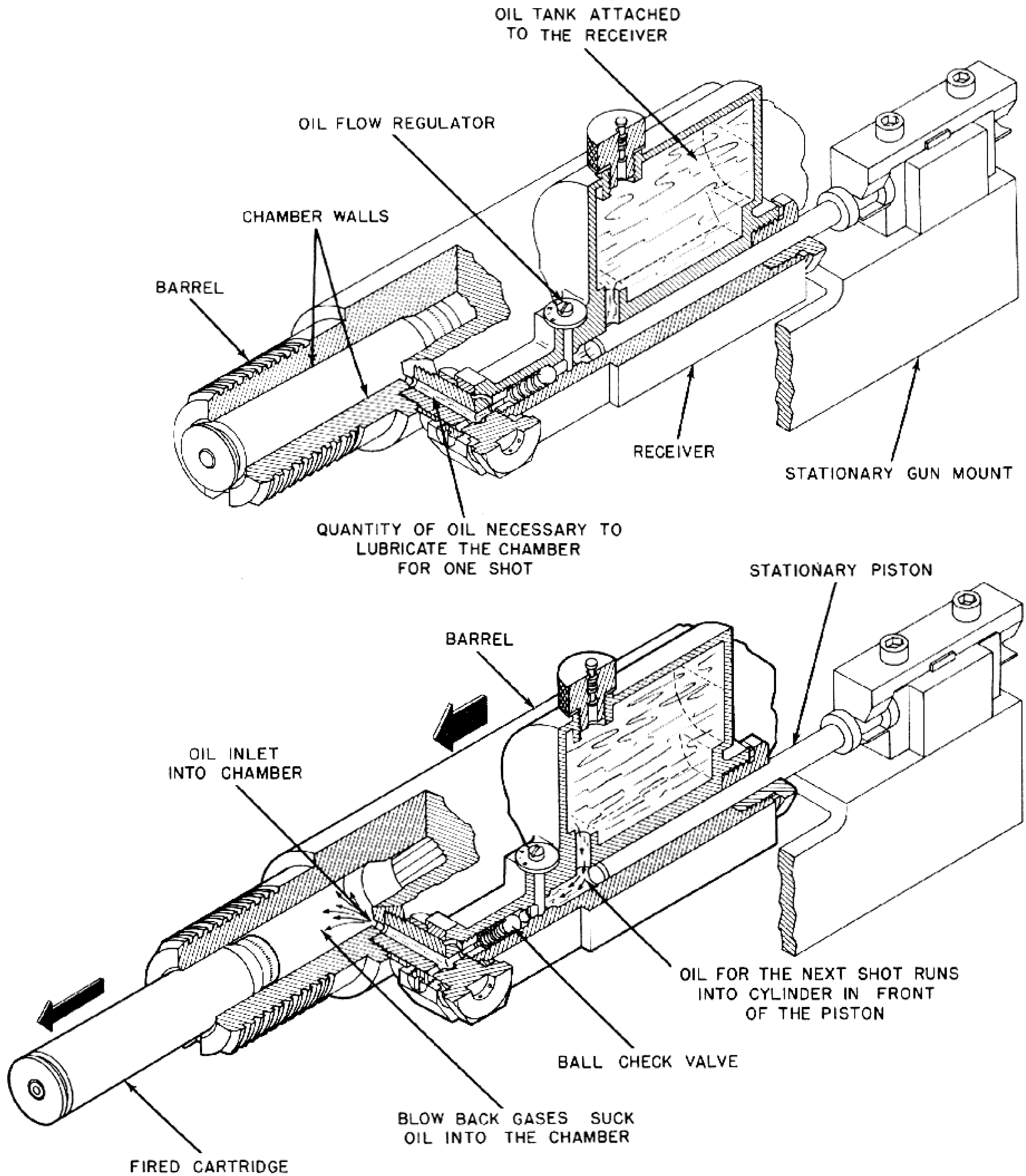


Figure 5–70. Blowback Gases Atomize Small Quantity of Oil, Lubricating Chamber. Oil Is Pumped by Action of Recoiling Gun.

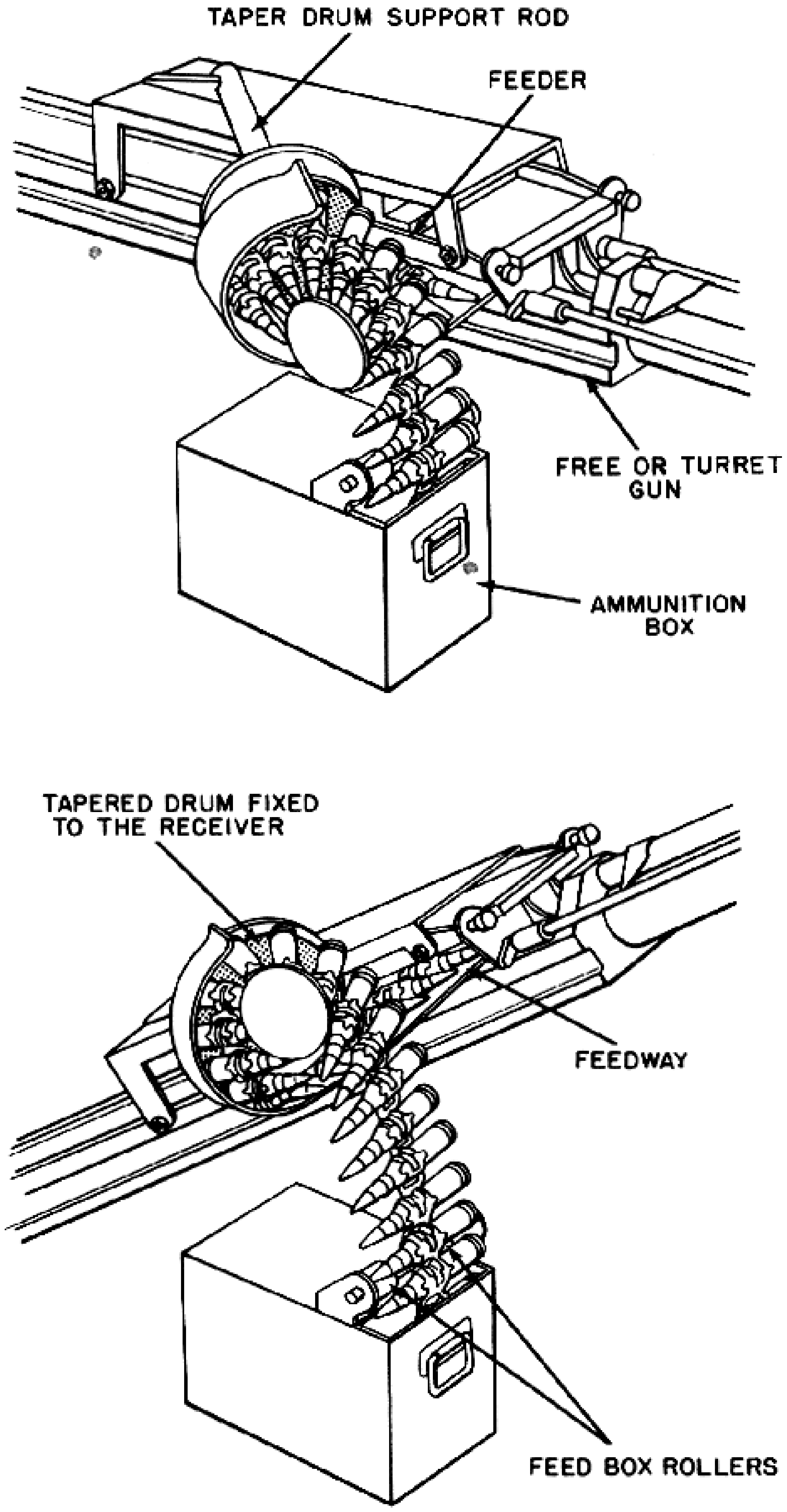


Figure 5–71. Kink-Proof Belt Guide.

Chapter 6

LOCKING SYSTEMS

A. Turning Bolt

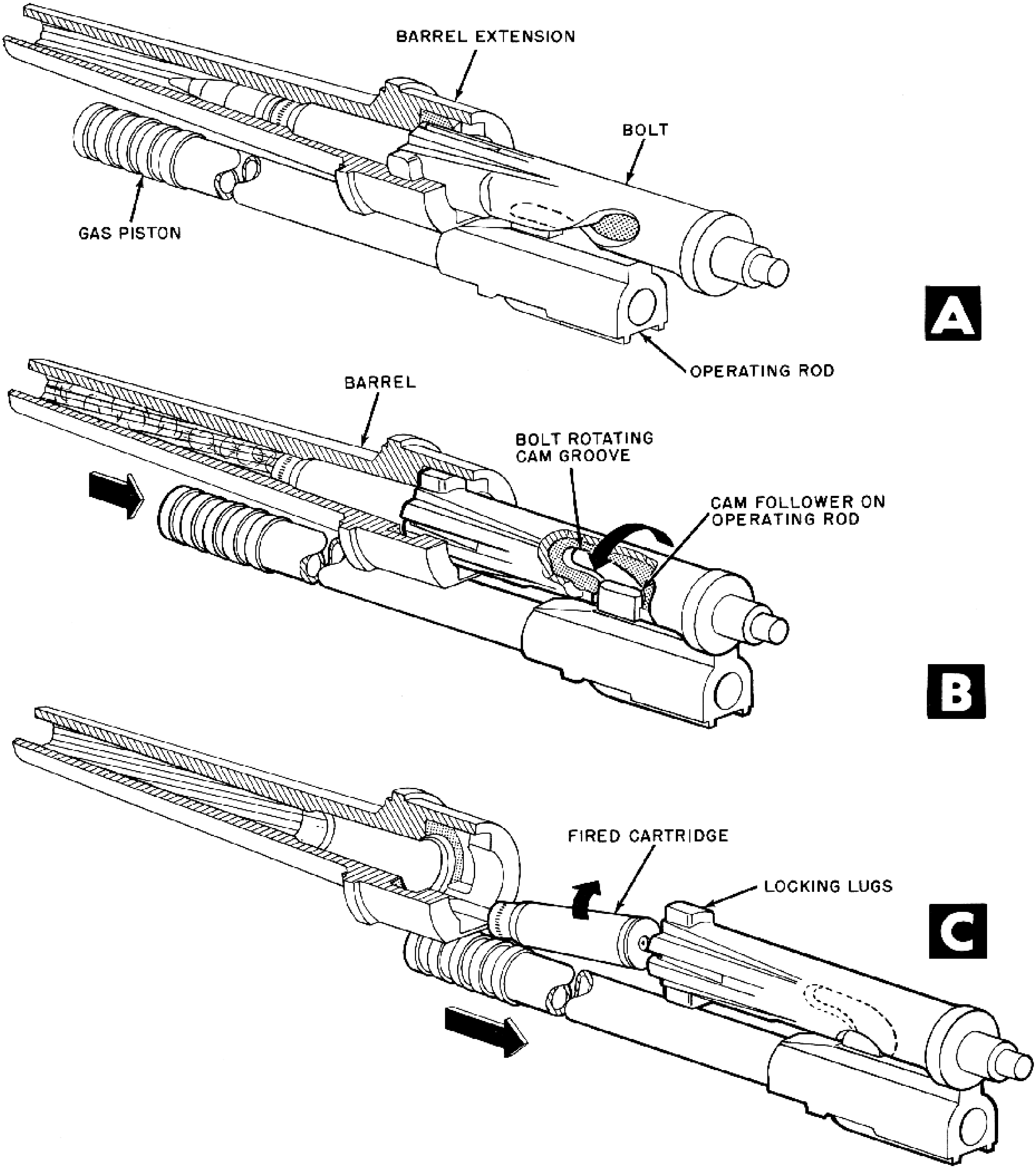


Figure 6–1. Solid Bolt Unlocked by Action of Operating Rod on Cam Groove in the Bolt.

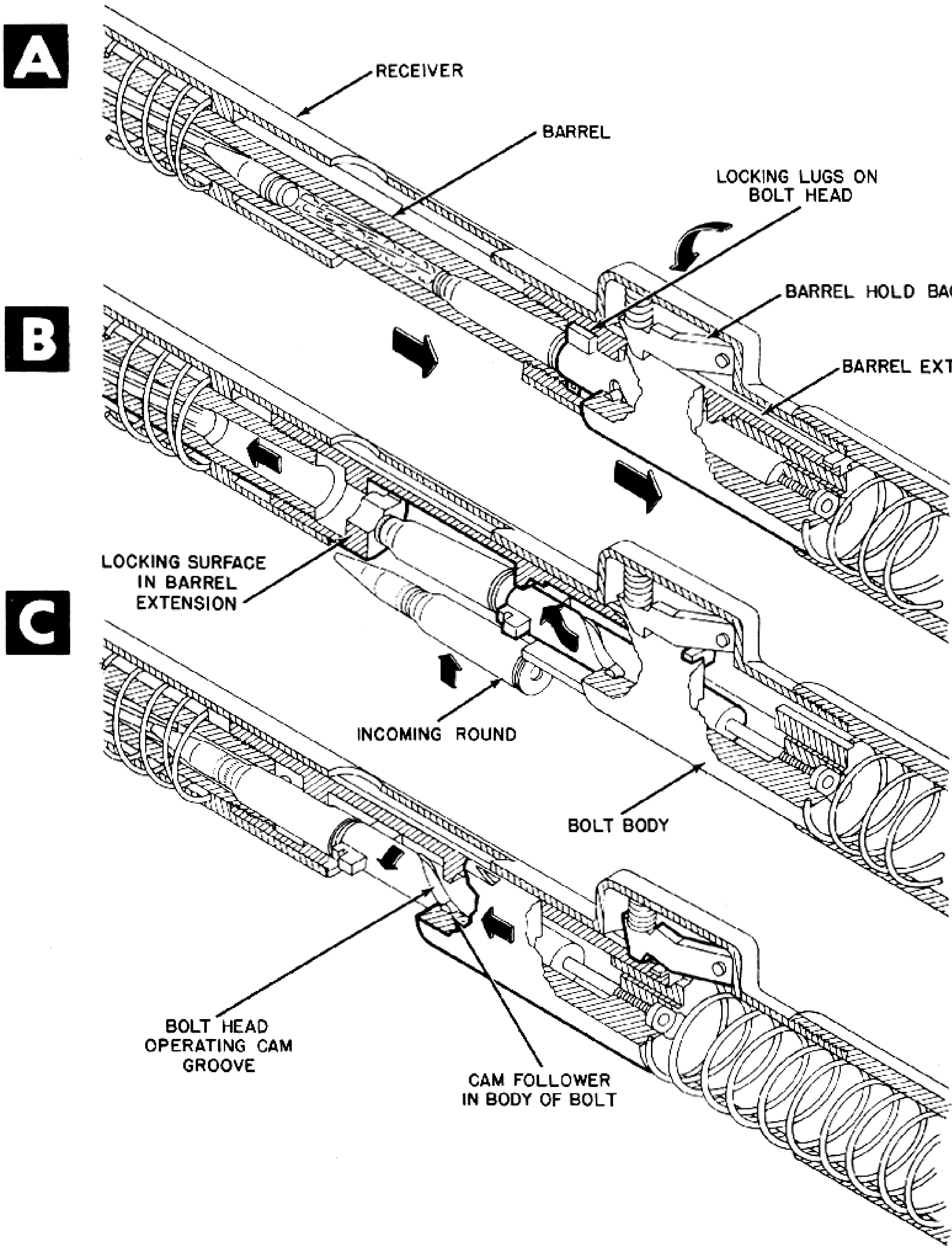


Figure 6–2. Solid Bolt Is Unlocked by the Counter-Recoiling Barrel Extension.

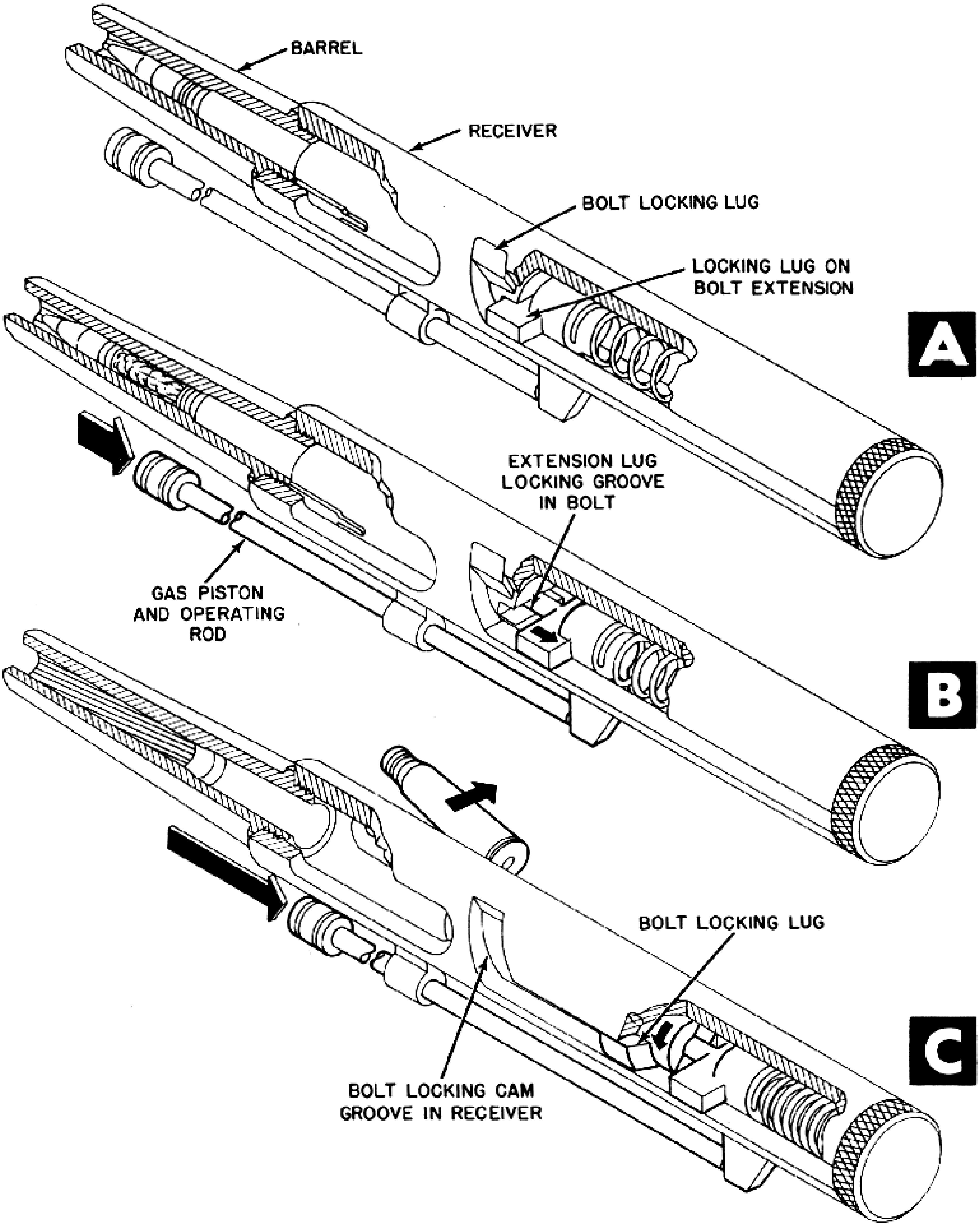


Figure 6–3. Gas Piston Actuates Locking Lug on Bolt Extension. Gas Pressure Then Unlocks Bolt.

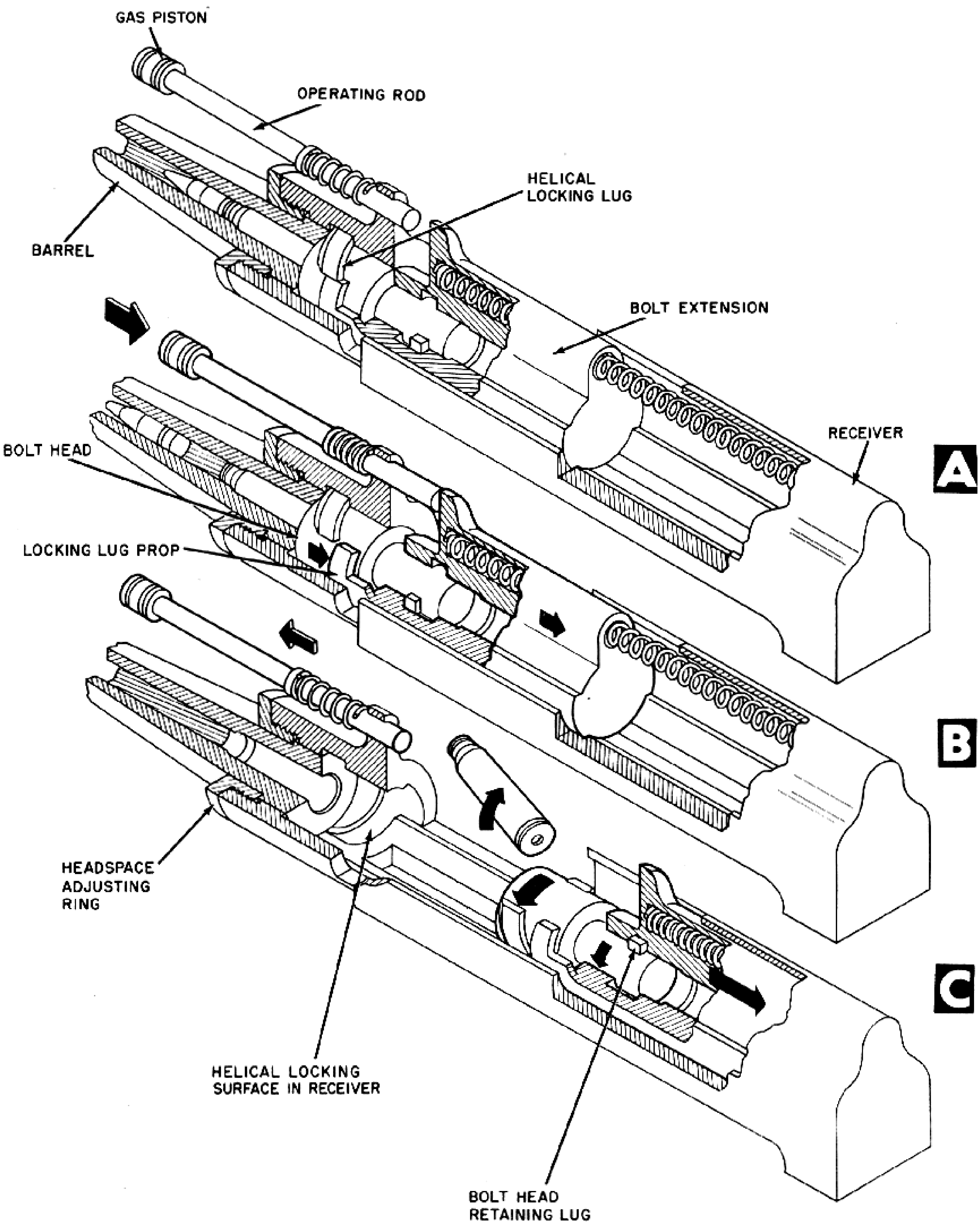


Figure 6–4. Gas Piston Actuates Locking Lug Prop. Gas Pressure Then Unlocks Bolt.

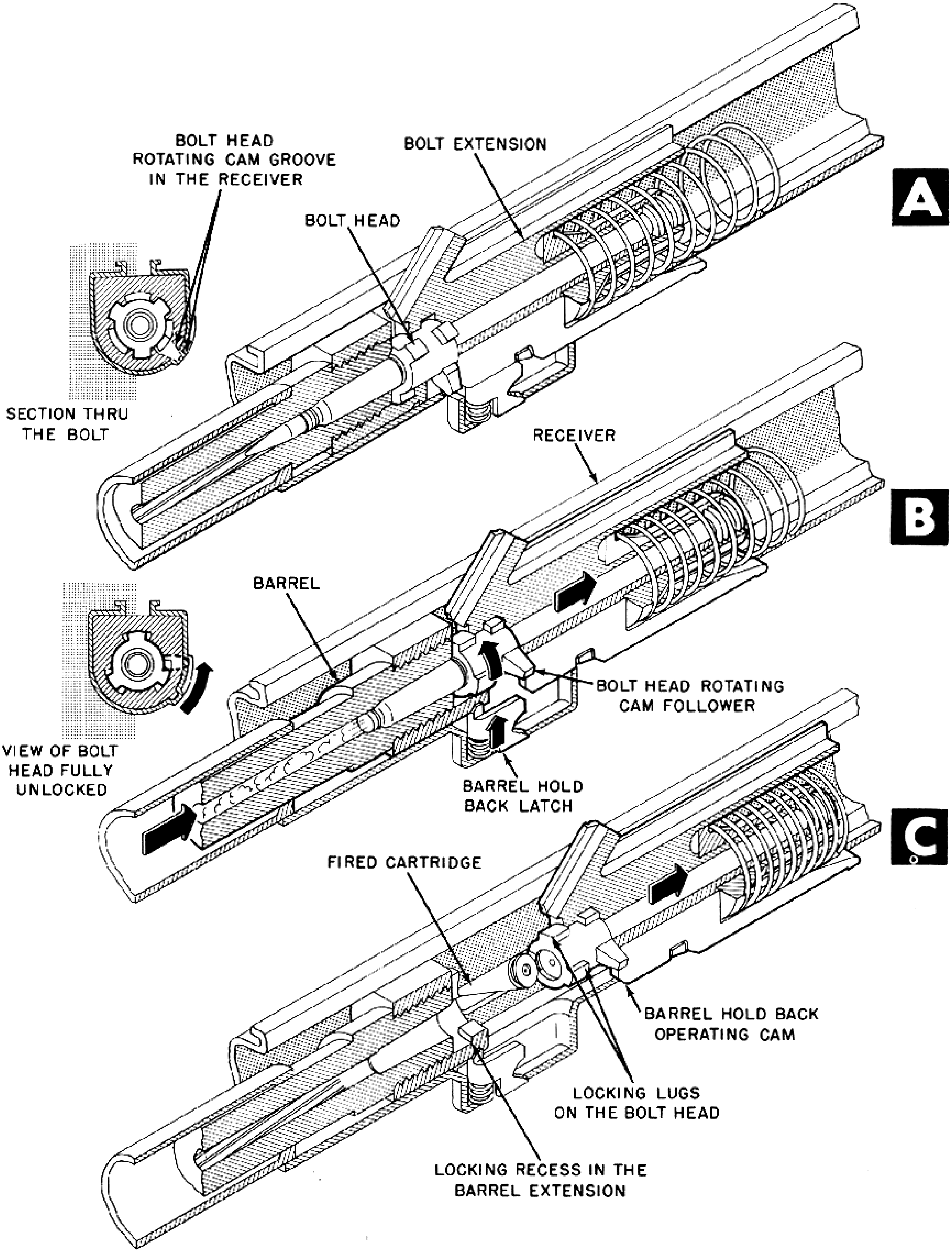


Figure 6–5. Solid Bolt Head Is Unlocked by Cam Groove in the Receiver.

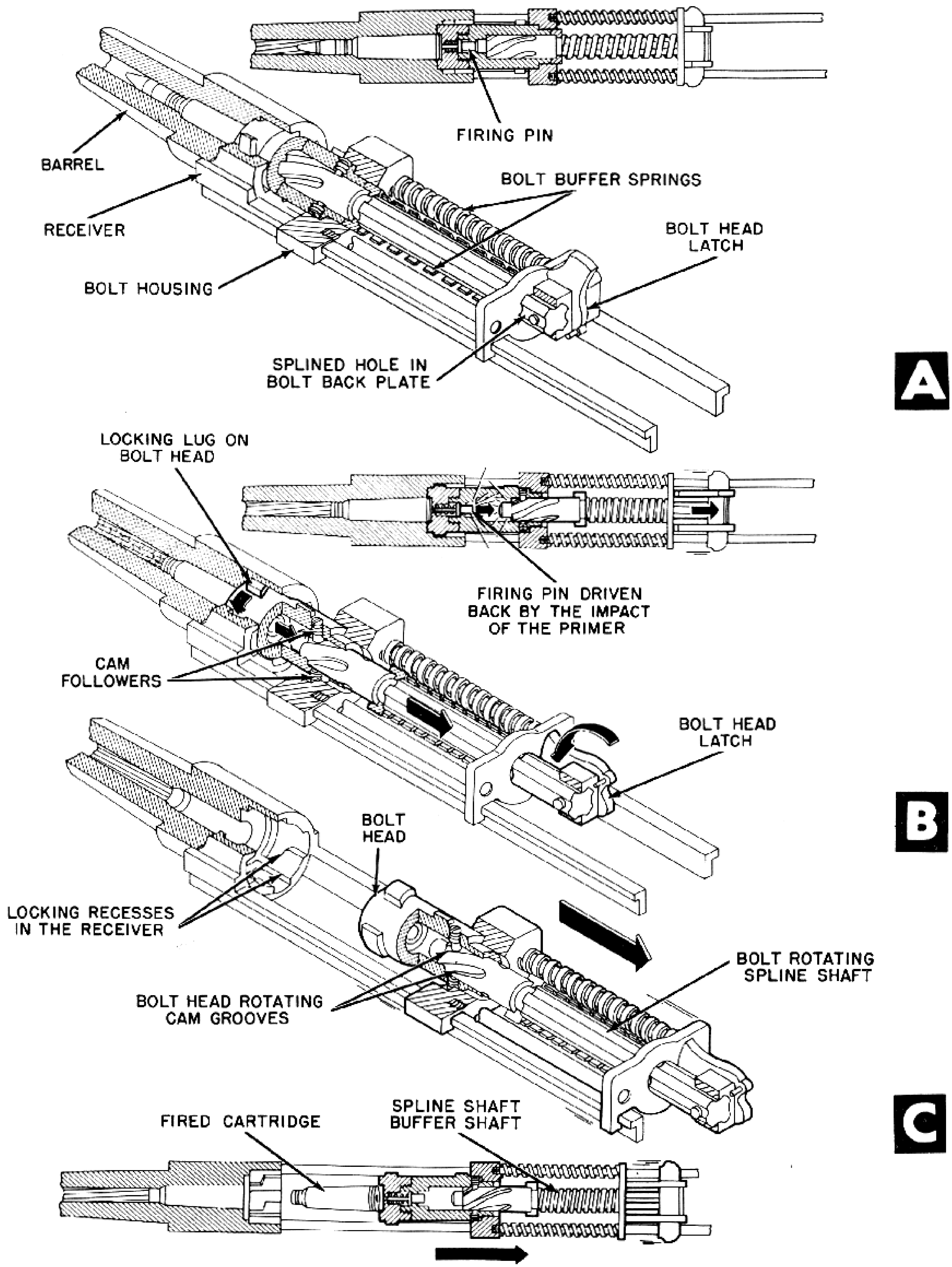


Figure 6–6. Rearward Thrust of Primer and Firing Pin Causes Bolt Head To Be Unlocked.

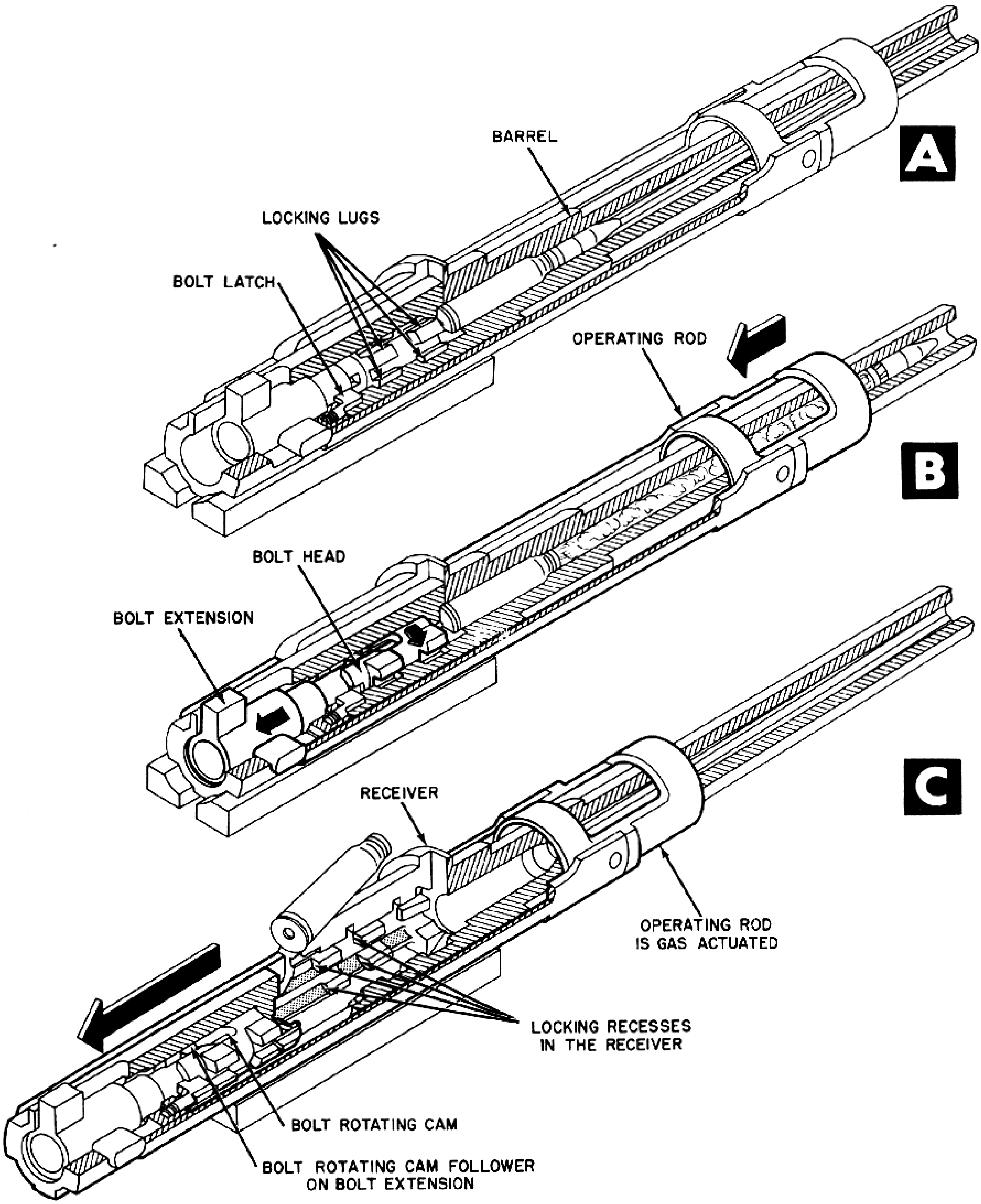


Figure 6–7. Rearward Motion of Bolt Extension Causes Cam To Unlock Bolt.

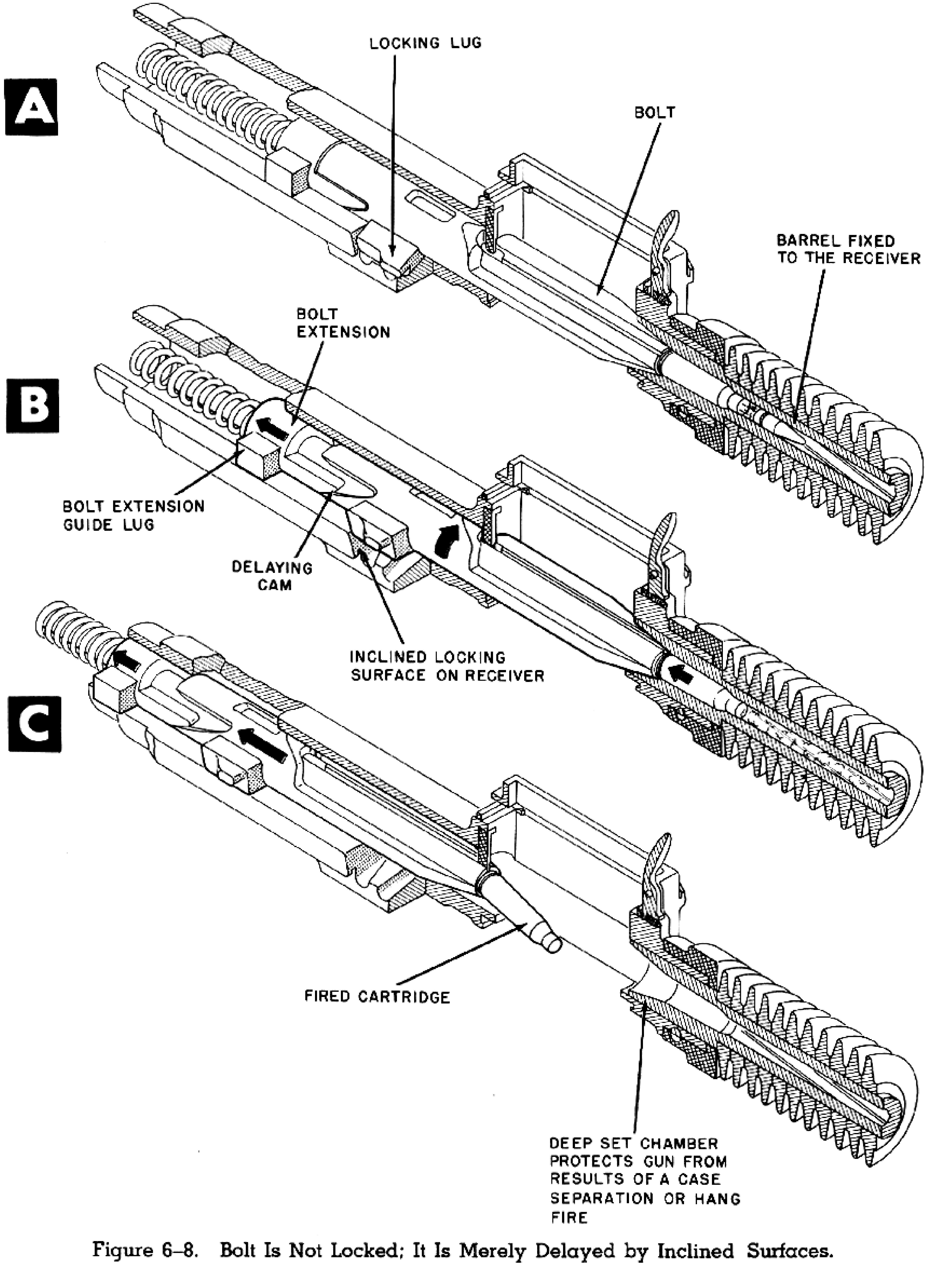


Figure 6–8. Bolt Is Not Locked; It Is Merely Delayed by Inclined Surfaces.

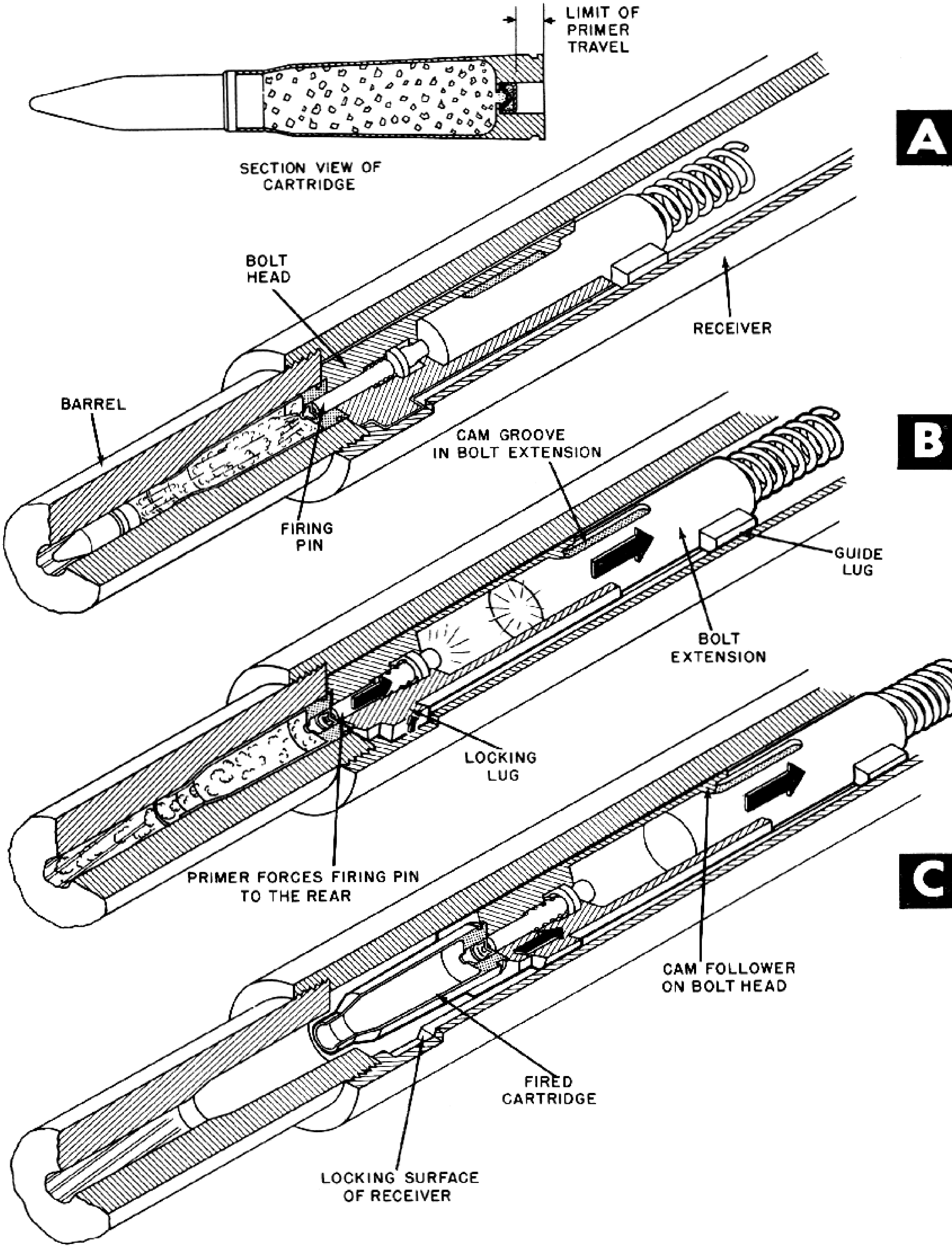


Figure 6–9. Action of Primer on Firing Pin Causes Bolt To Unlock.

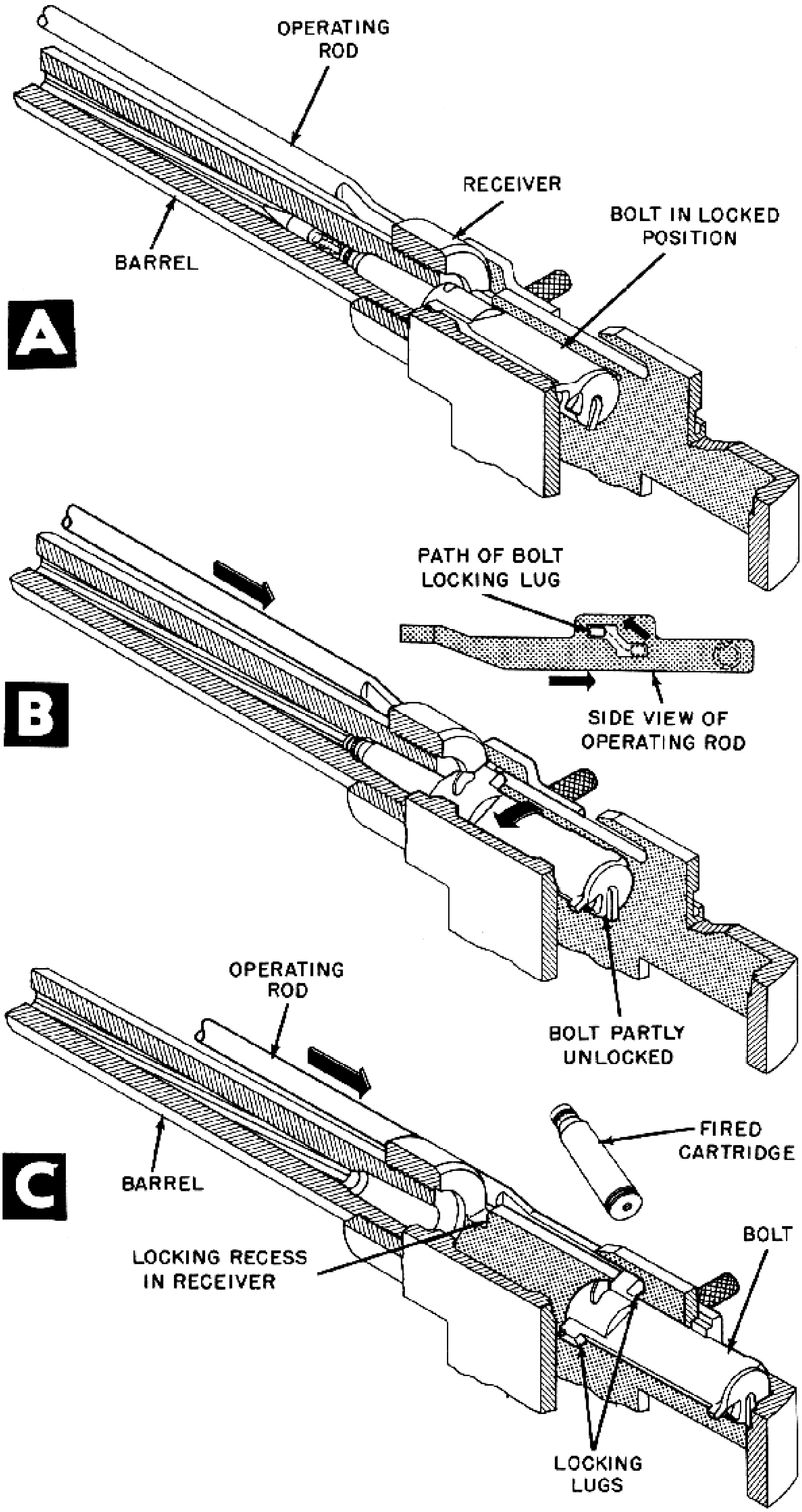


Figure 6–10. Cam on Operating Rod Unlocks Solid Bolt.

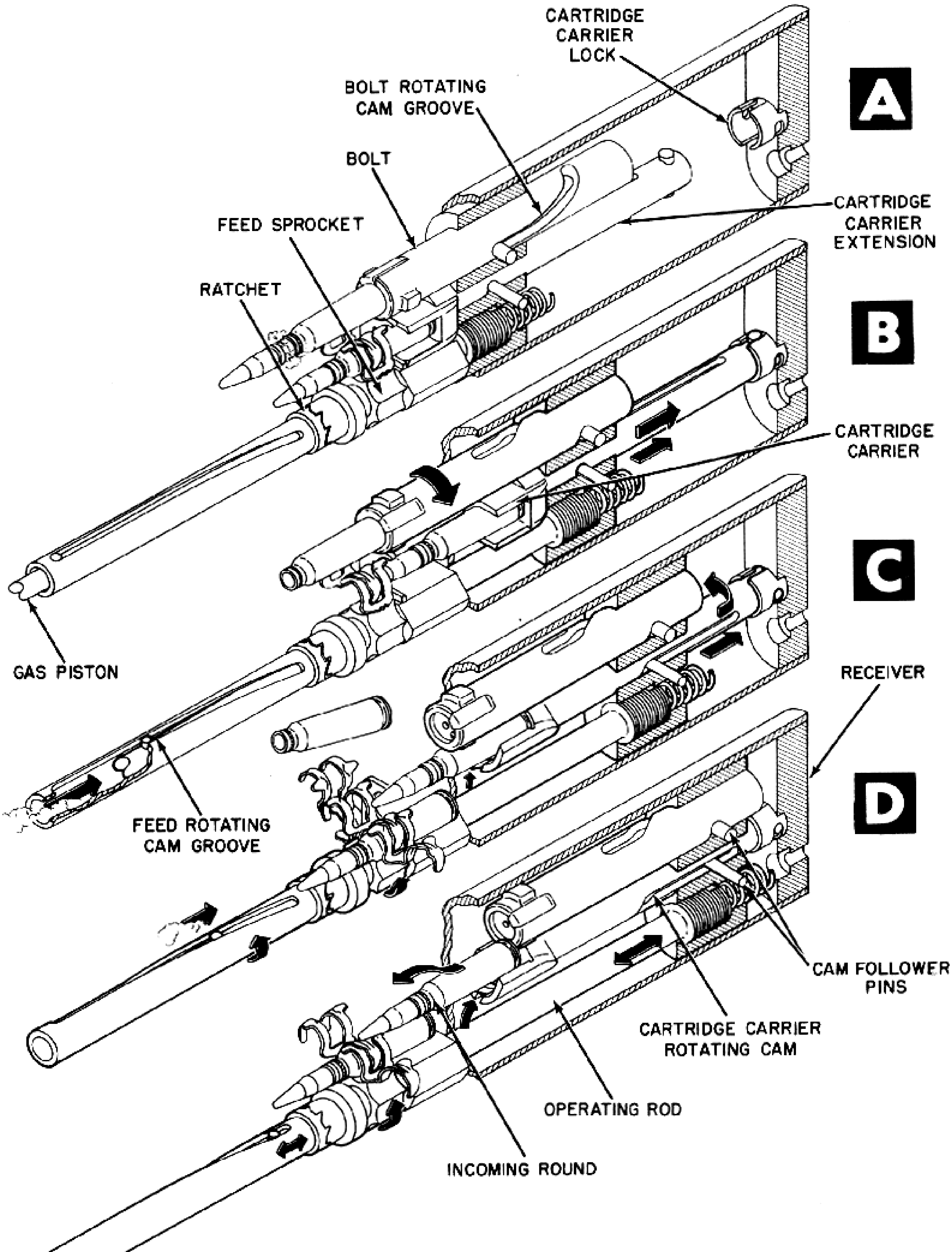


Figure 6–11. Solid Bolt Unlocked by Action of Operating Rod on Cam Groove in the Bolt.

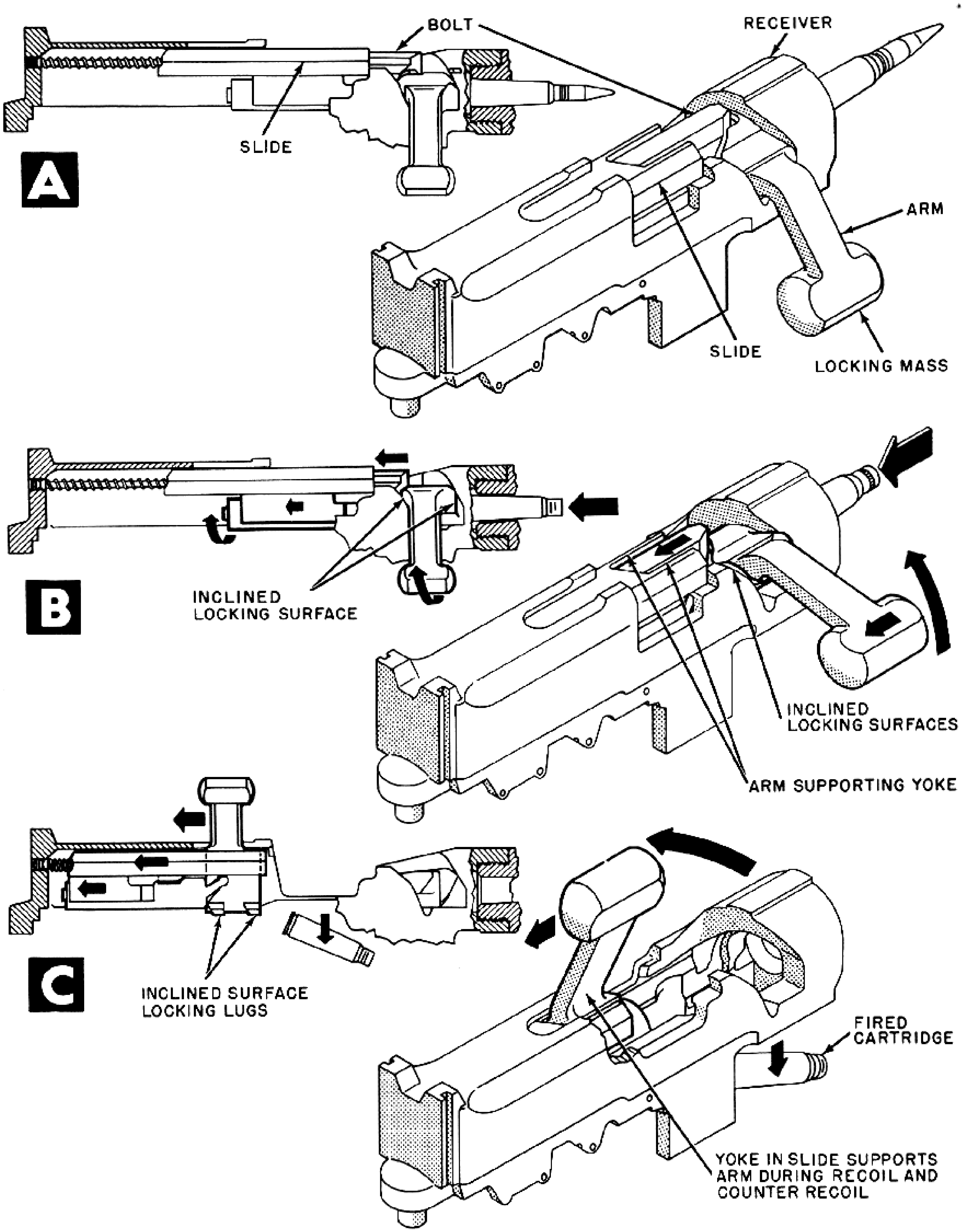


Figure 6–12. Gas Pressure on Inclined Surfaces Force Locking Mass and Bolt to Unlocked Position.

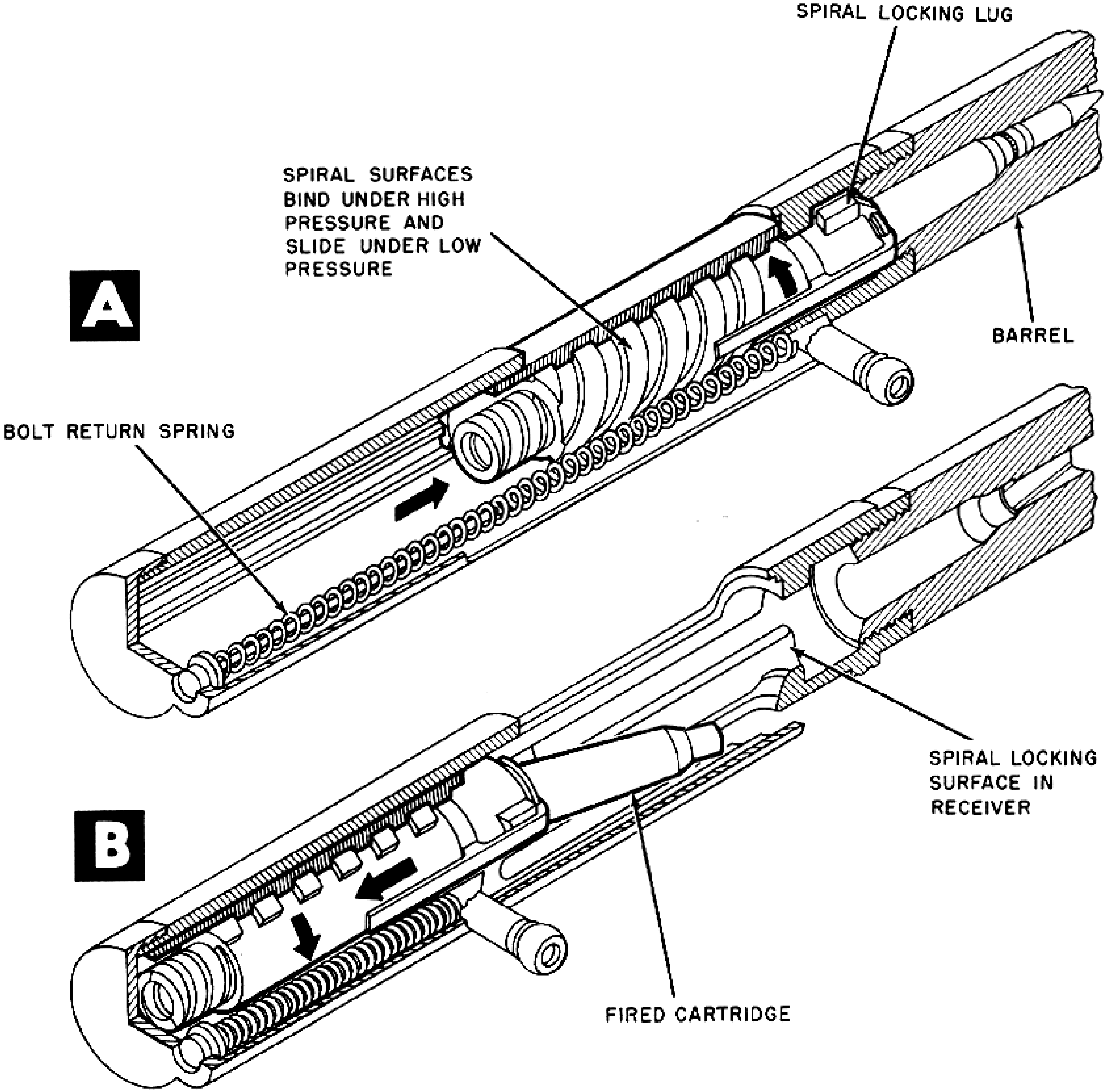


Figure 6–13. High Gas Pressure Causes Spirals To Bind. When Pressure Lowers, Spirals Slide, Unlocking the Bolt.

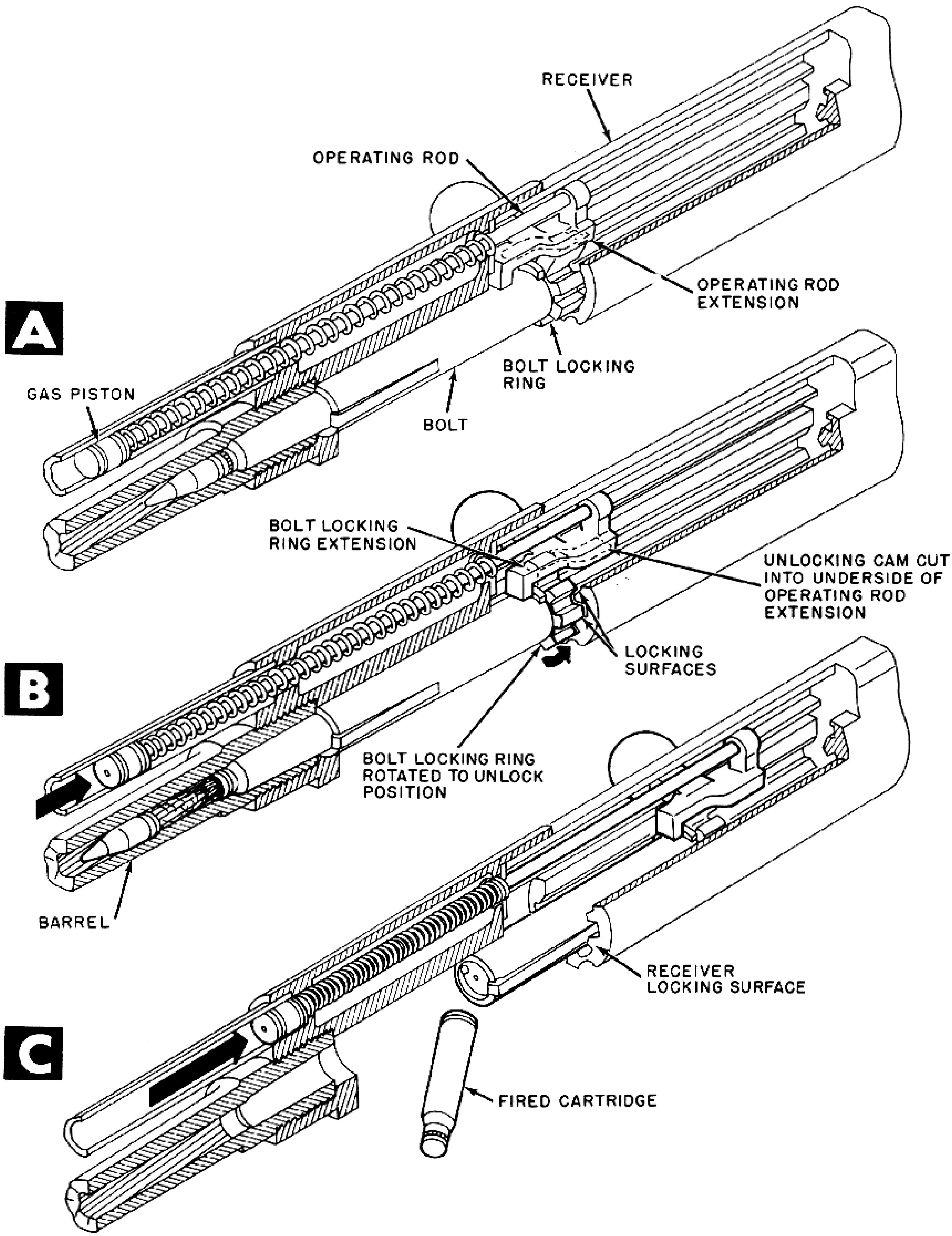


Figure 6–14. Cam on Operating Rod Rotates Bolt Locking Ring.

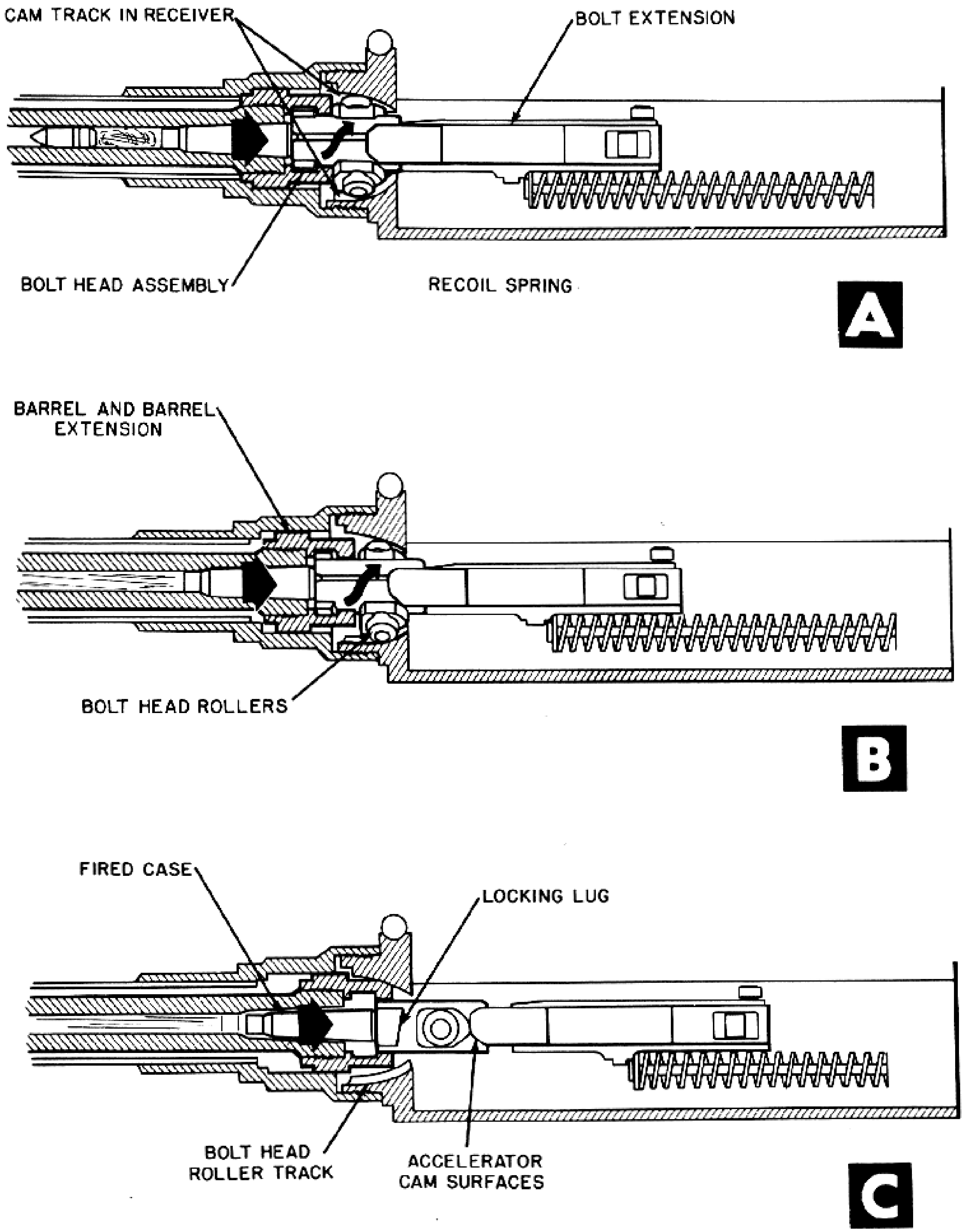


Figure 6–15. Cam Grooves on the Receiver Force Recoiling Bolt to Rotate to Unlock Position.

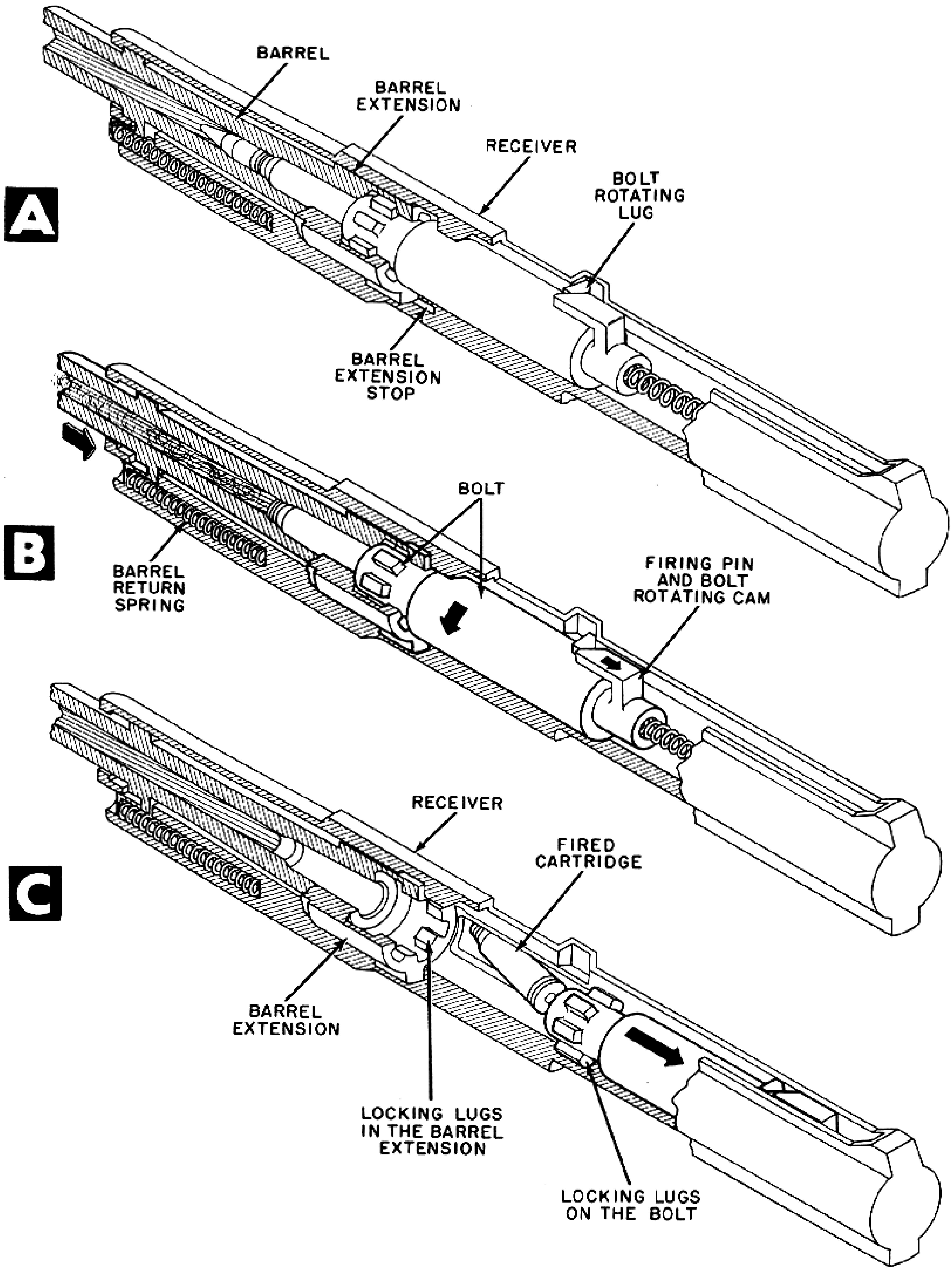


Figure 6–16. Cam Grooves in Receiver Cause Recoiling Bolt Extension To Unlock Bolt.

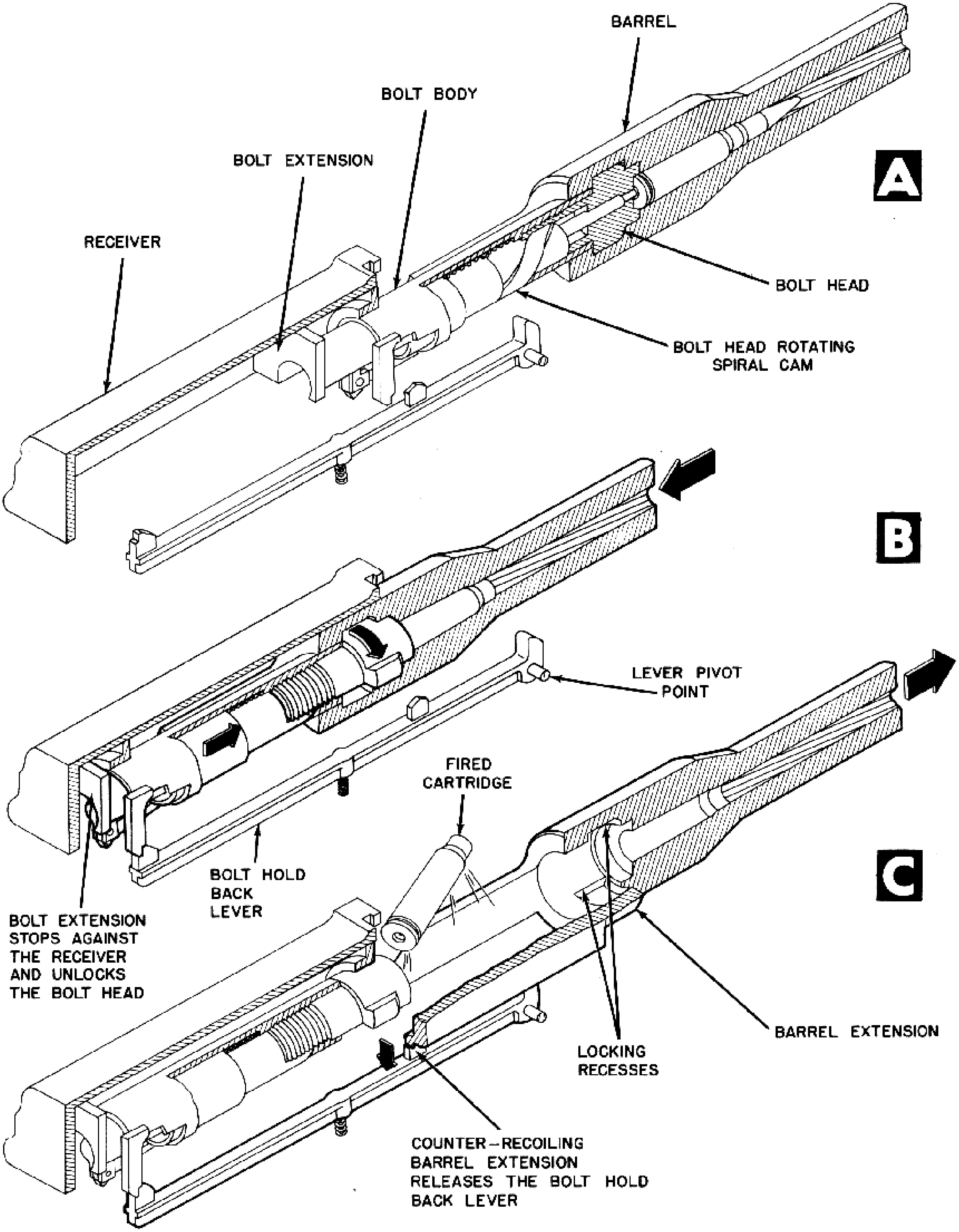
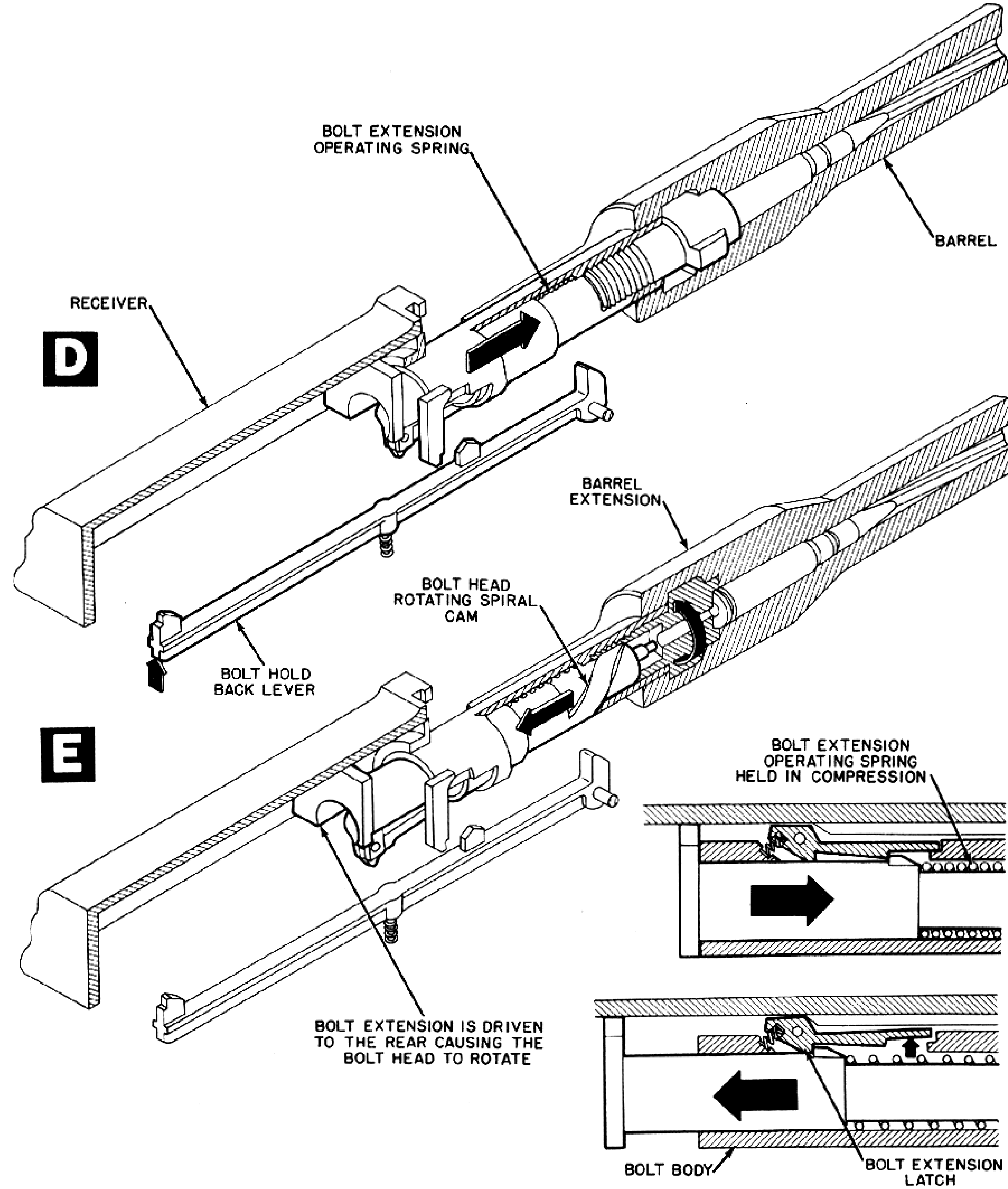


Figure 6–17. Bolt Is Unlocked by Action of



Counter-Recoiling Barrel Extension.

B. Sleeve

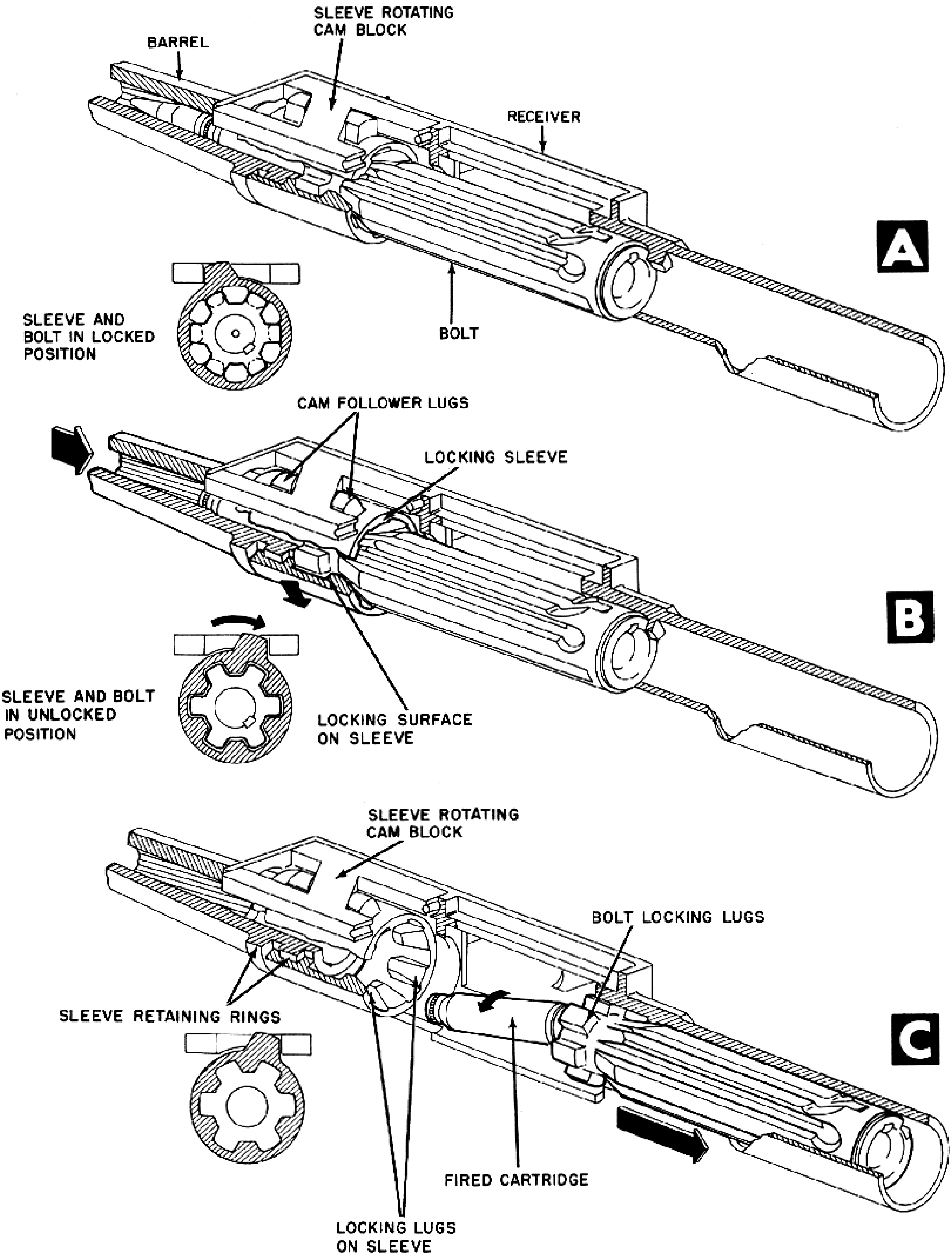


Figure 6–18. Bolt Is Unlocked by Rotation of Locking Sleeve.

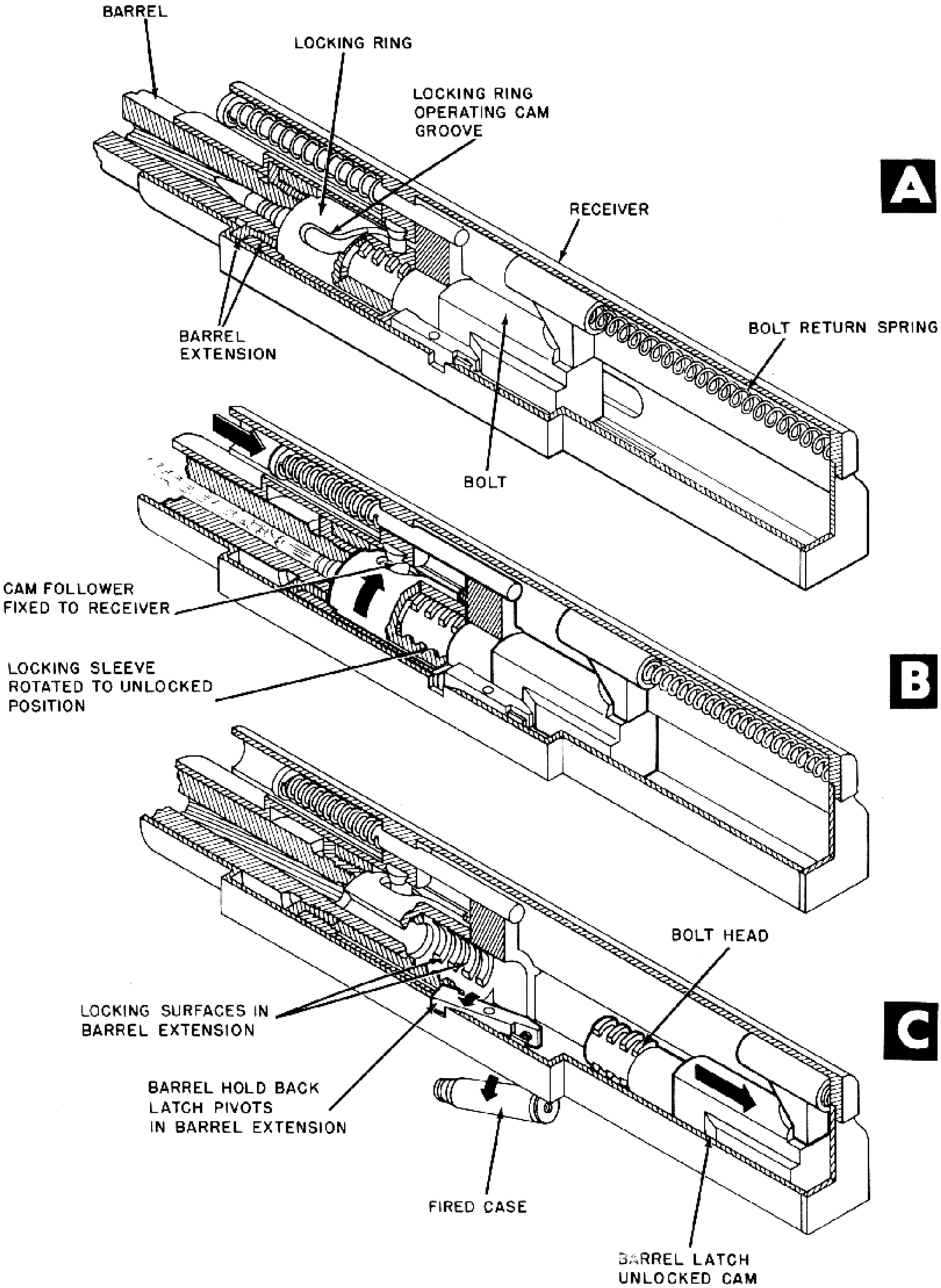


Figure 6–19. Cam Follower in Receiver Causes Recoiling Locking Sleeve To Rotate, Unlocking the Bolt.

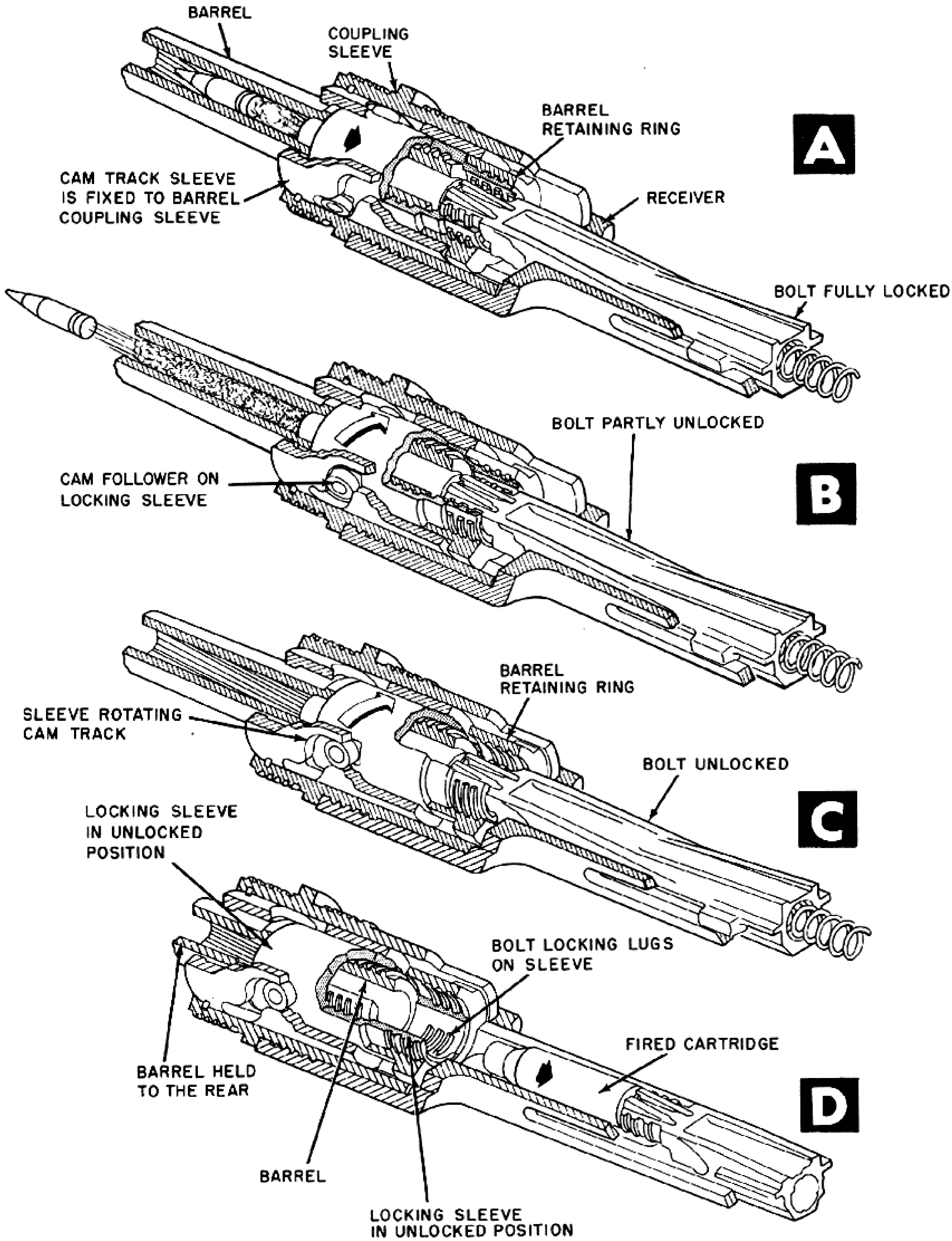


Figure 6–20. Cam Groove in Receiver Causes Locking Sleeve To Rotate, Unlocking the Bolt.

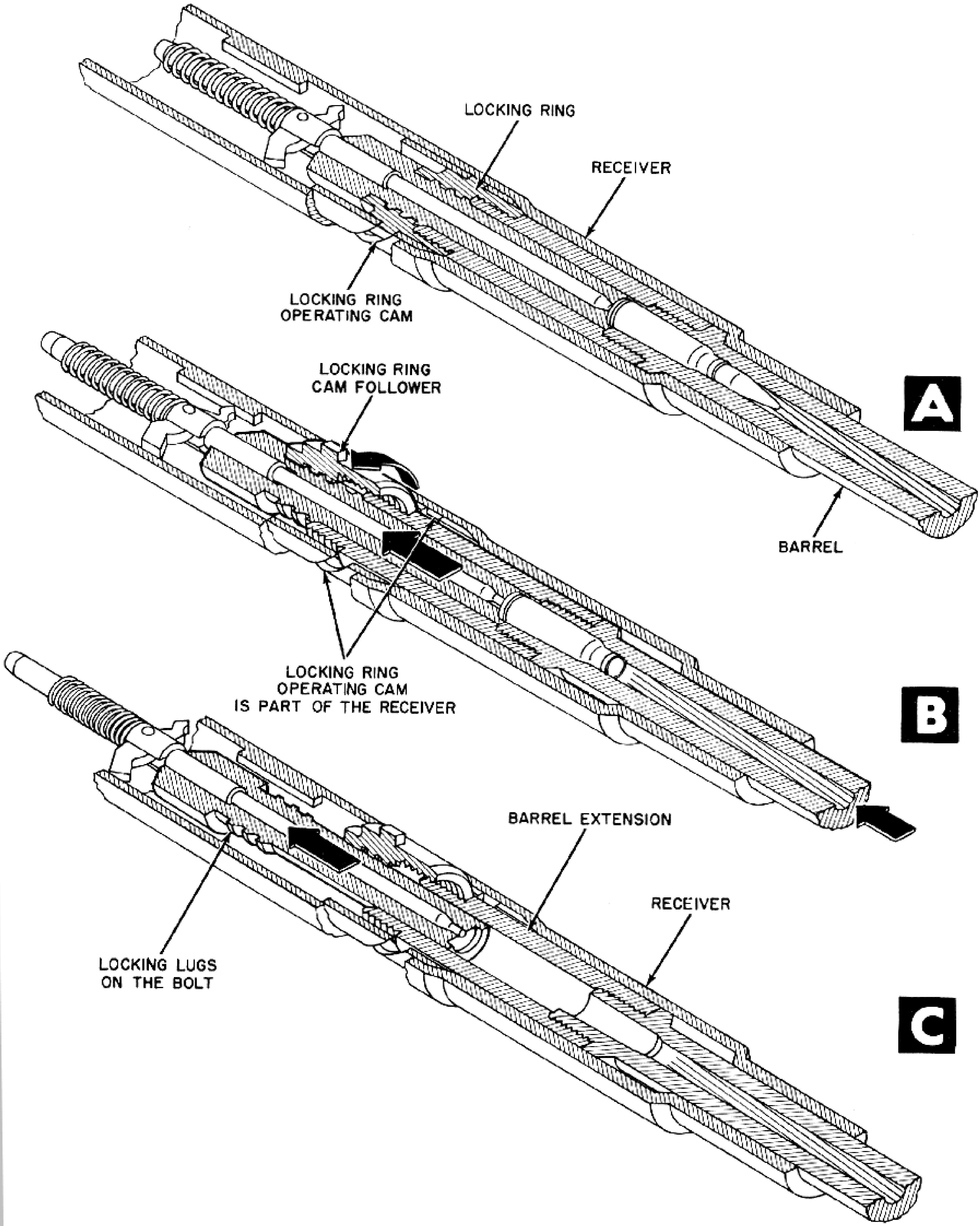


Figure 6–21. Cam Groove in Receiver Causes Locking Sleeve To Rotate, Unlocking the Bolt.

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C. Toggle

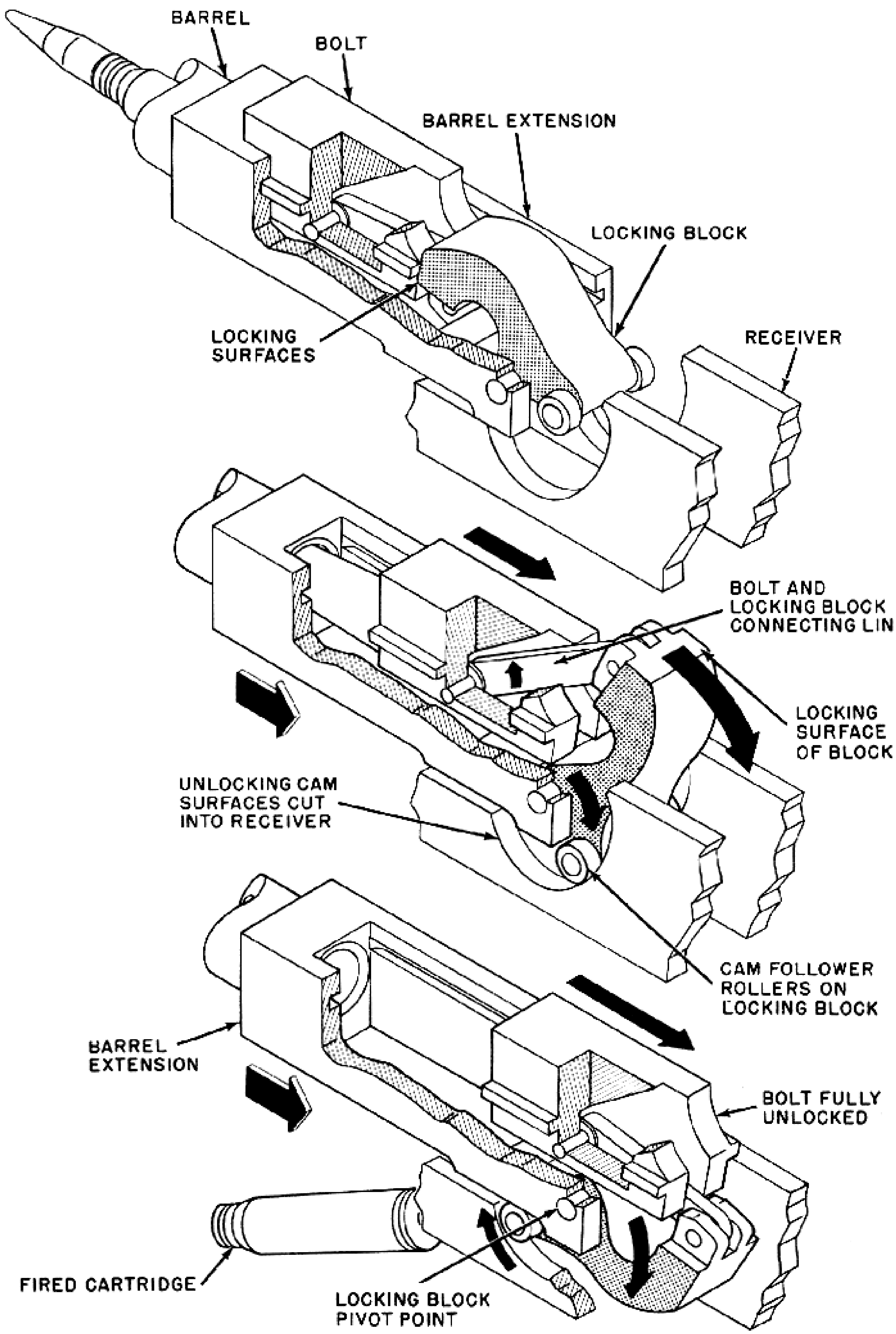

Figure 6–22. Bolt Is Unlocked by Action of Cam Followers on the Locking Block Recoiling Against Cams in the Receiver.

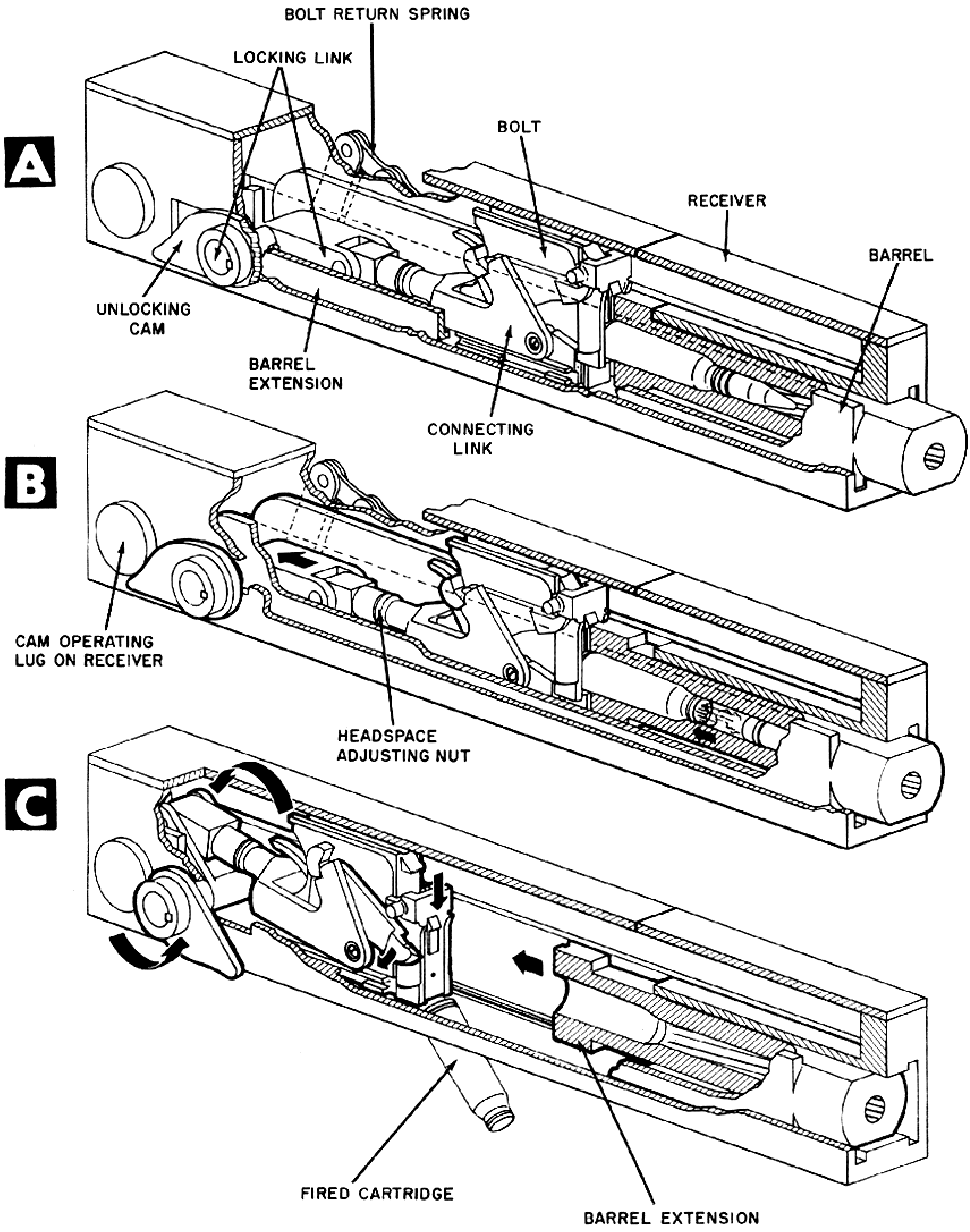

Figure 6–23. Bolt Is Unlocked by the Action of the Unlocking Cam on a Lug on the Receiver.

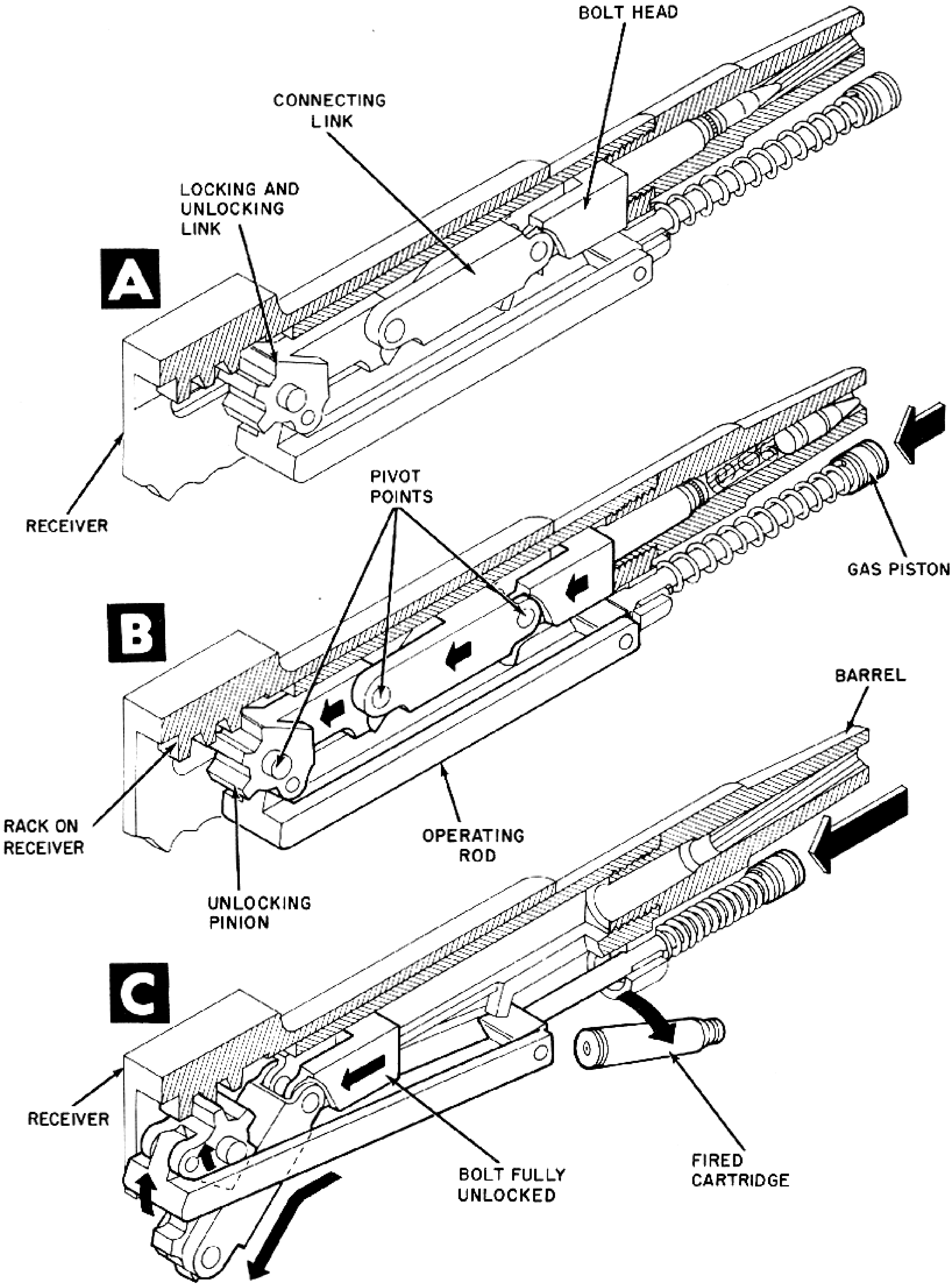

Figure 6–24. Bolt Is Unlocked When Operating Rod Rotates Unlocking Pinion.

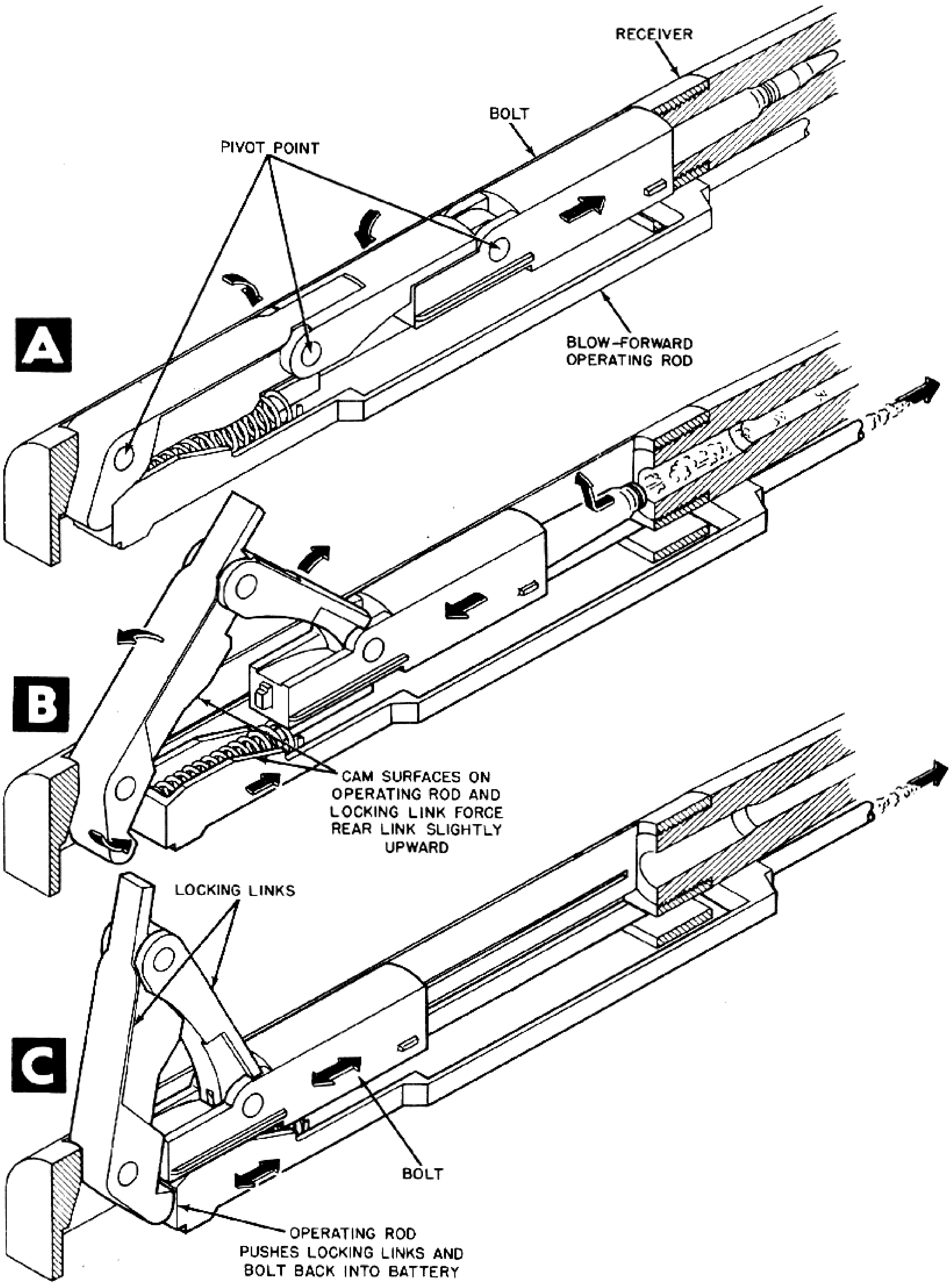

Figure 6–25. Bolt Is Unlocked When Operating Rod Is Blown Forward Leaving the Locking Link Unsupported.

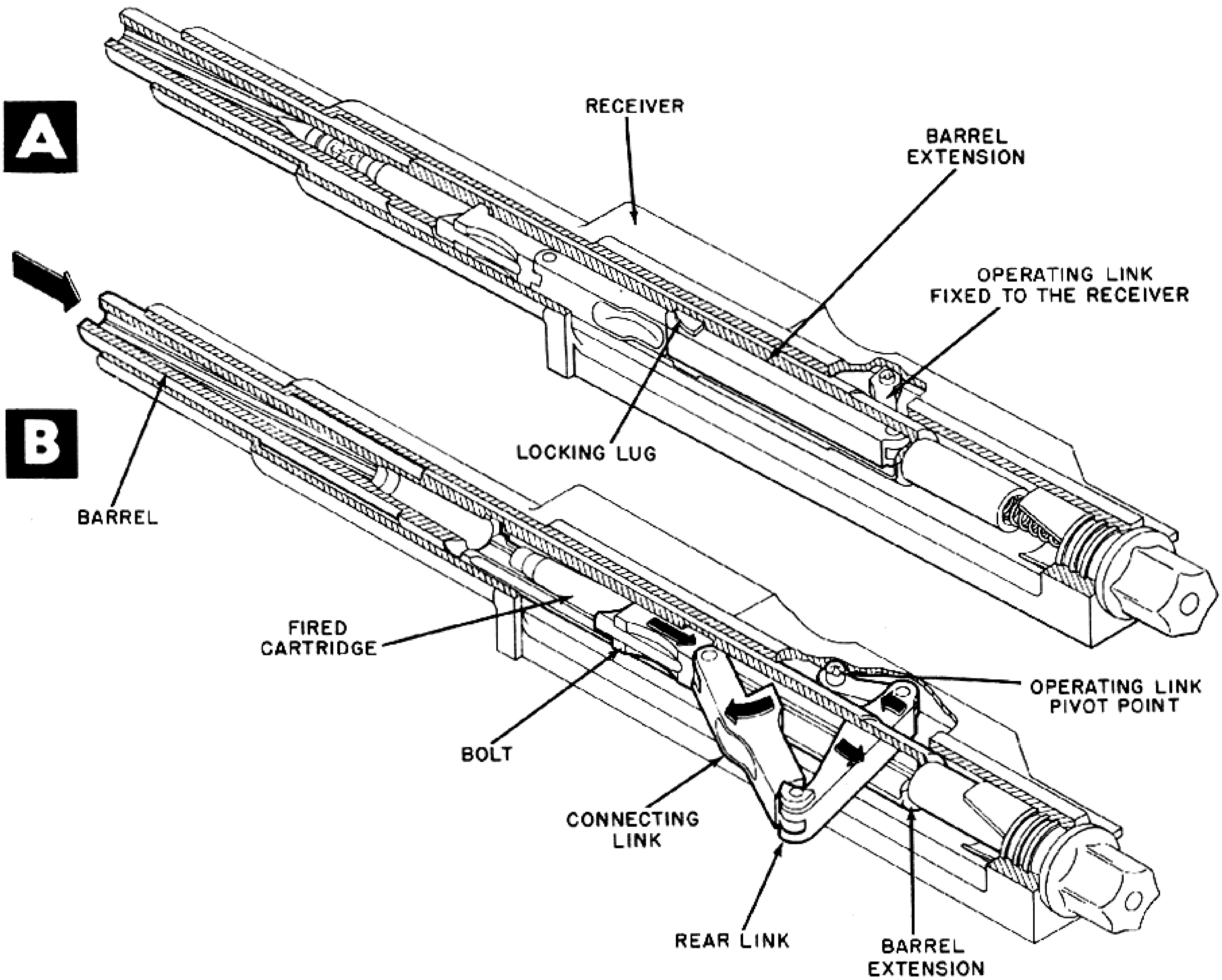

Figure 6–26. Action of the Fixed Link on End of Recoiling Bolt Causes It To Unlock.

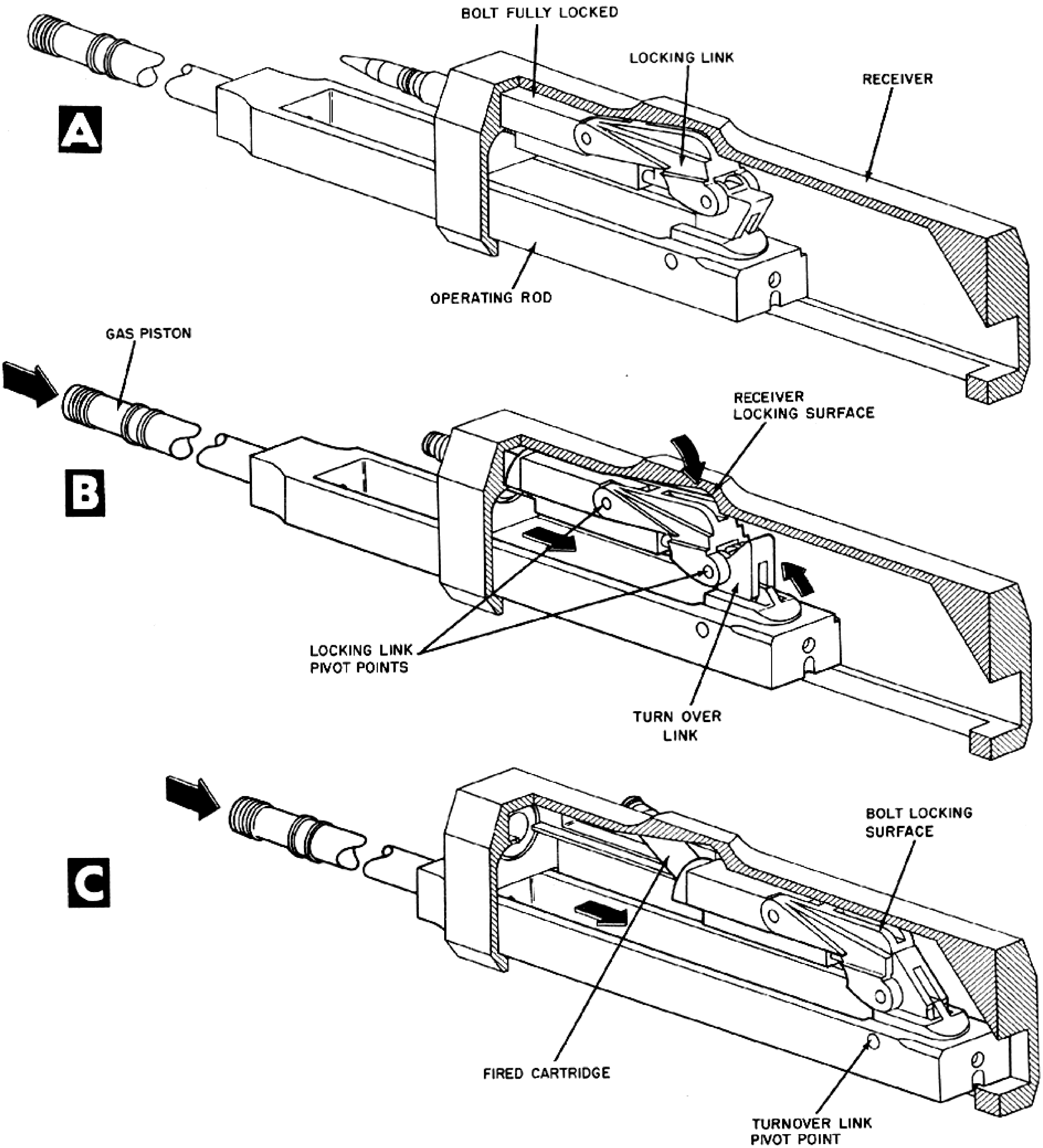

Figure 6–27. Operating Rod Pulls the Turn Over Link Out From Under the Locking Block, Unlocking the Bolt.

D. Propped Breech

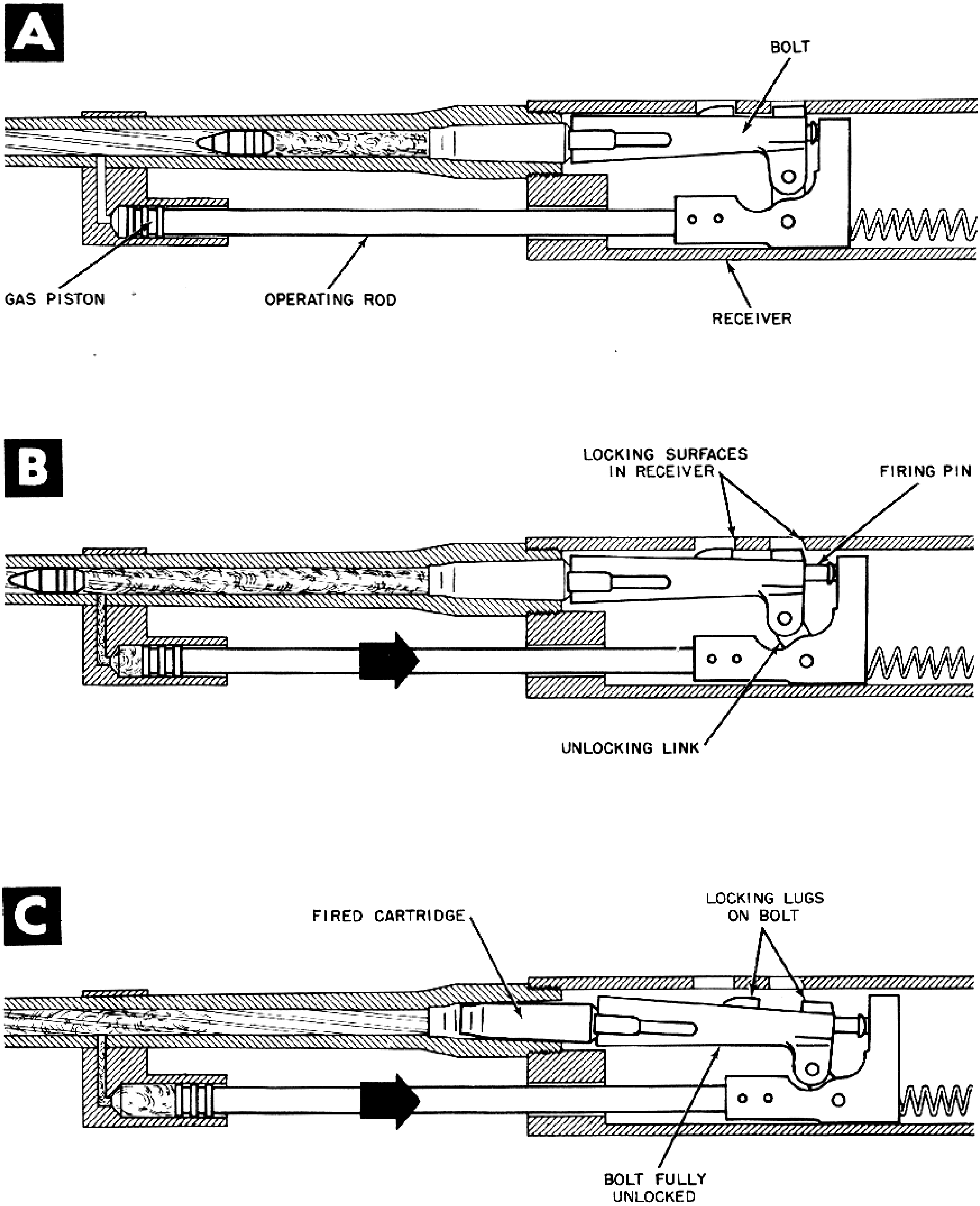

Figure 6–28. Recoiling Locking Link Pulls Bolt Free of Locking Surfaces in Receiver.

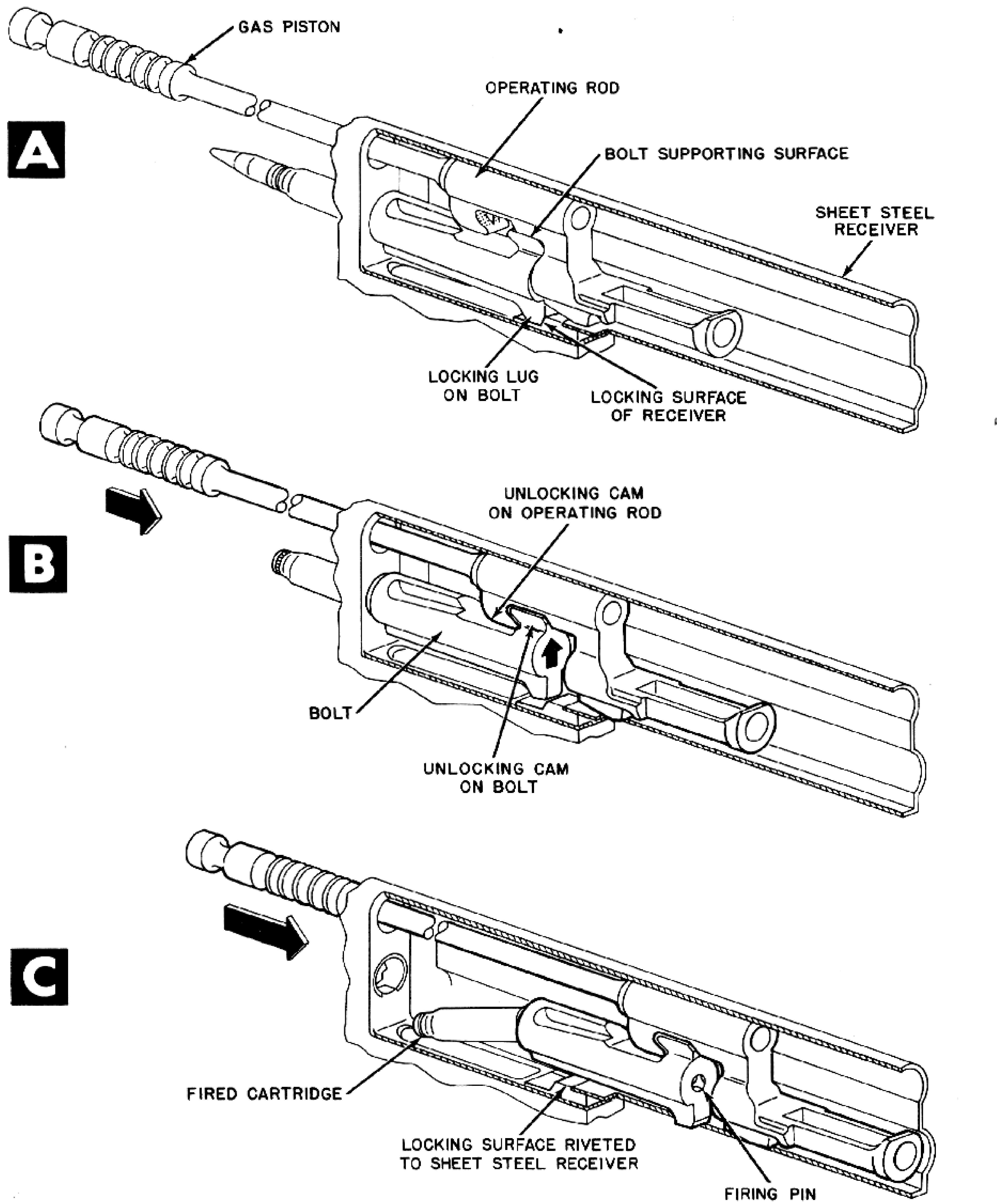

Figure 6–29. Cam Lug on Operating Rod Lifts Bolt Free of Locking Surface.

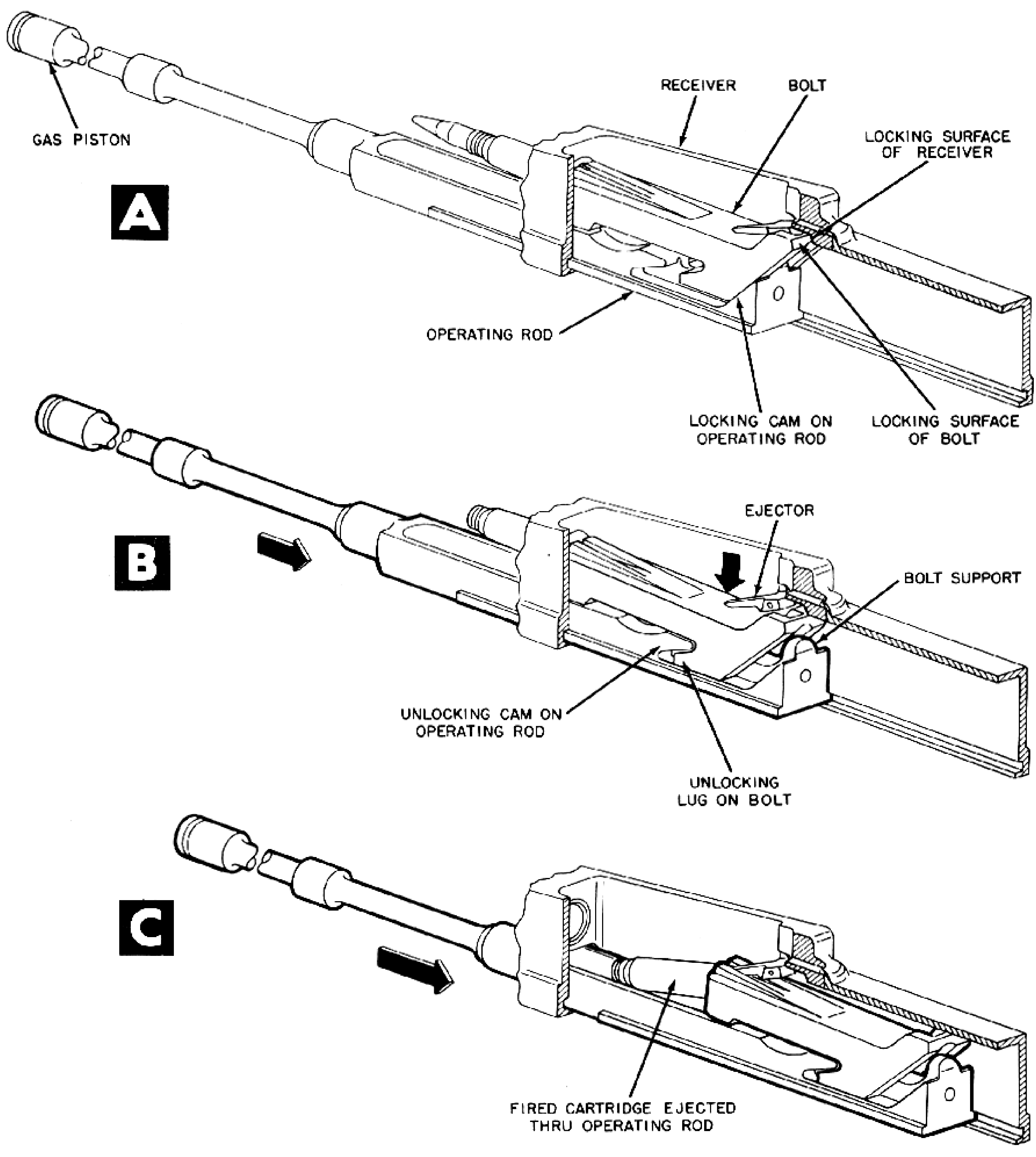

Figure 6–30. Cam on Operating Rod Pulls Bolt Free of Locking Surface After Withdrawing Bolt Support.

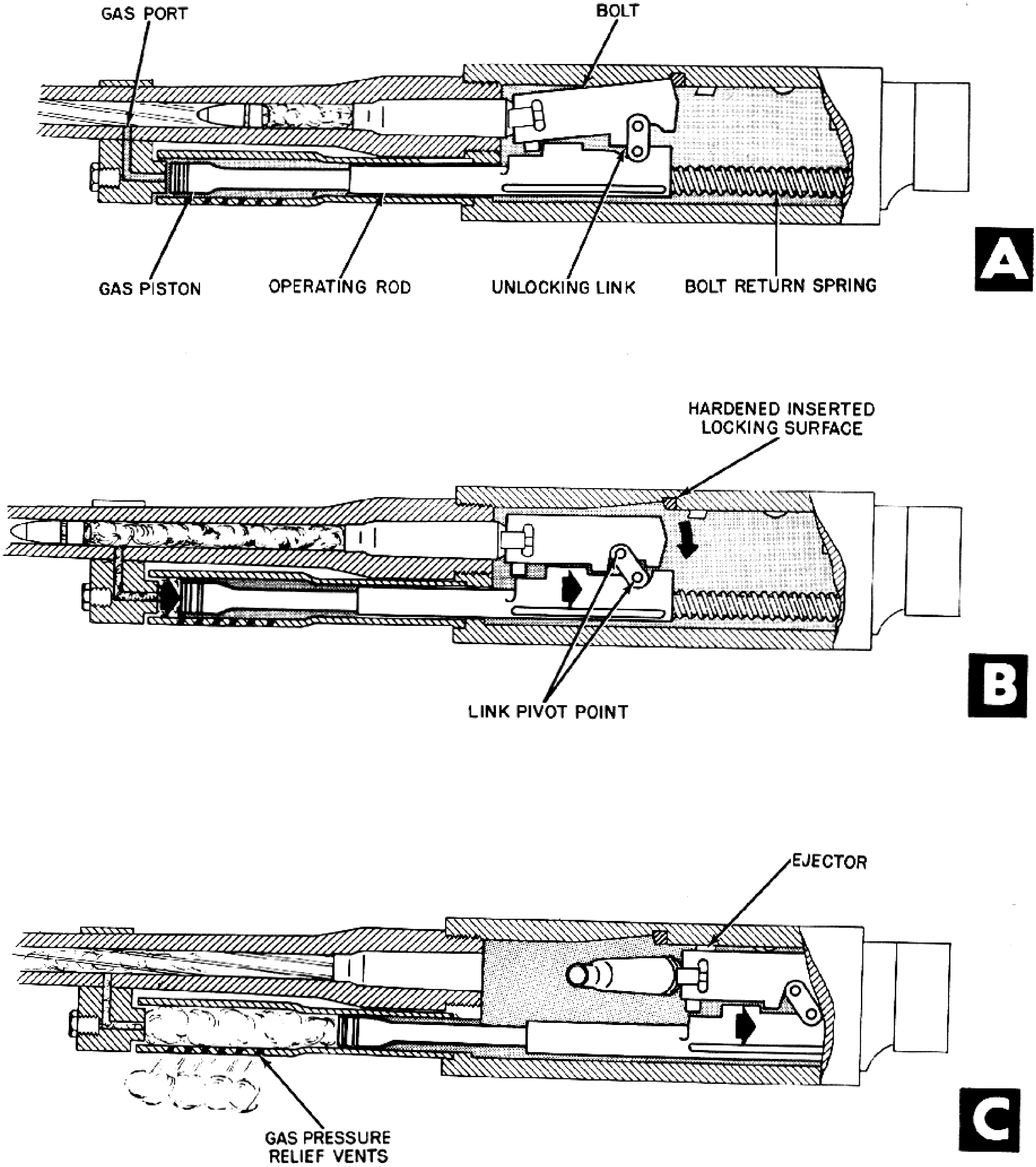

Figure 6-31. Recoiling Link Pulls Bolt Free of Locking Surface.

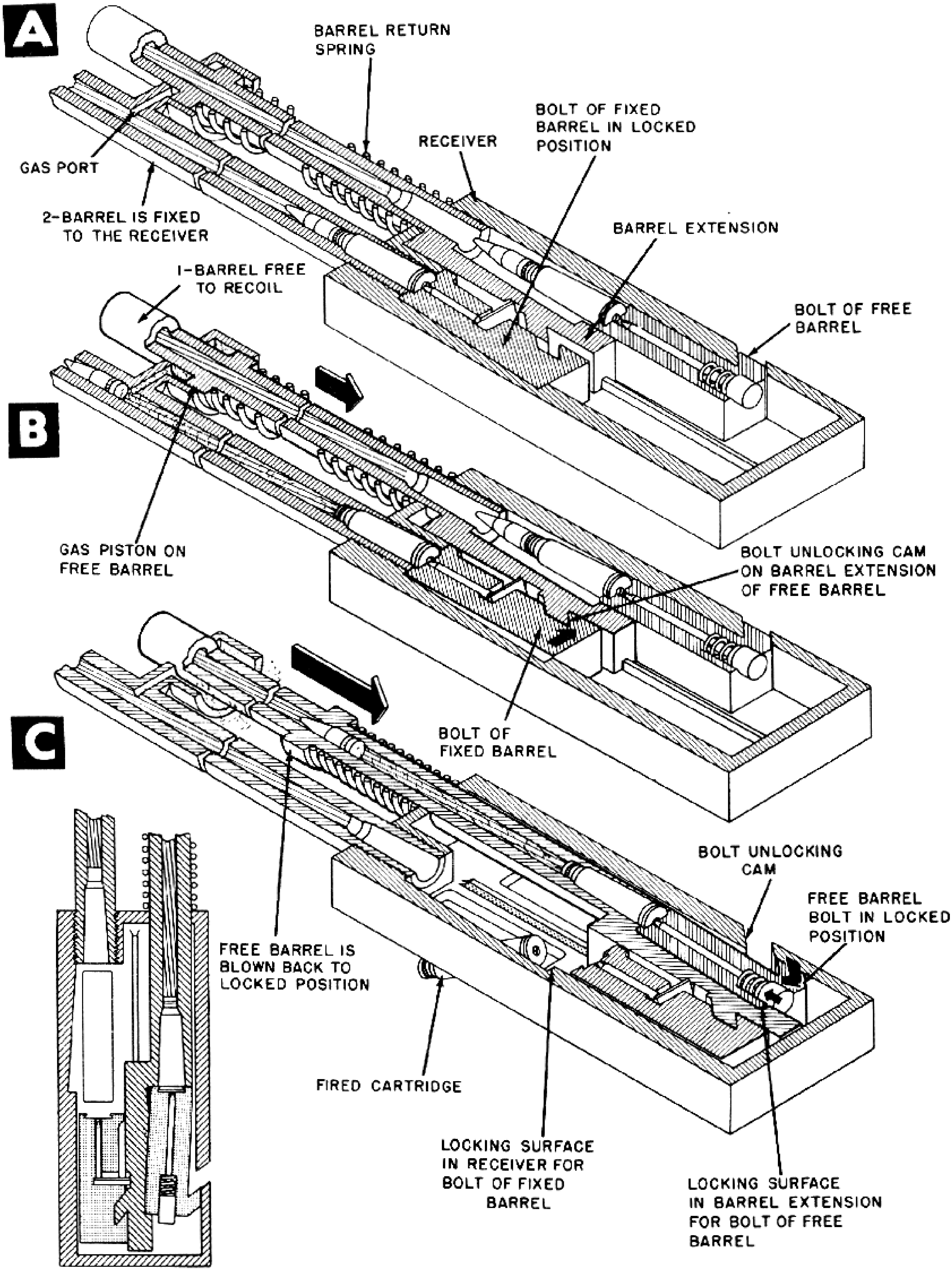

Figure 6–32. Double Barrel Gun Unlocked by Gas and Recoil Operation.

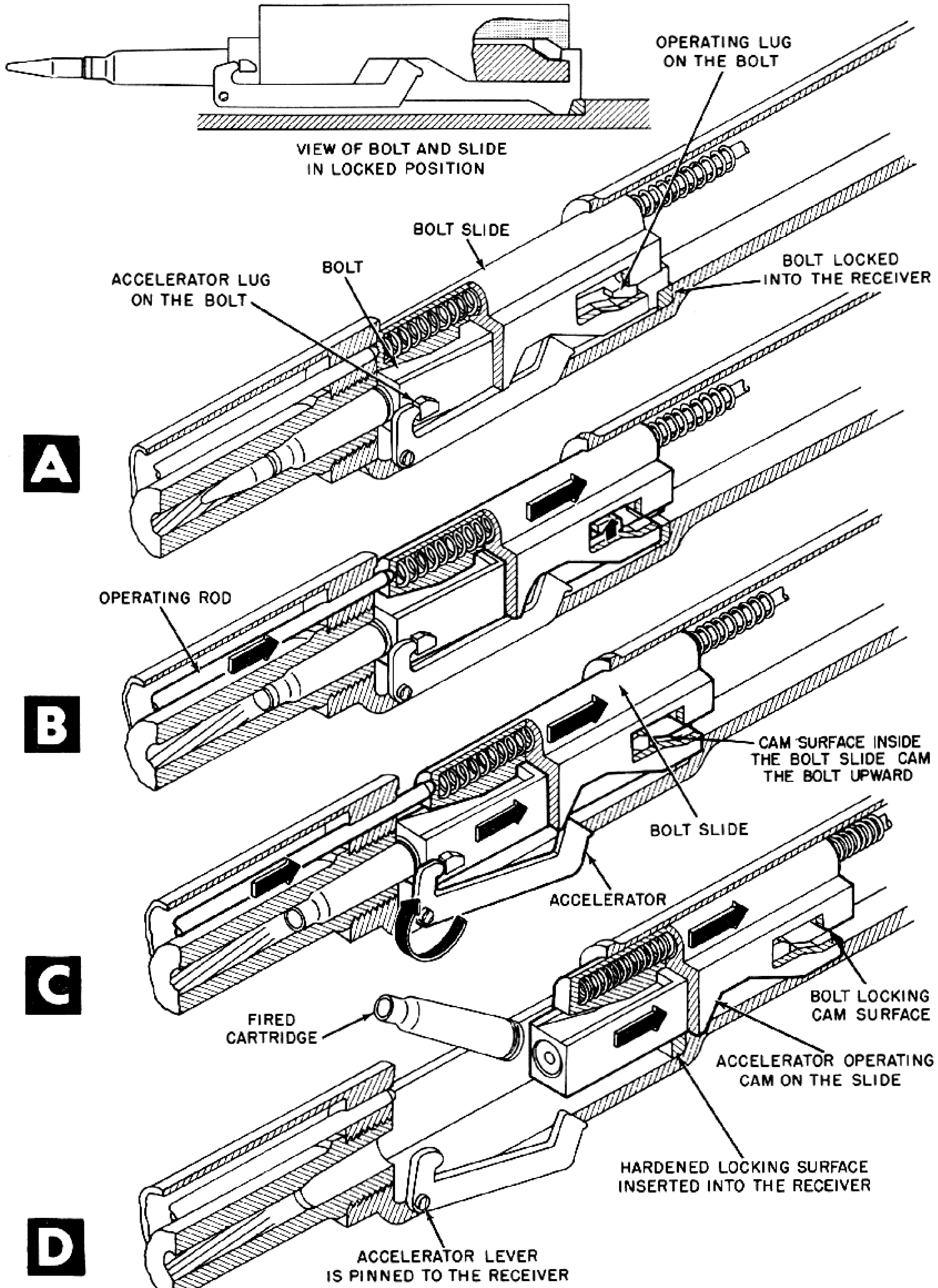

Figure 6-33. Bolt Slide Lifts Bolt Free of Locking Surfaces as It Recoils to Rear.

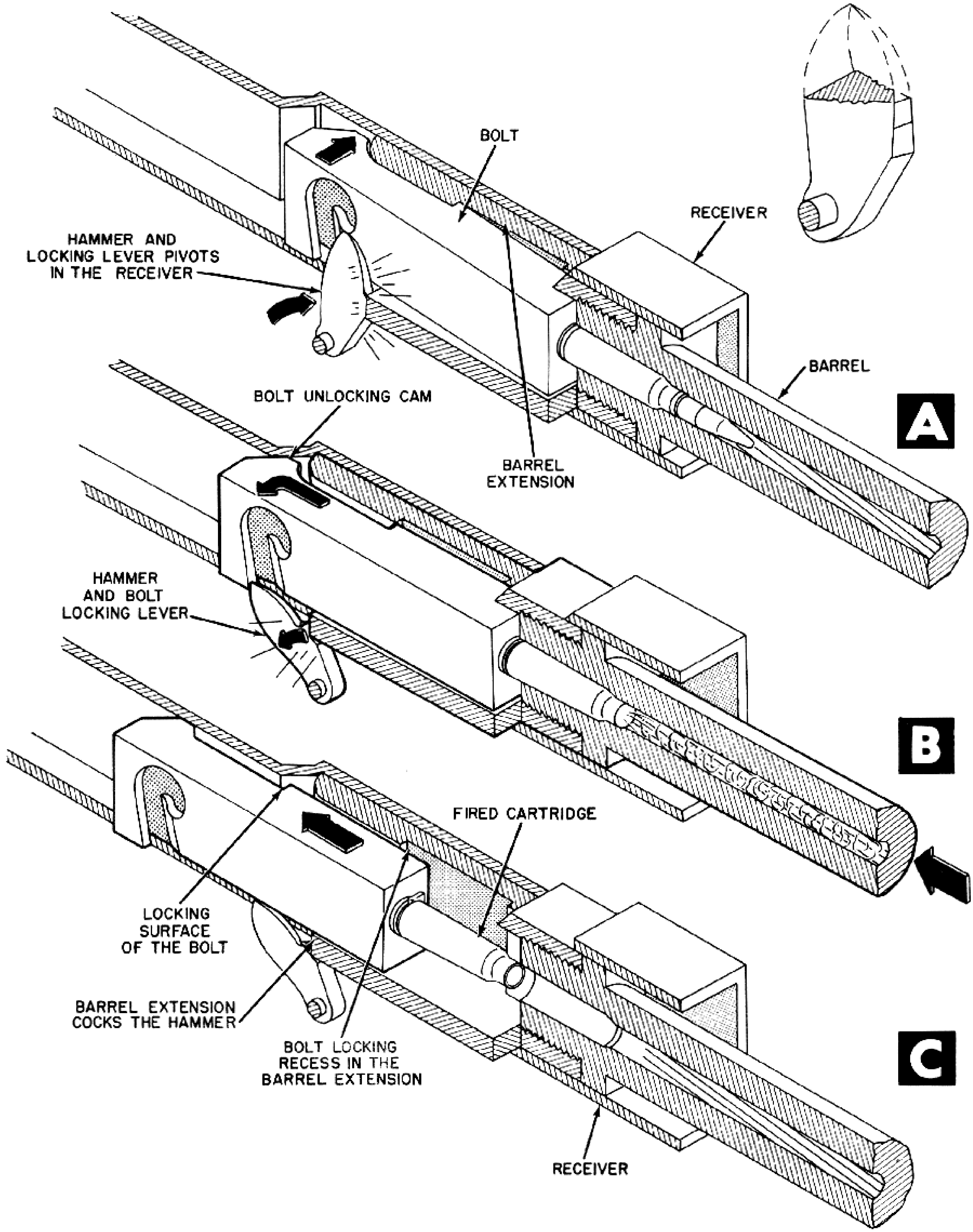

Figure 6–34. Bolt Is Forced Into Locked Position by Action of Hammer.

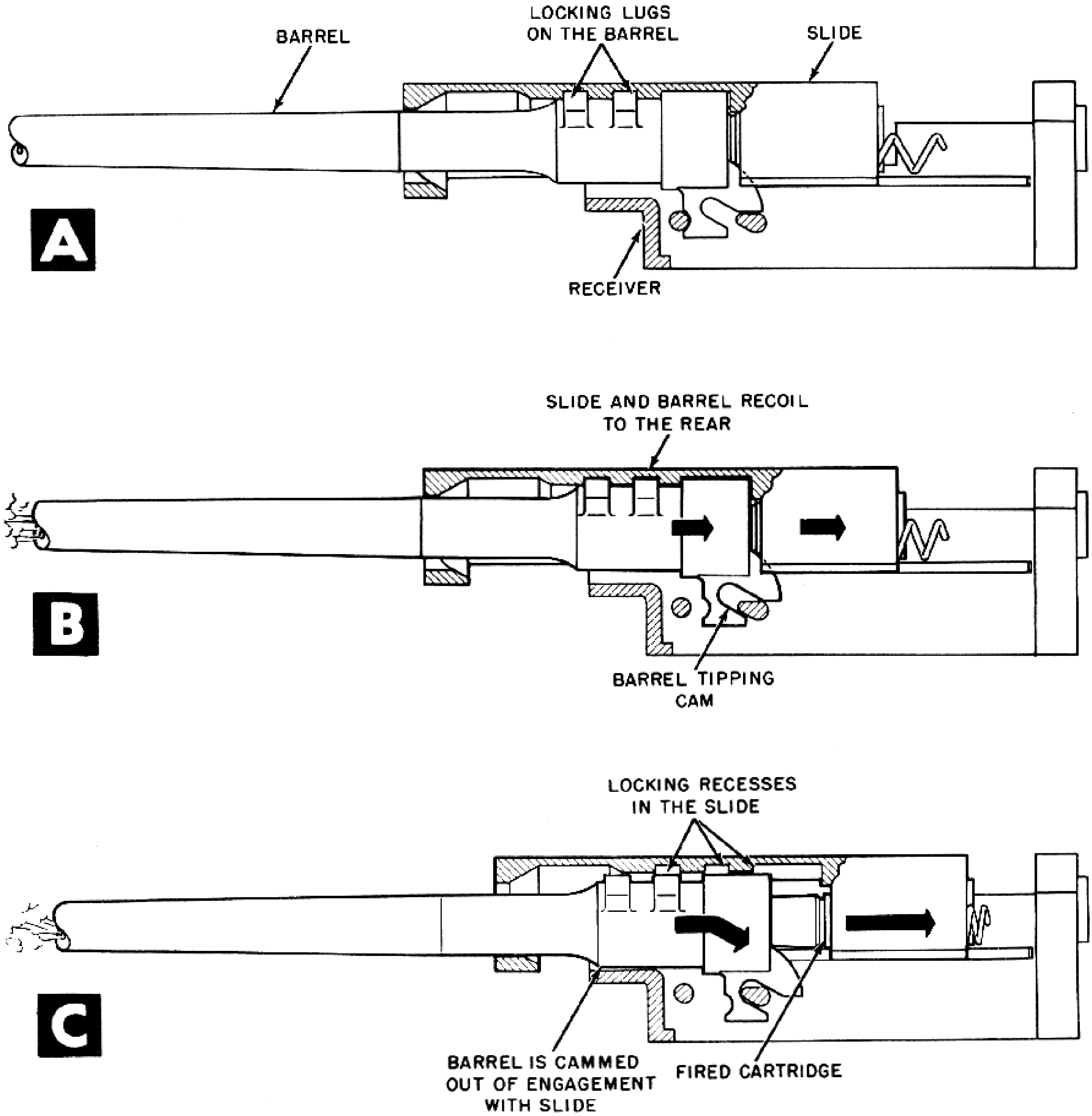

Figure 6–35. As Barrel Recoils, It Is Cammed Free of the Slide.

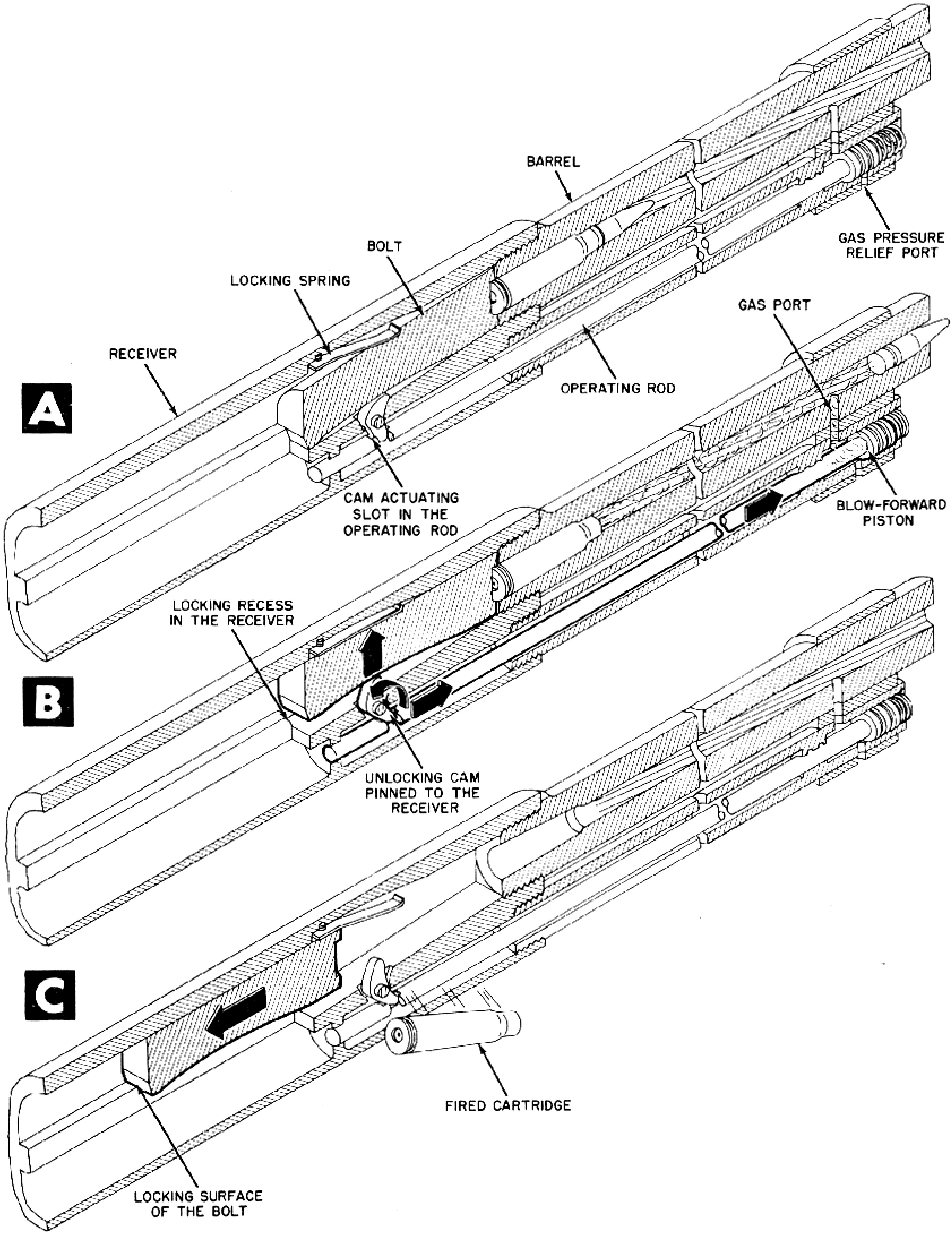

Figure 6–36. Spring Pushes Bolt Into Locking Surface When Operating Rod Removes Unlocking Cam.

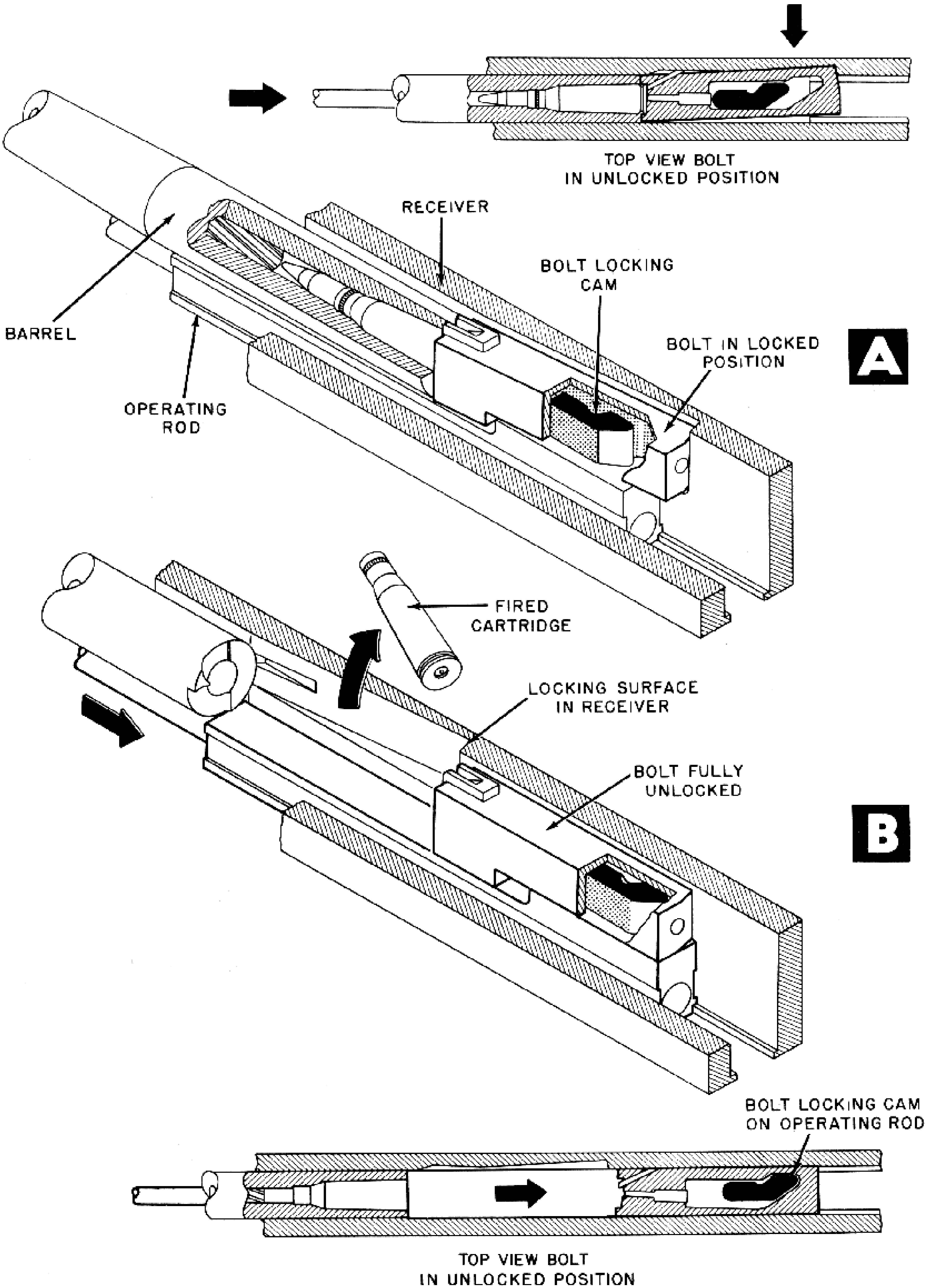

Figure 6–37. Lug on Operating Rod Cams Bolt Out of Side Locking Surface.

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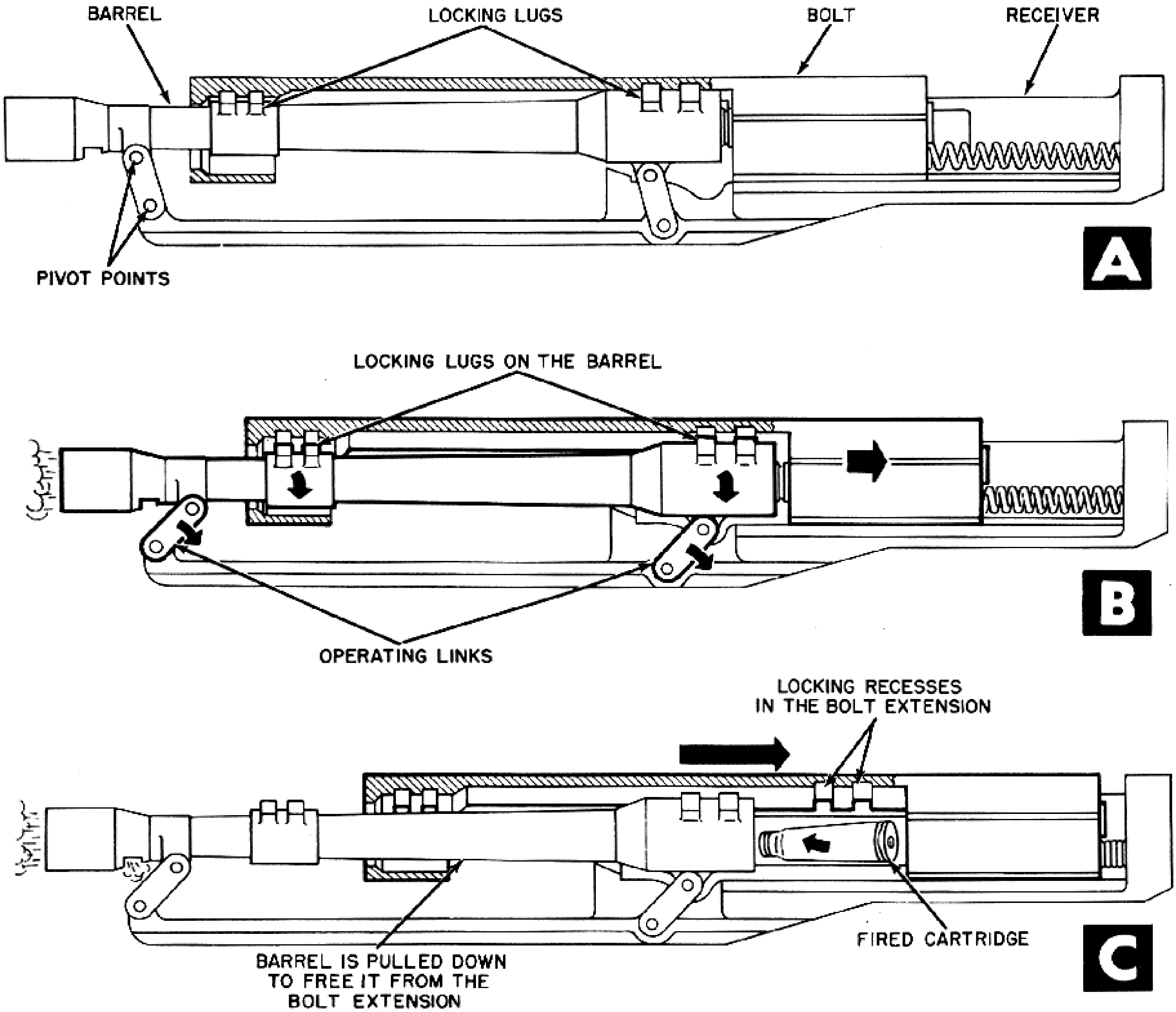


Figure 6–38. Locking Link Unlocks Barrel From Bolt.

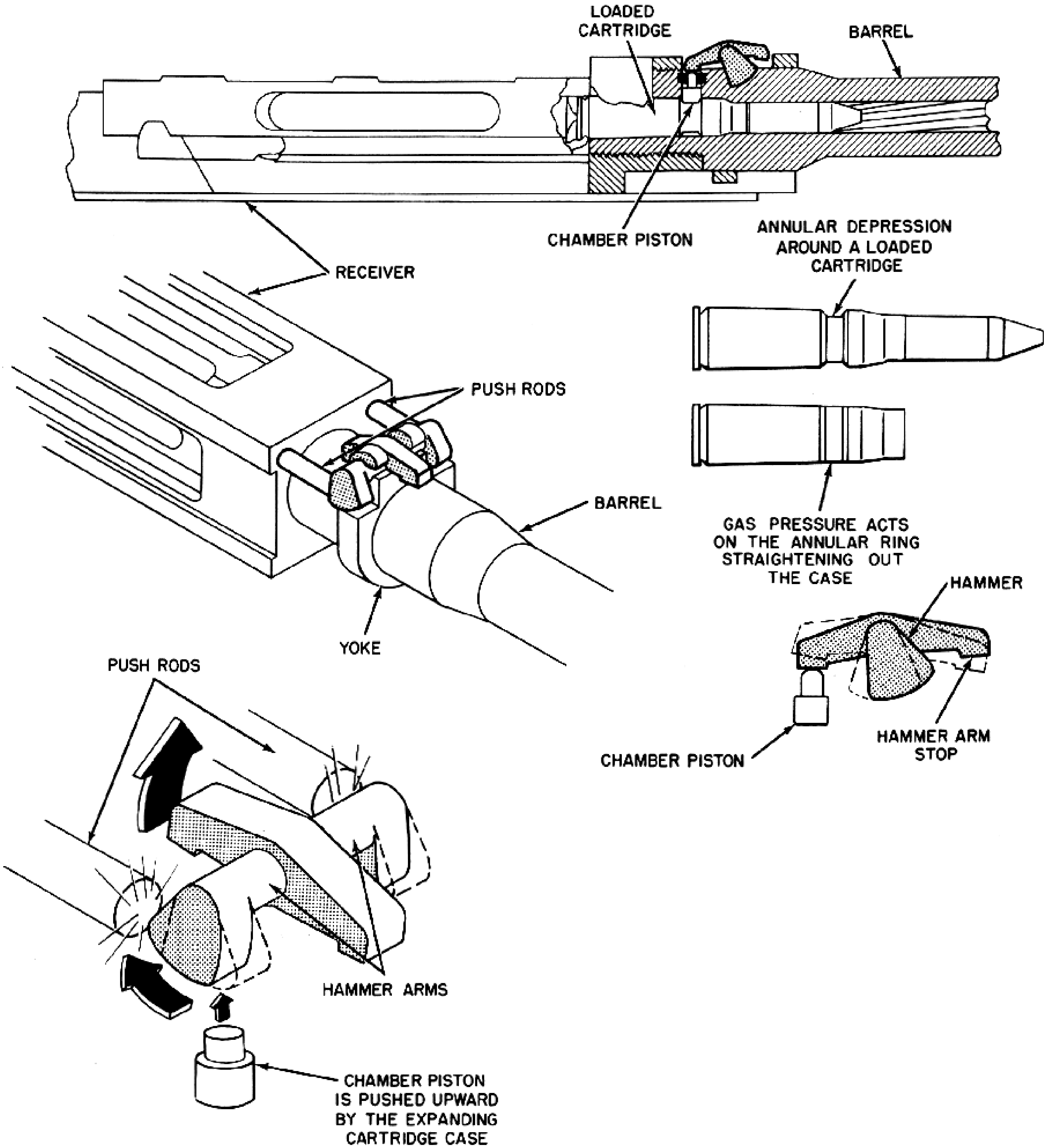


Figure 6–39. Expansion of Cartridge Case Operates Bolt Unlocking Mechanism.

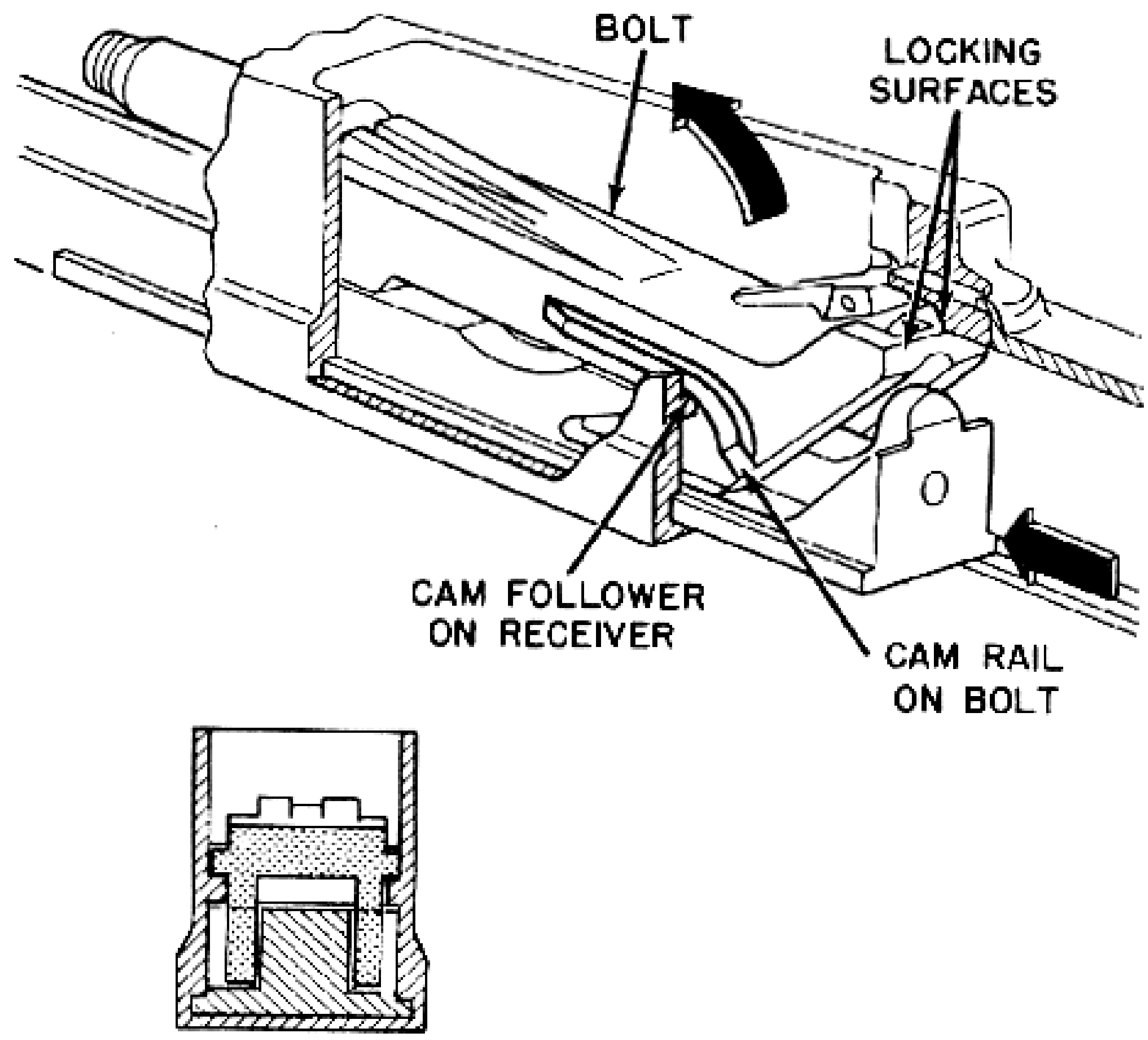


Figure 6-40. Lug on Receiver Cams Breech Block Up at a Predetermined Rate.

E. Locking Block

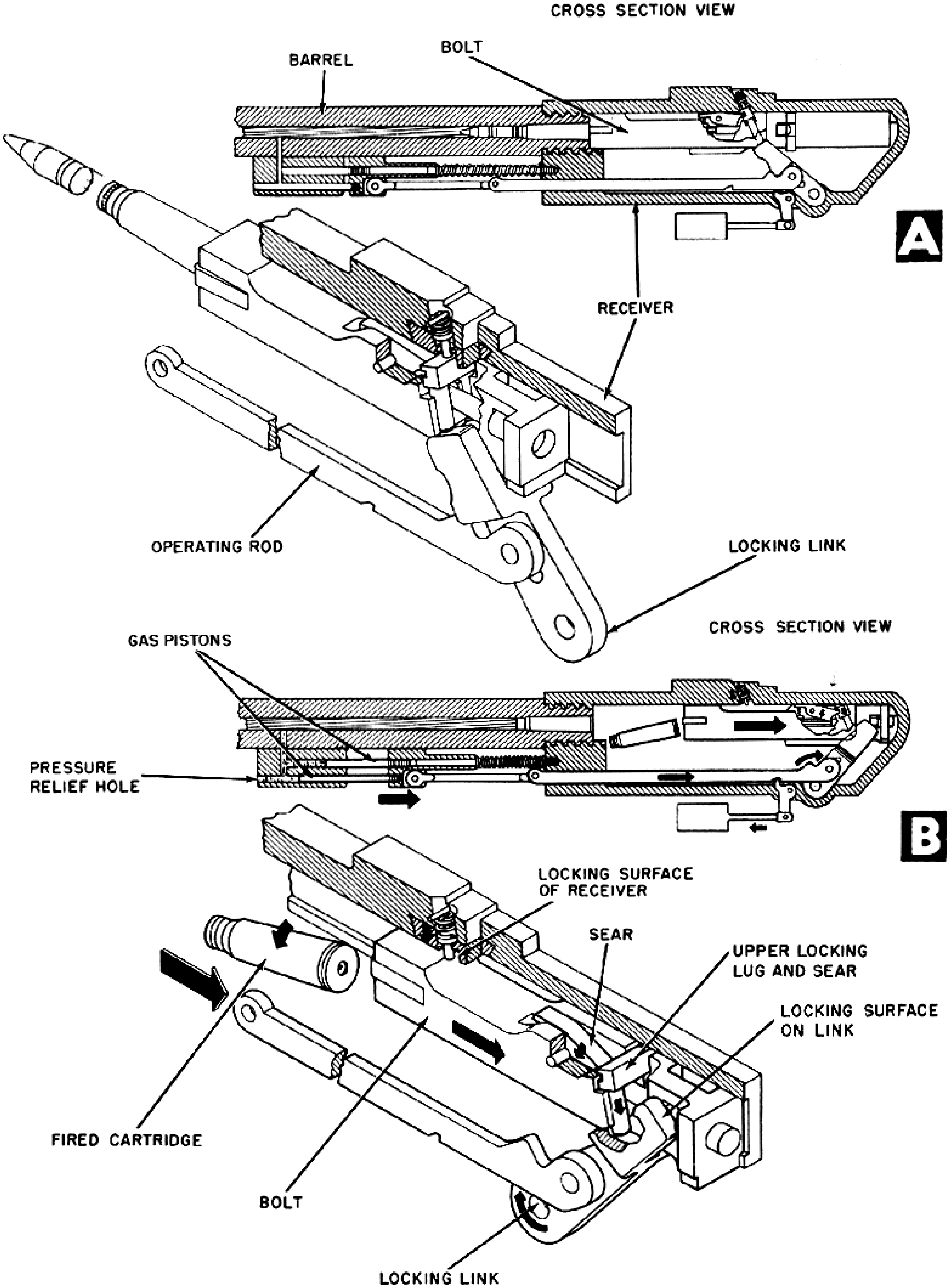


Figure 6–41. Spring Pressure Unlocks Locking Lug When Link Support Is Removed.

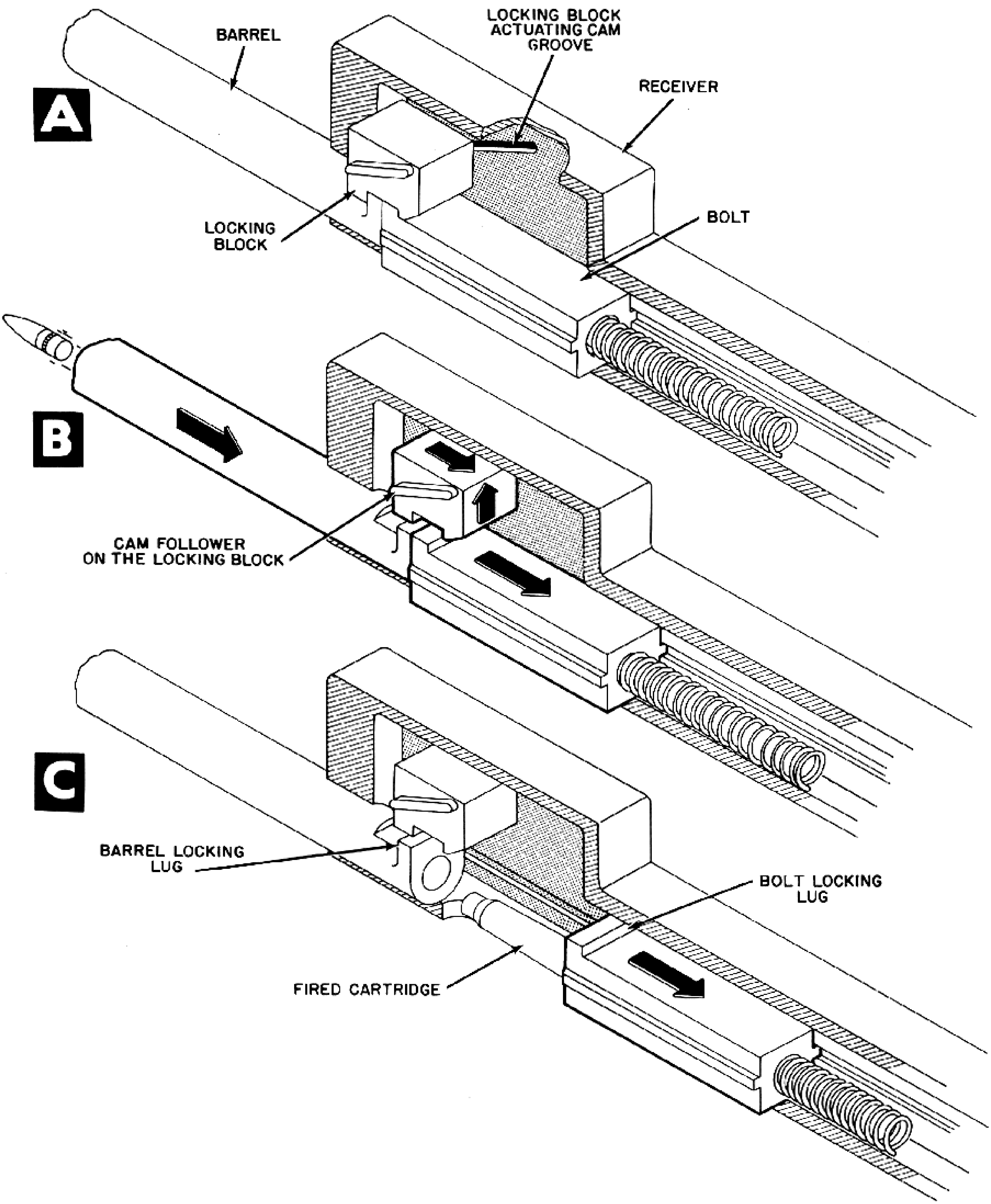


Figure 6–42. Locking Block Is Cammed Free by Grooves in Receiver as Gun Recoils.

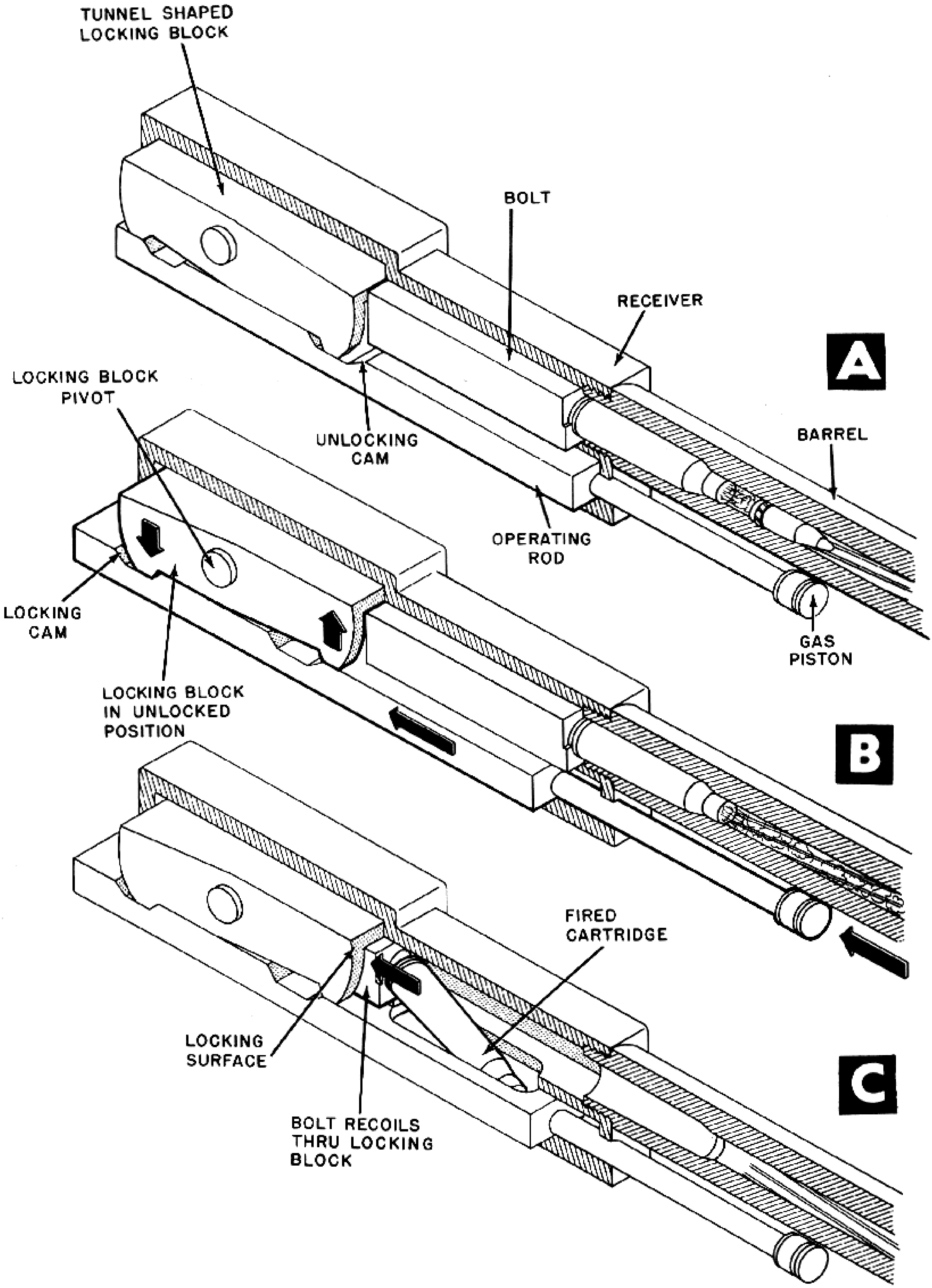


Figure 6–43. Operating Rod Cams Pivoted Locking Block To Unlock Bolt.

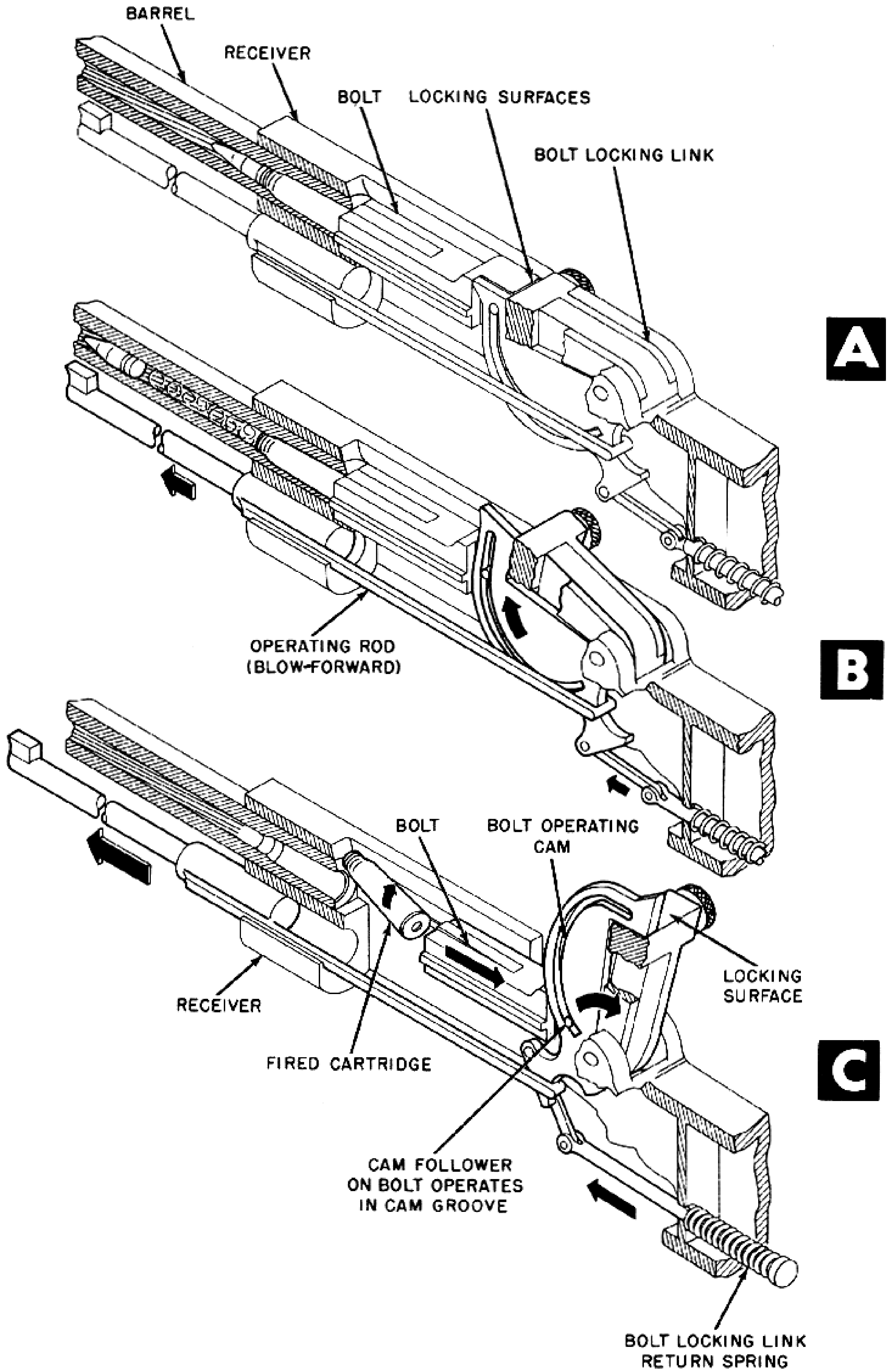


Figure 6–44. Operating Rod Lifts Locking Link Free of Bolt.

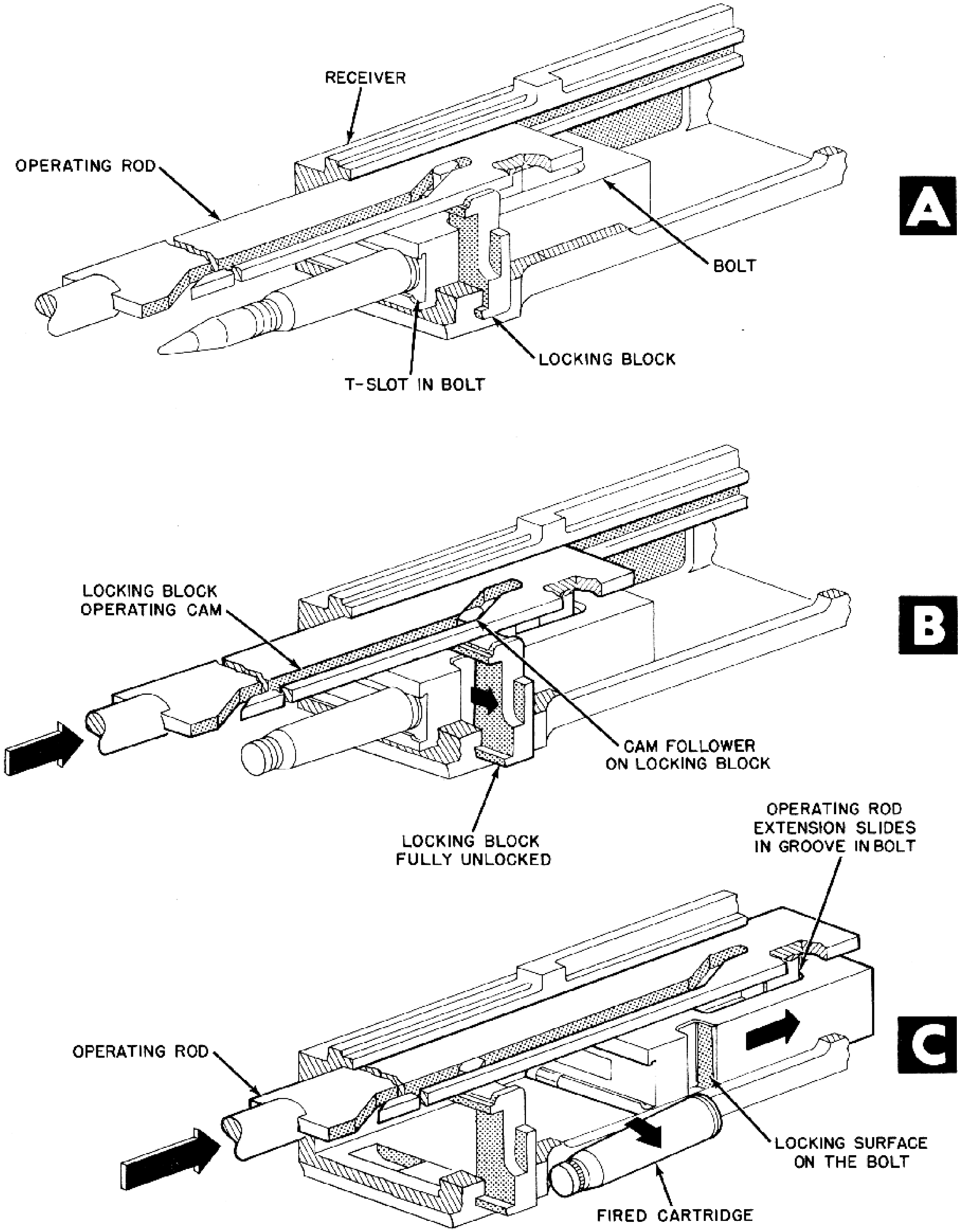


Figure 6–45. Cam Grooved Operating Rod Moves Locking Block Free of Bolt.

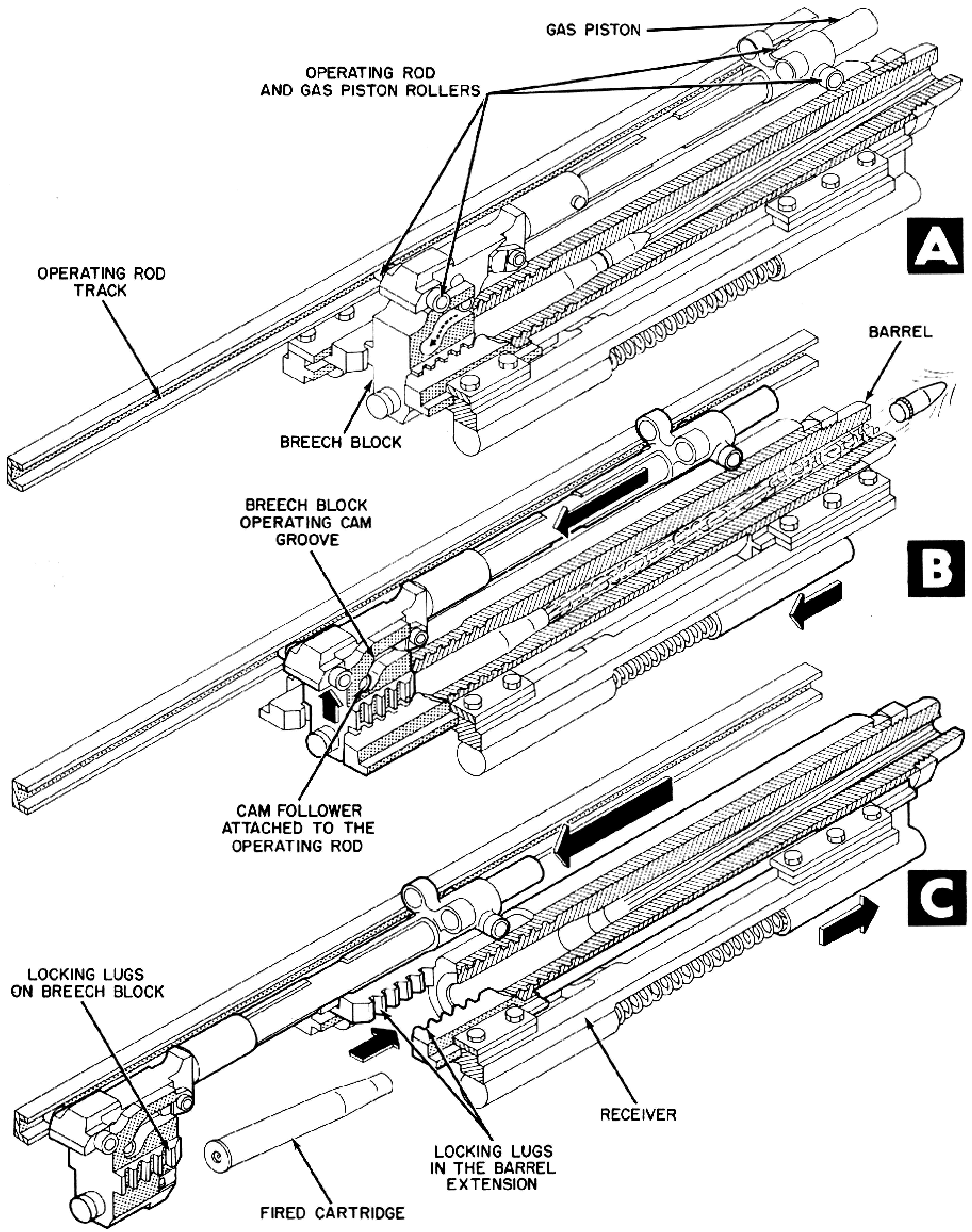


Figure 6-46. Operating Rod Cams Breech Block Free of Barrel Extension.

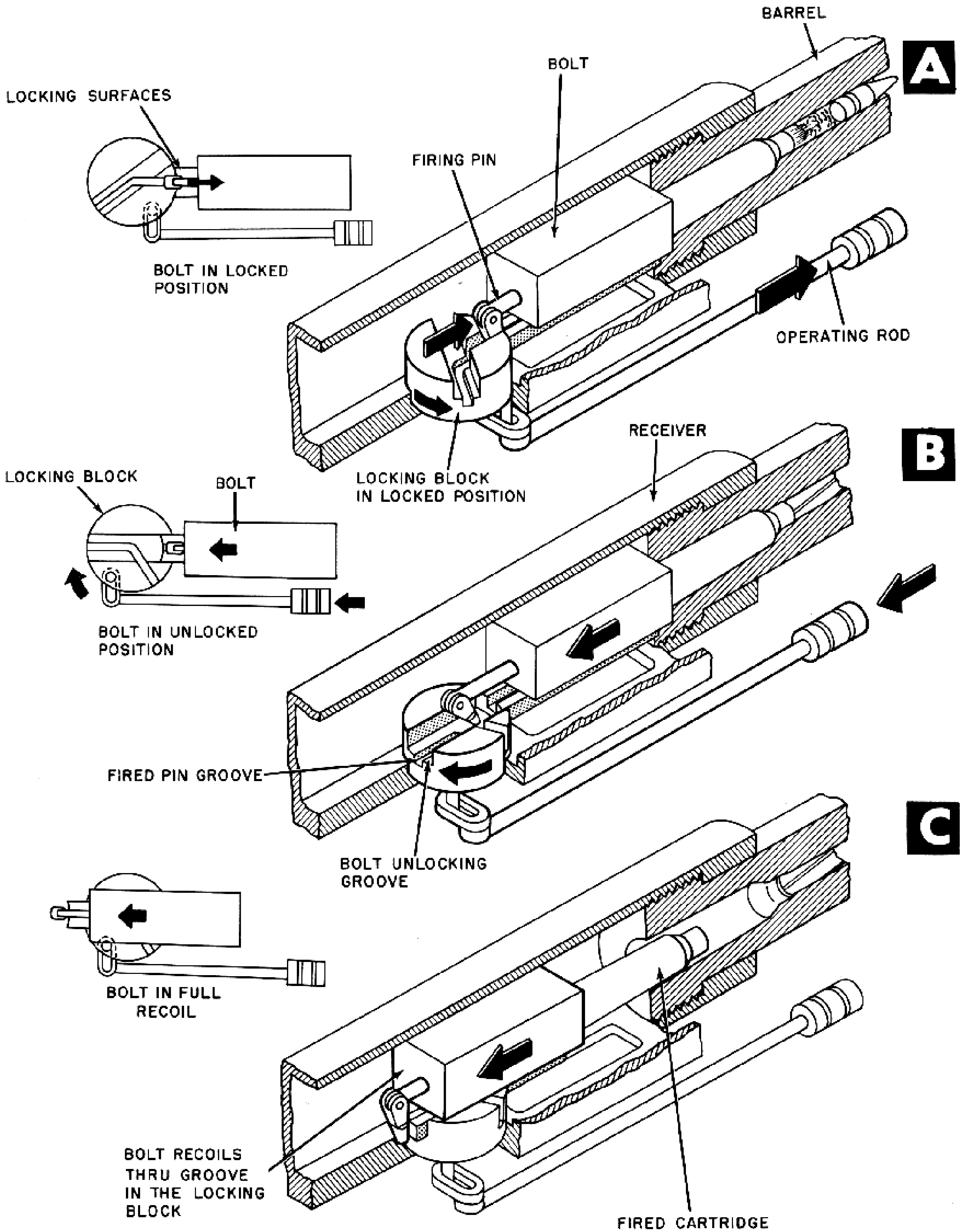


Figure 6-47. Gas Piston Rotates Locking Block to Unlocked Position.

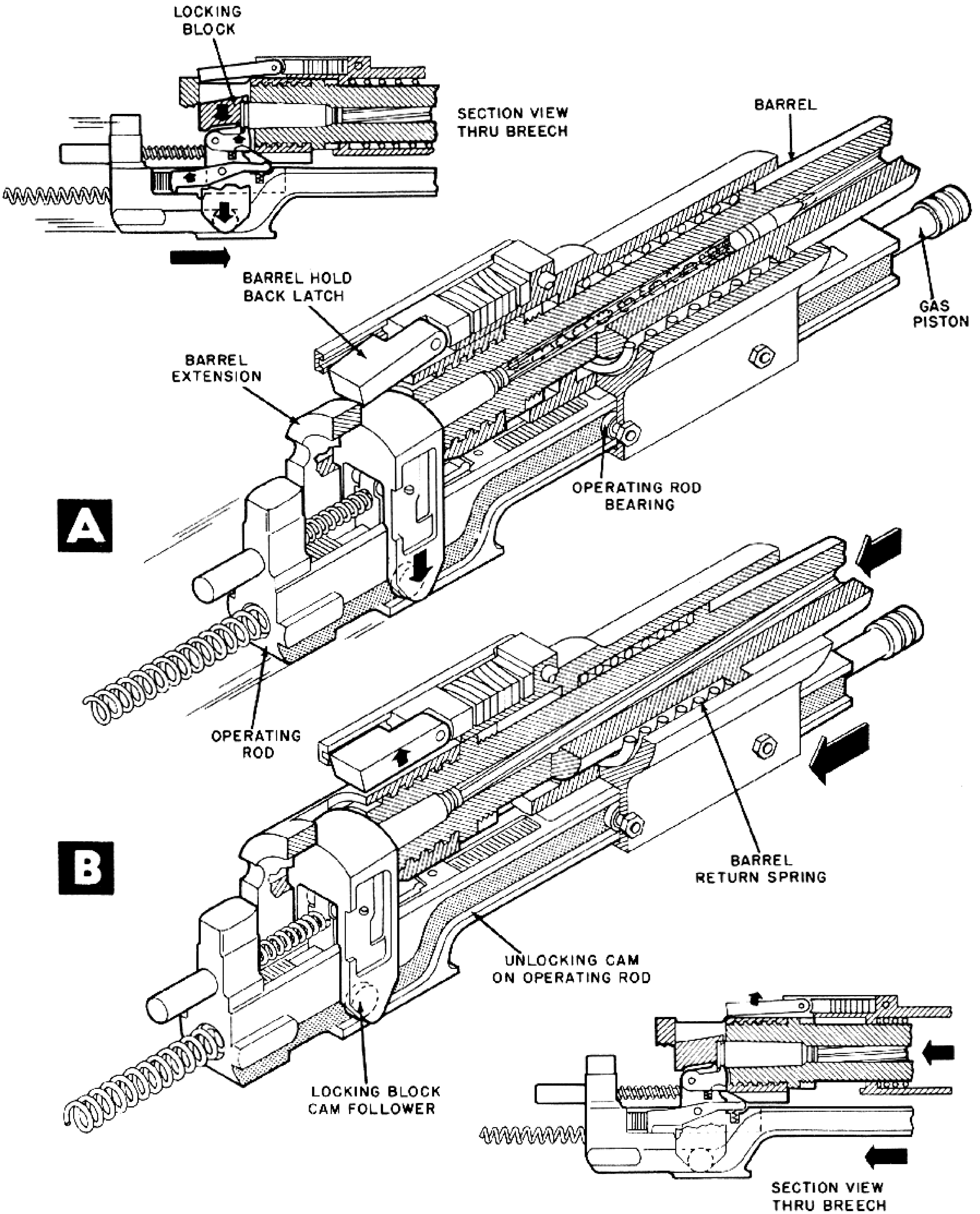
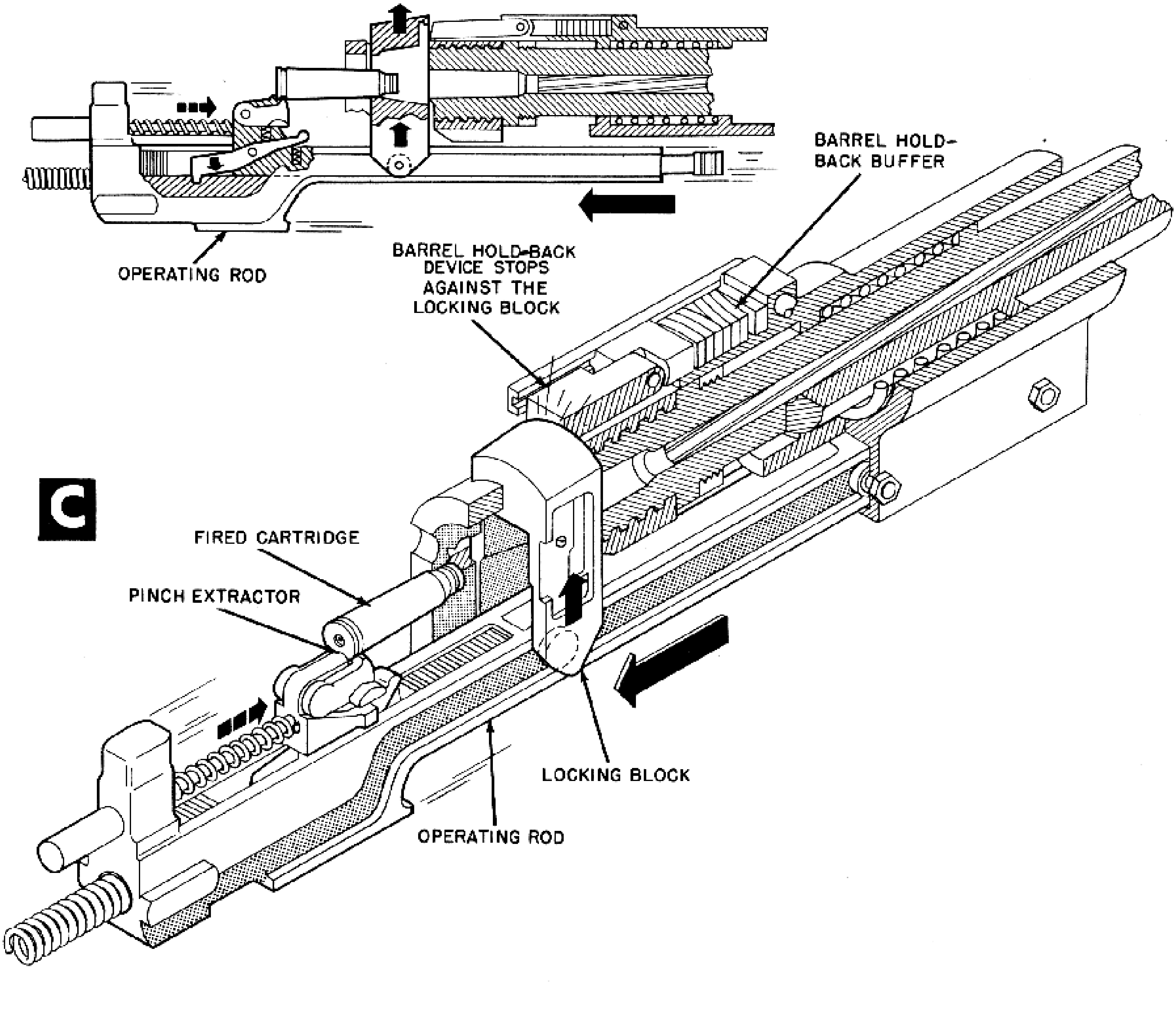


Figure 6–48. Cam Groove on Operating



Rod Moves Locking Block Free of Barrel Face.

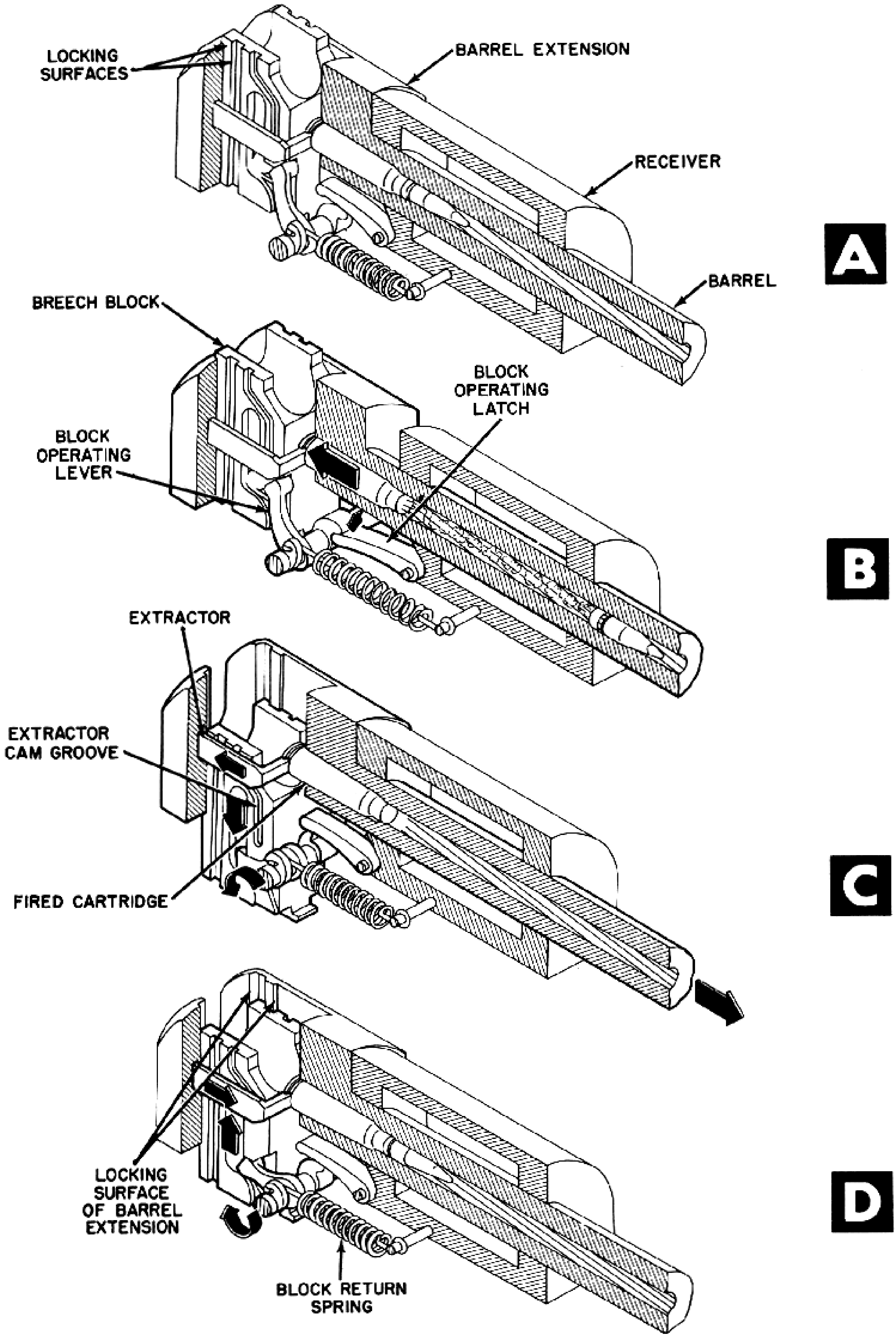


Figure 6–49. Block Operating Latch Opens Breech Block on Counter-Recoil.

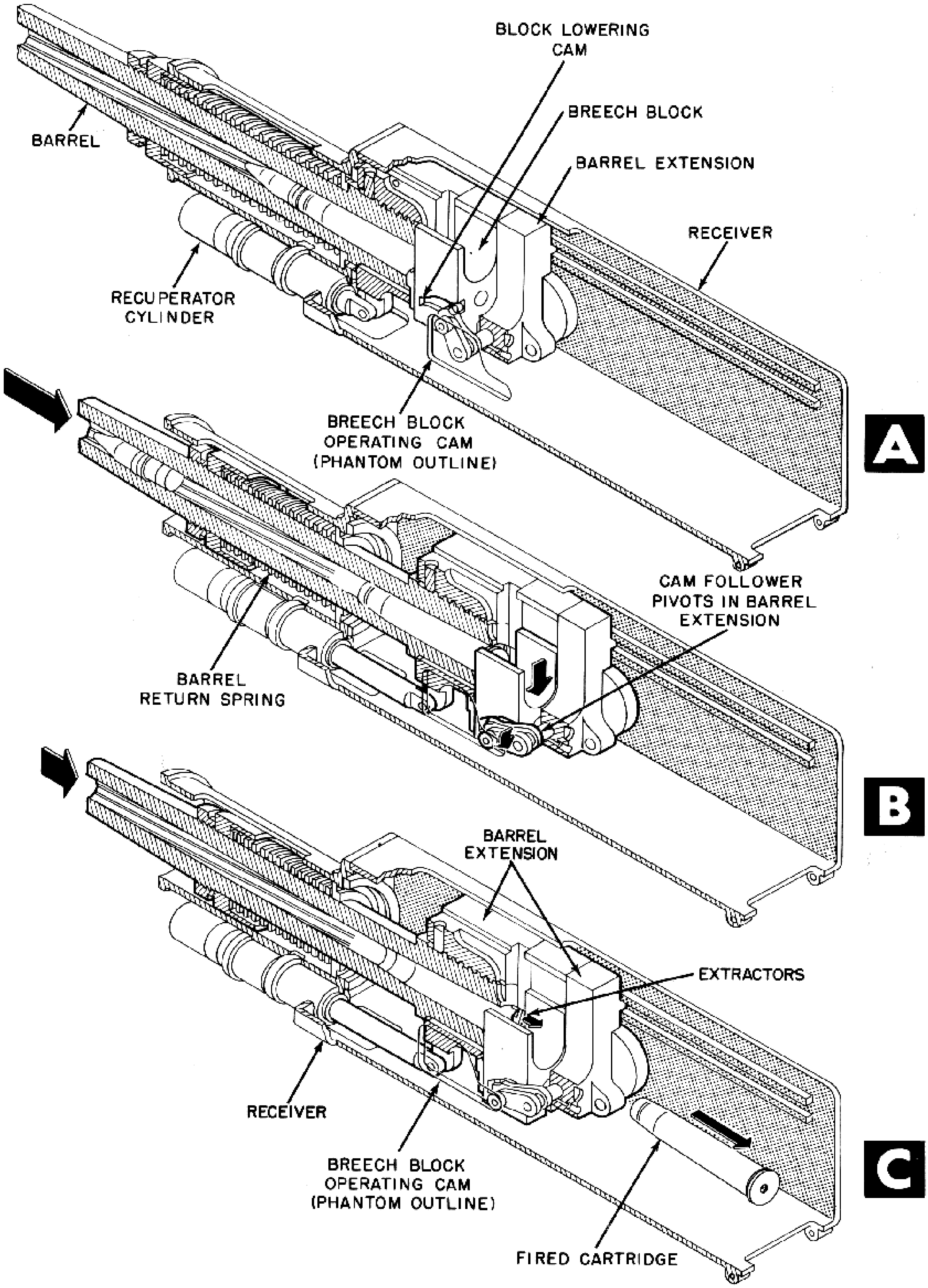


Figure 6–50. Breech Block Operating Cam Opens Breech Block During Recoil.

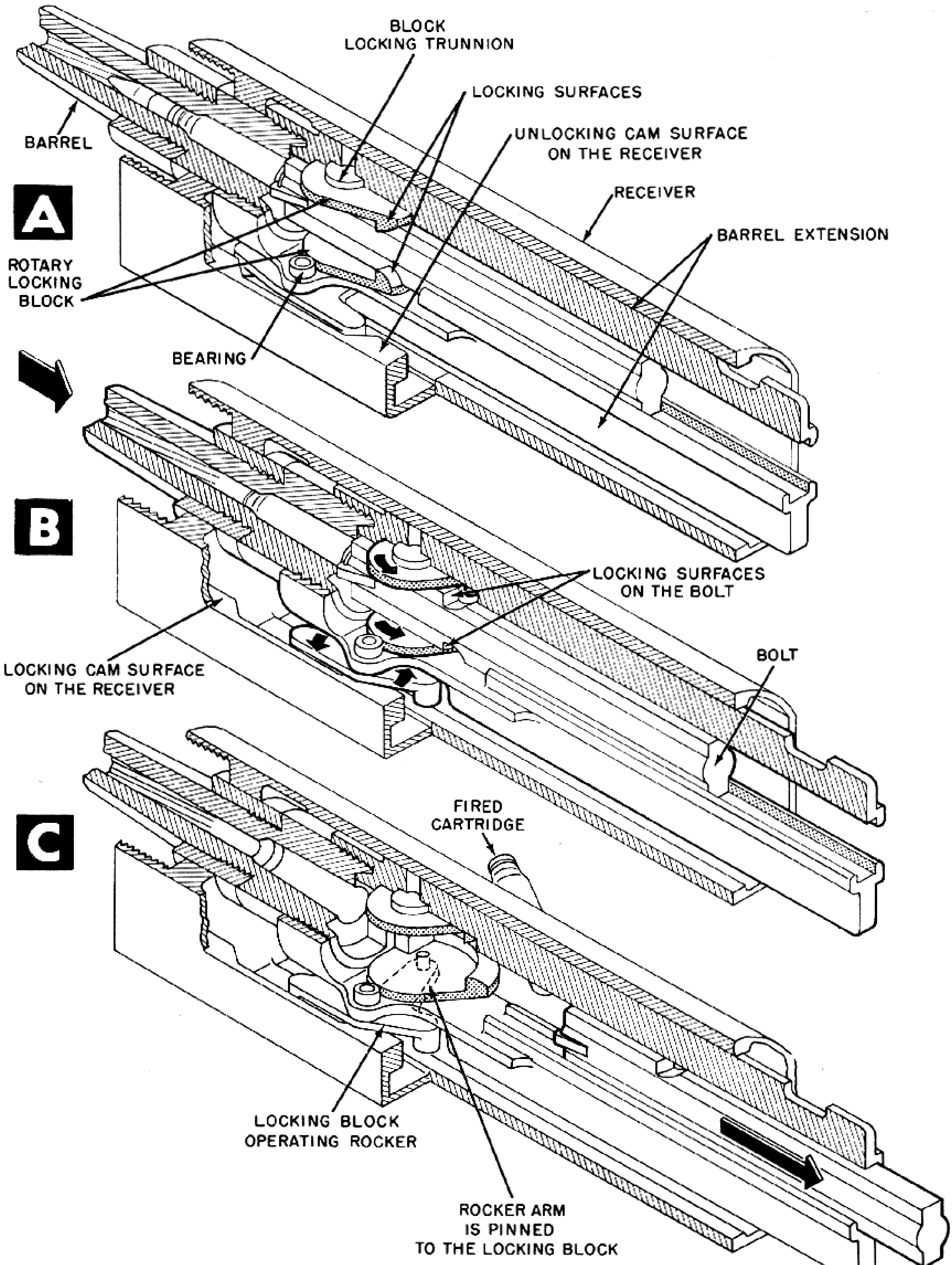


Figure 6–51. Bolt Is Unlocked by Action of Rotary Locking Block.

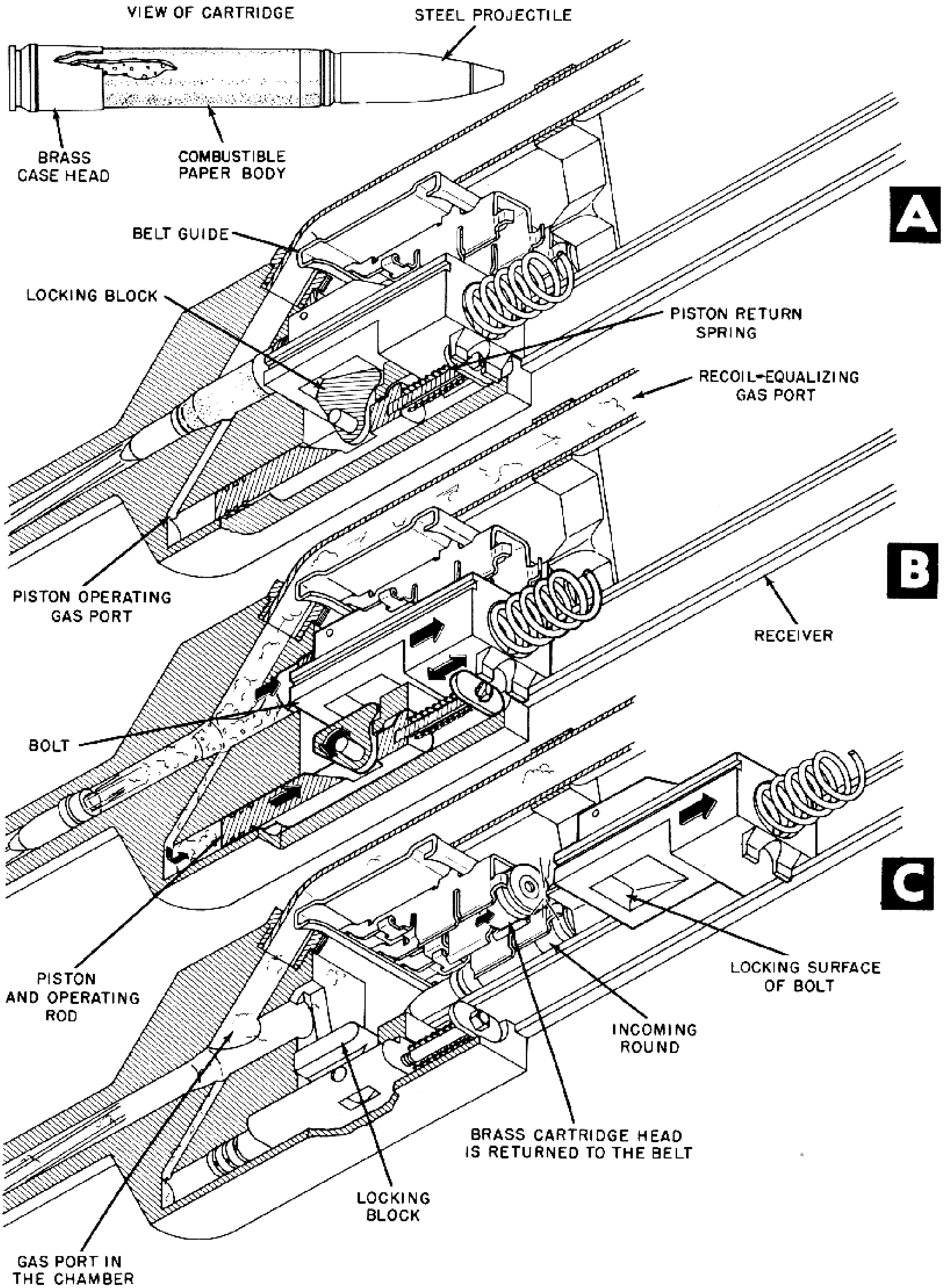


Figure 6–52. Gas Piston Cams Locking Block Free of the Bolt.

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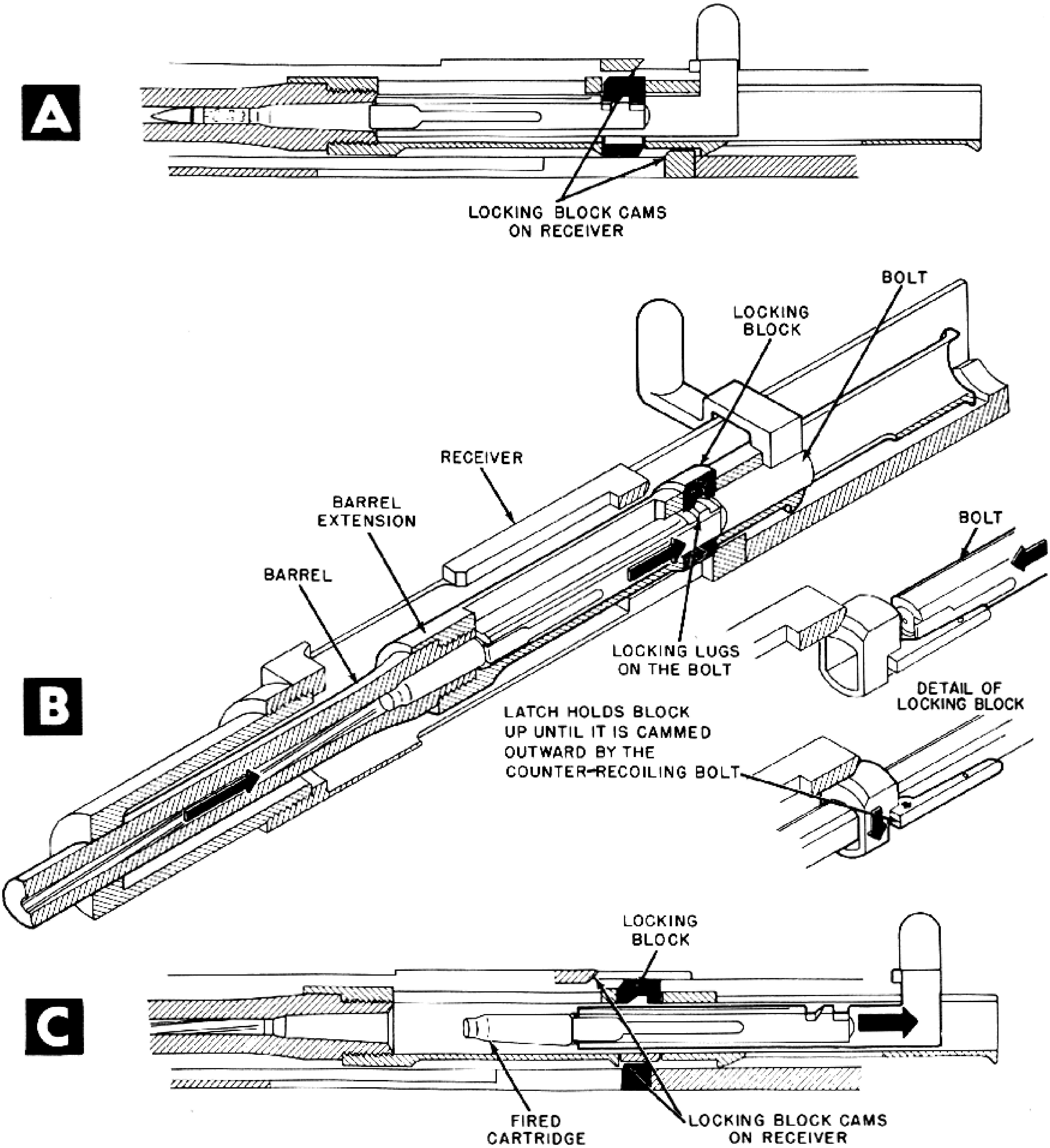


Figure 6–53. Recoiling Barrel Extension Cams Locking Block Free of the Bolt.

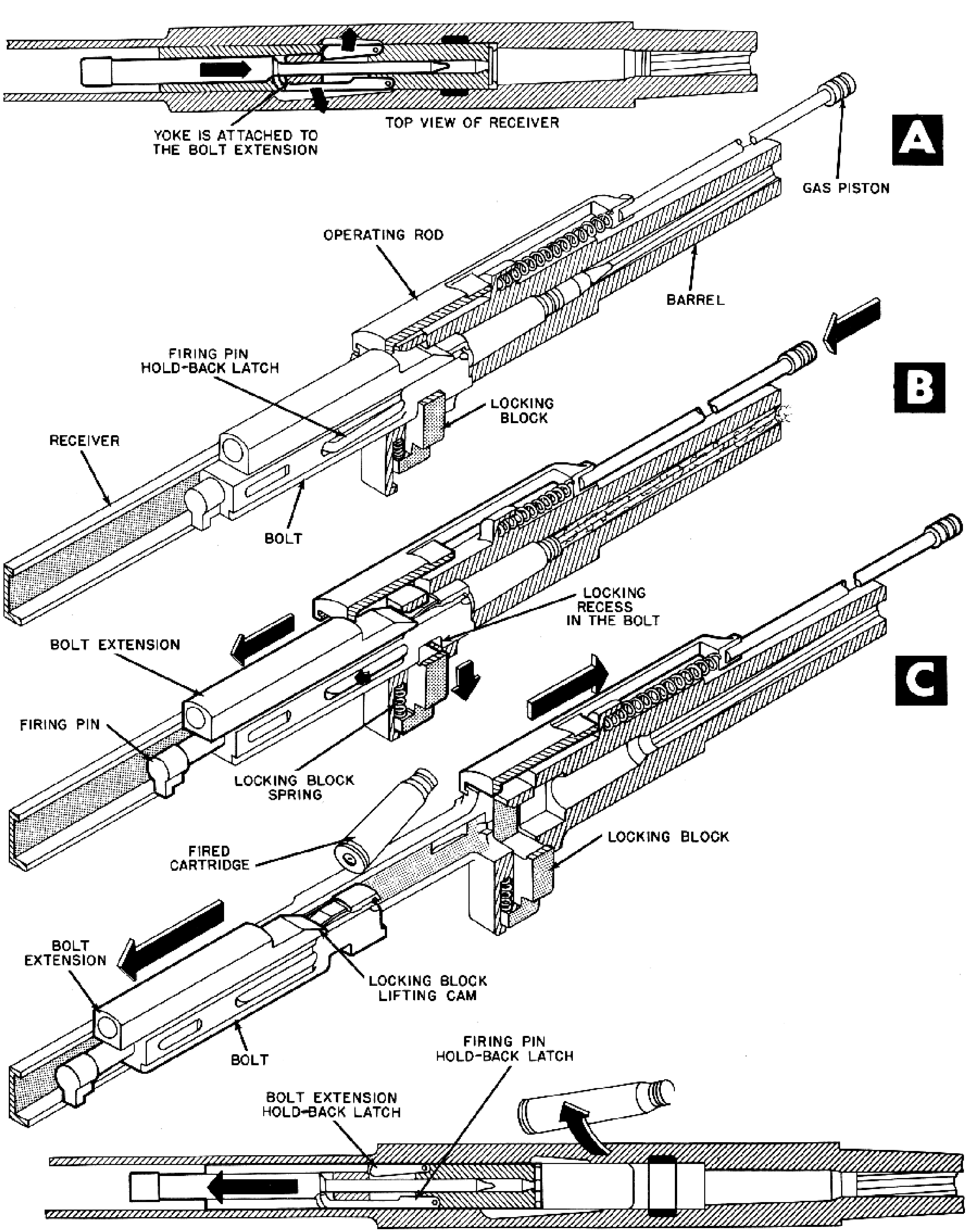


Figure 6–54. After Bolt Extension Recoils, Spring Forces Locking Block Free of the Bolt.

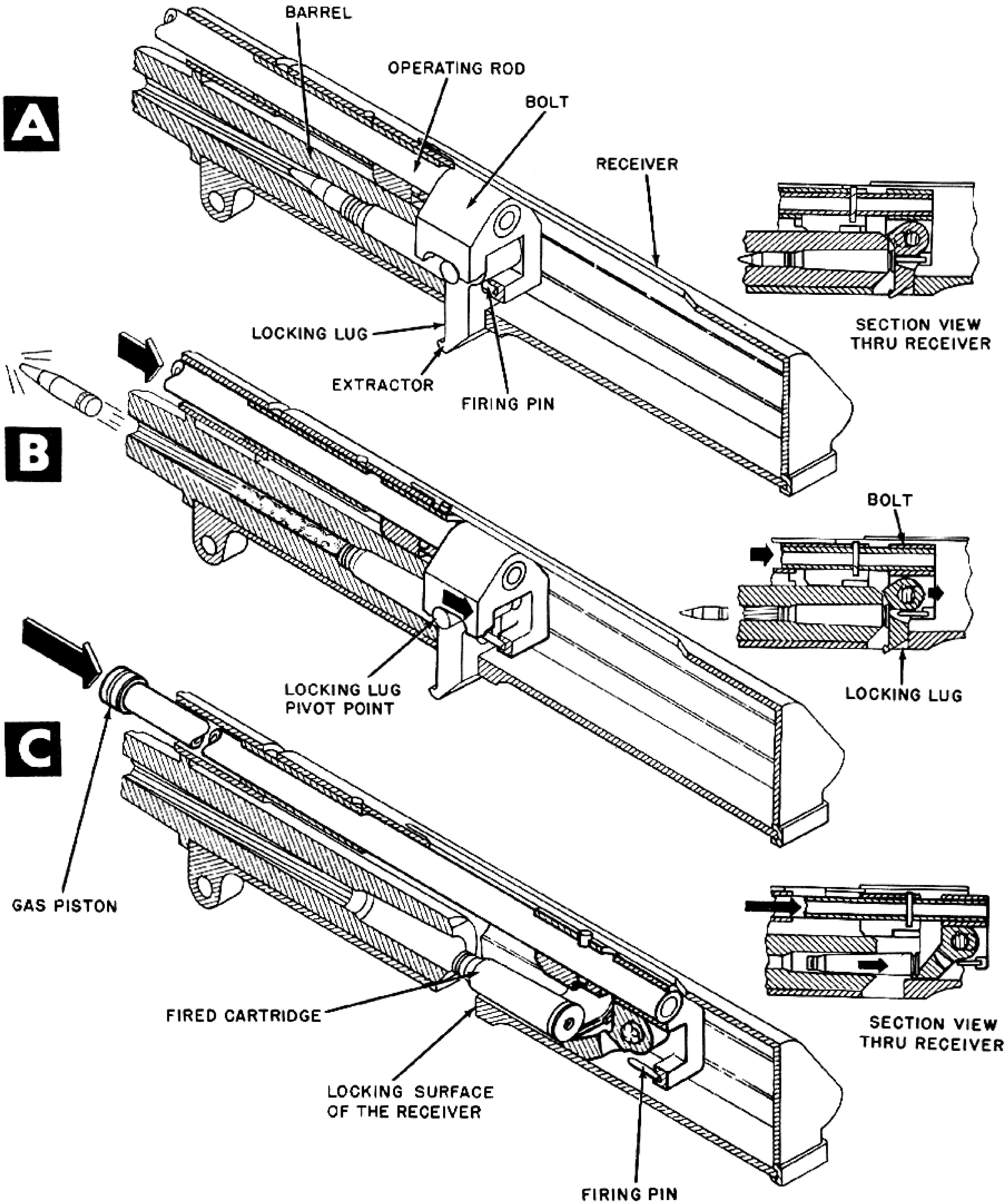


Figure 6-55. Operating Rod Rotates Locking Lug Free of Locking Surface.

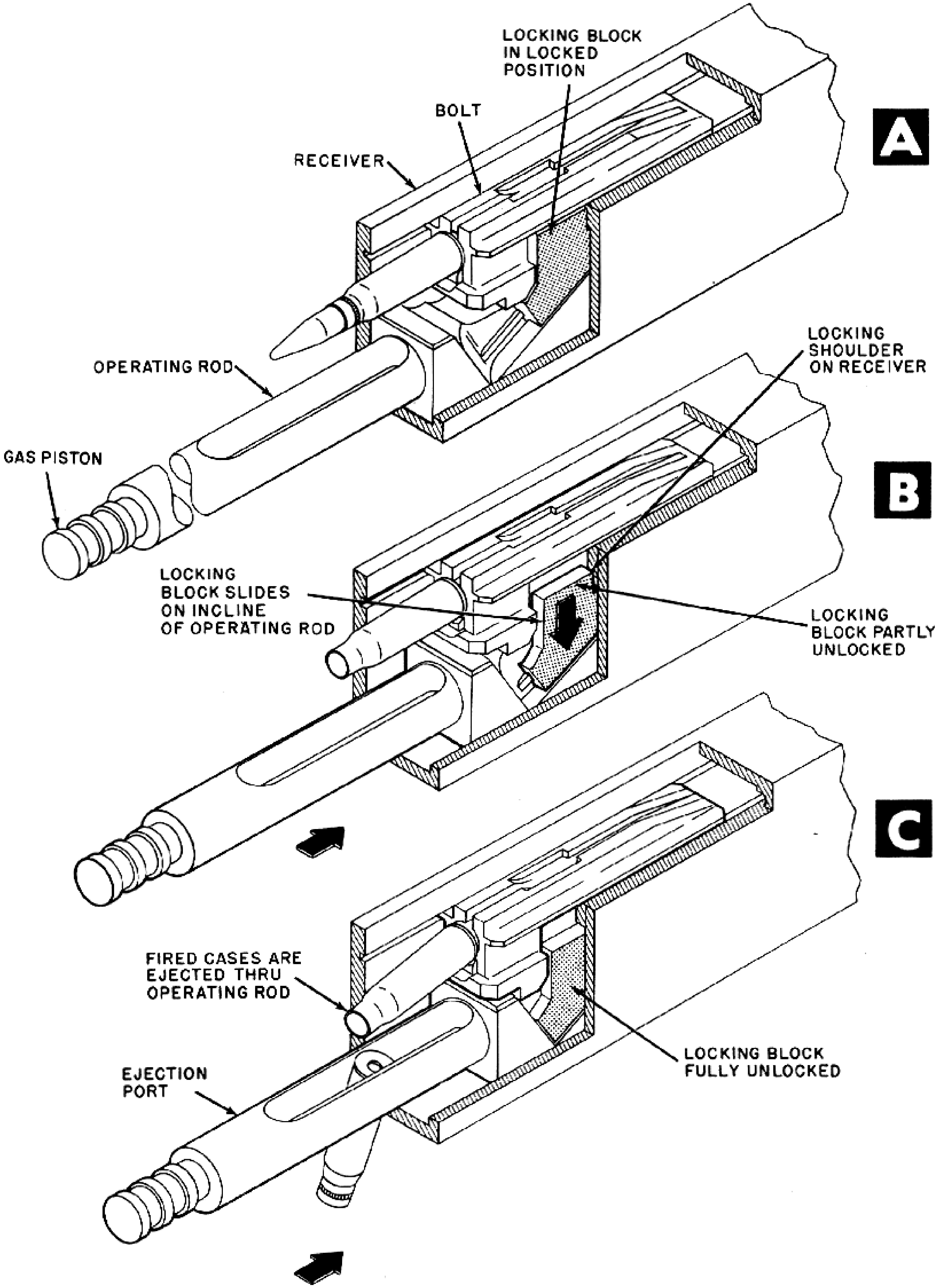


Figure 6–56. Operating Rod Cams Locking Block Free of Locking Surfaces of Receiver.

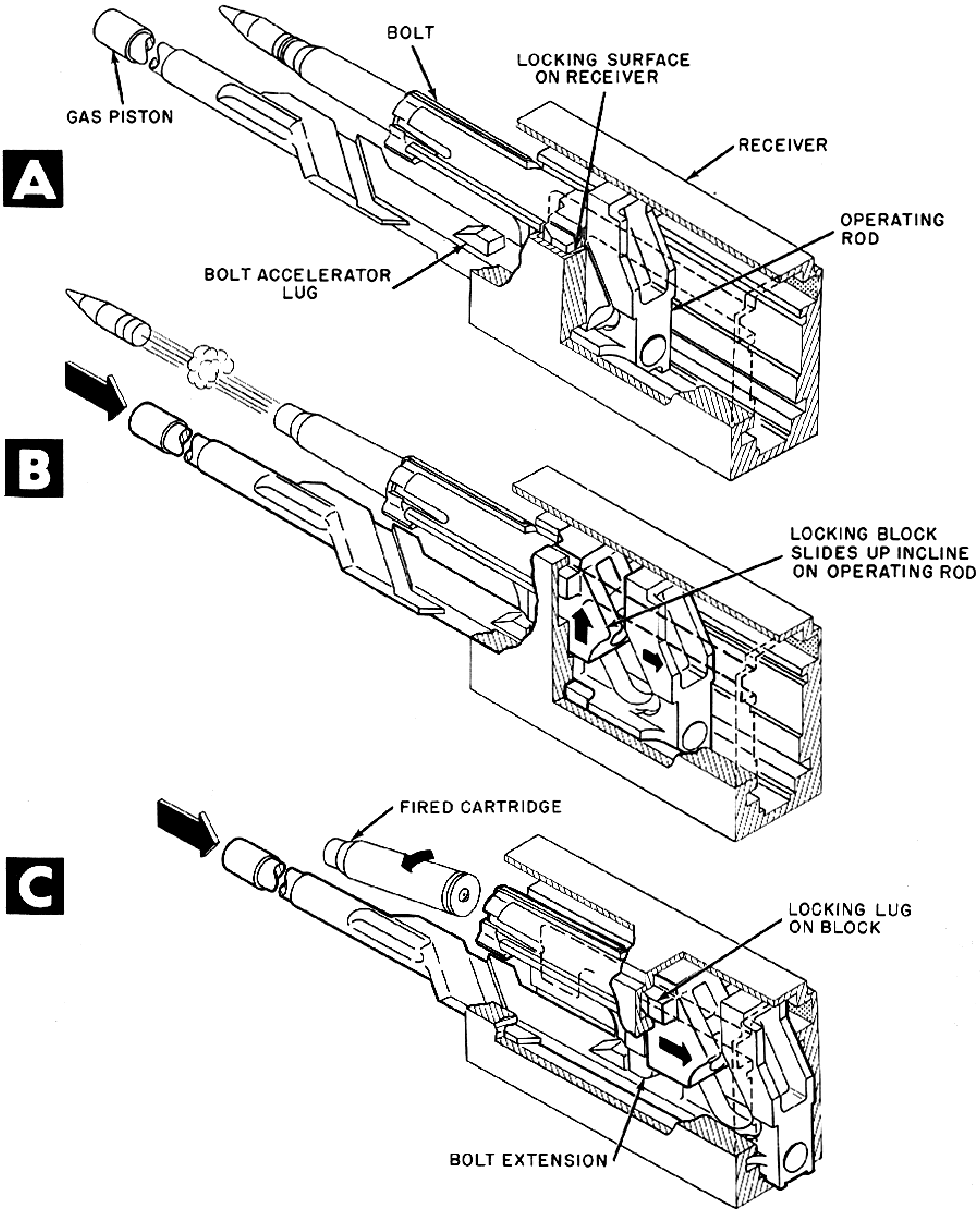


Figure 6–57. Operating Rod Cams Locking Block Free of Locking Surfaces of Receiver.

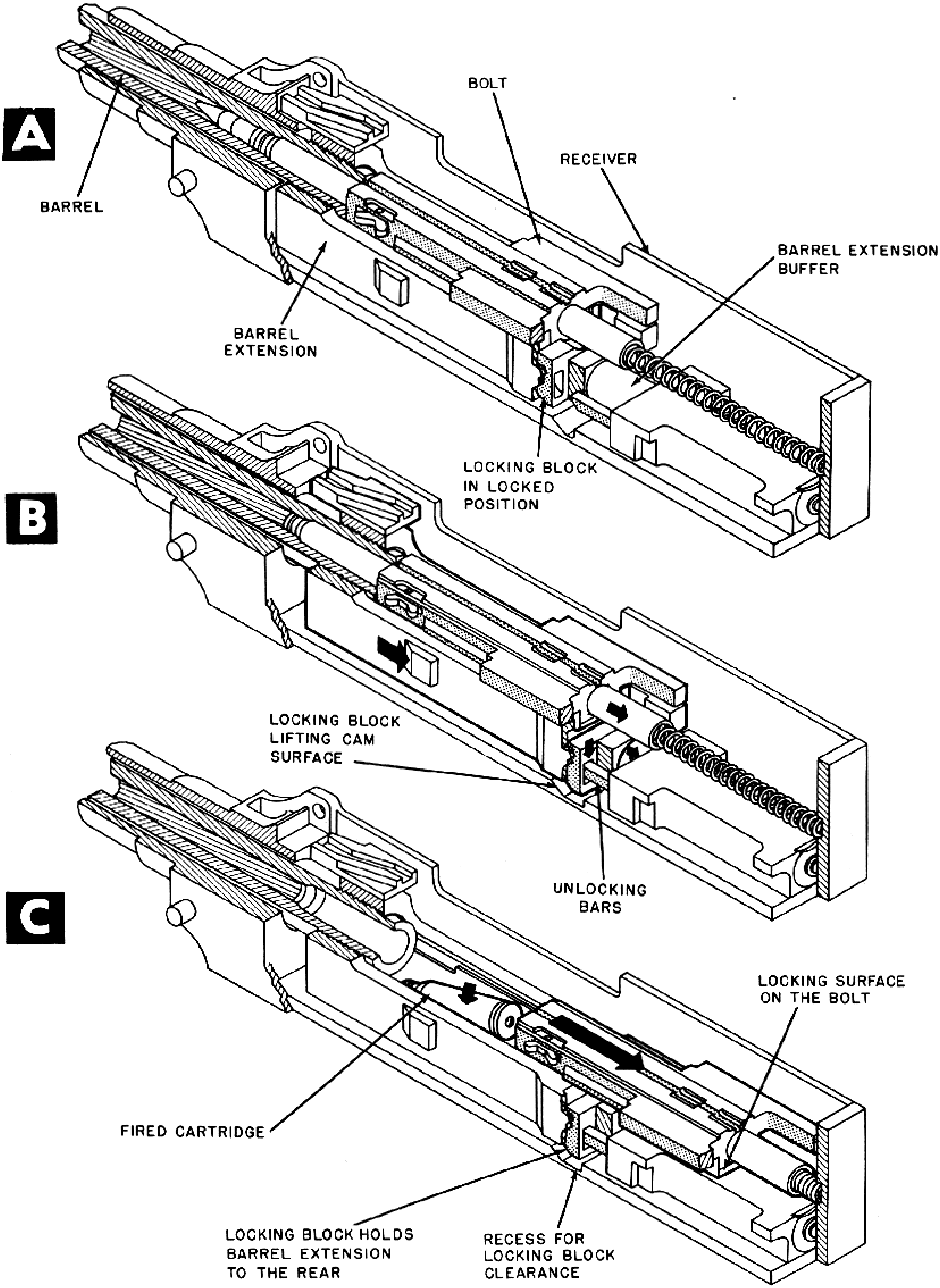


Figure 6–58. Recoiling Barrel Extension Forces Locking Block Over Unlocking Bars.

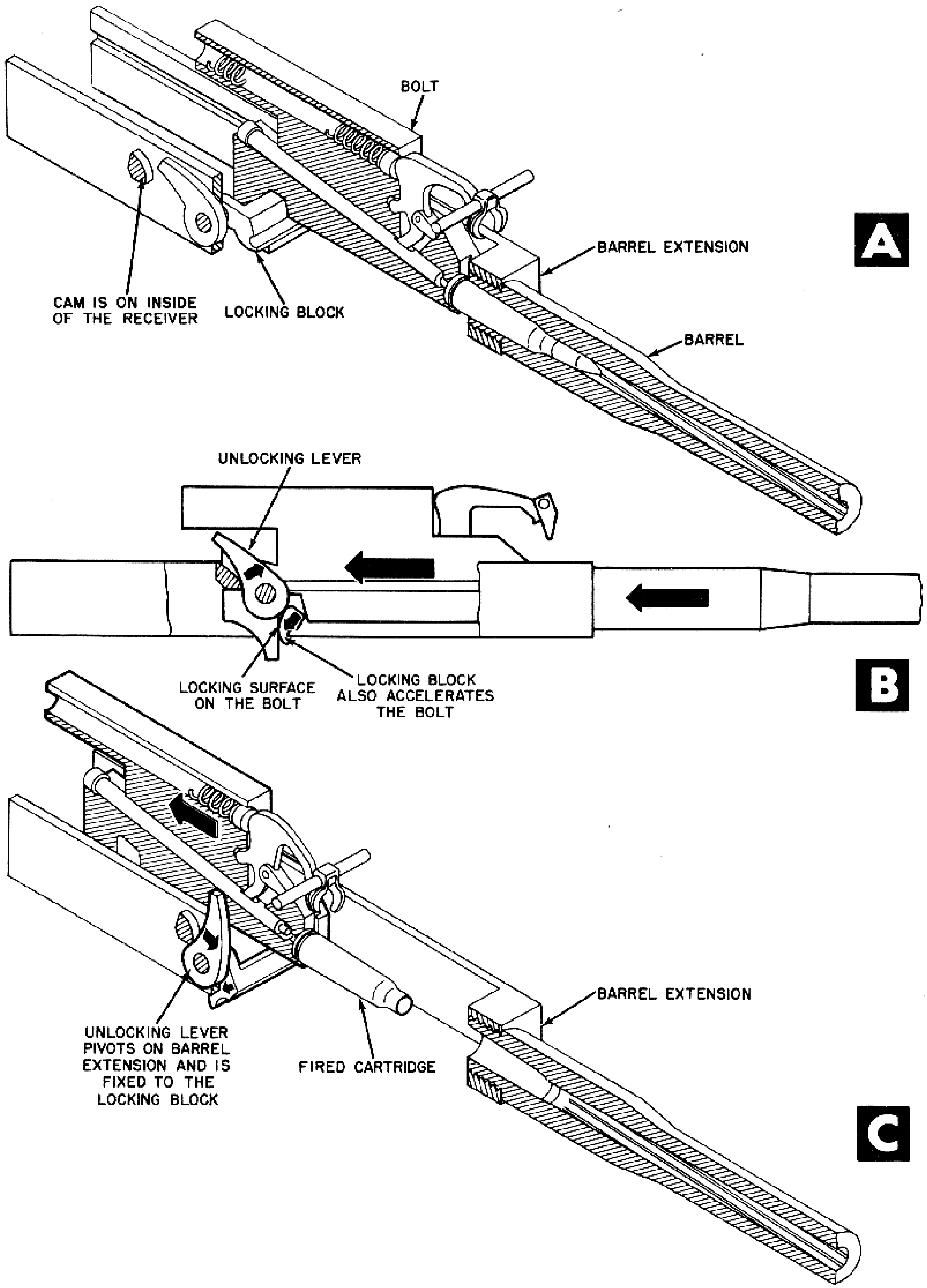


Figure 6–59. Locking Block Is Cammed Free of Bolt by Lugs on Inside of Receiver.

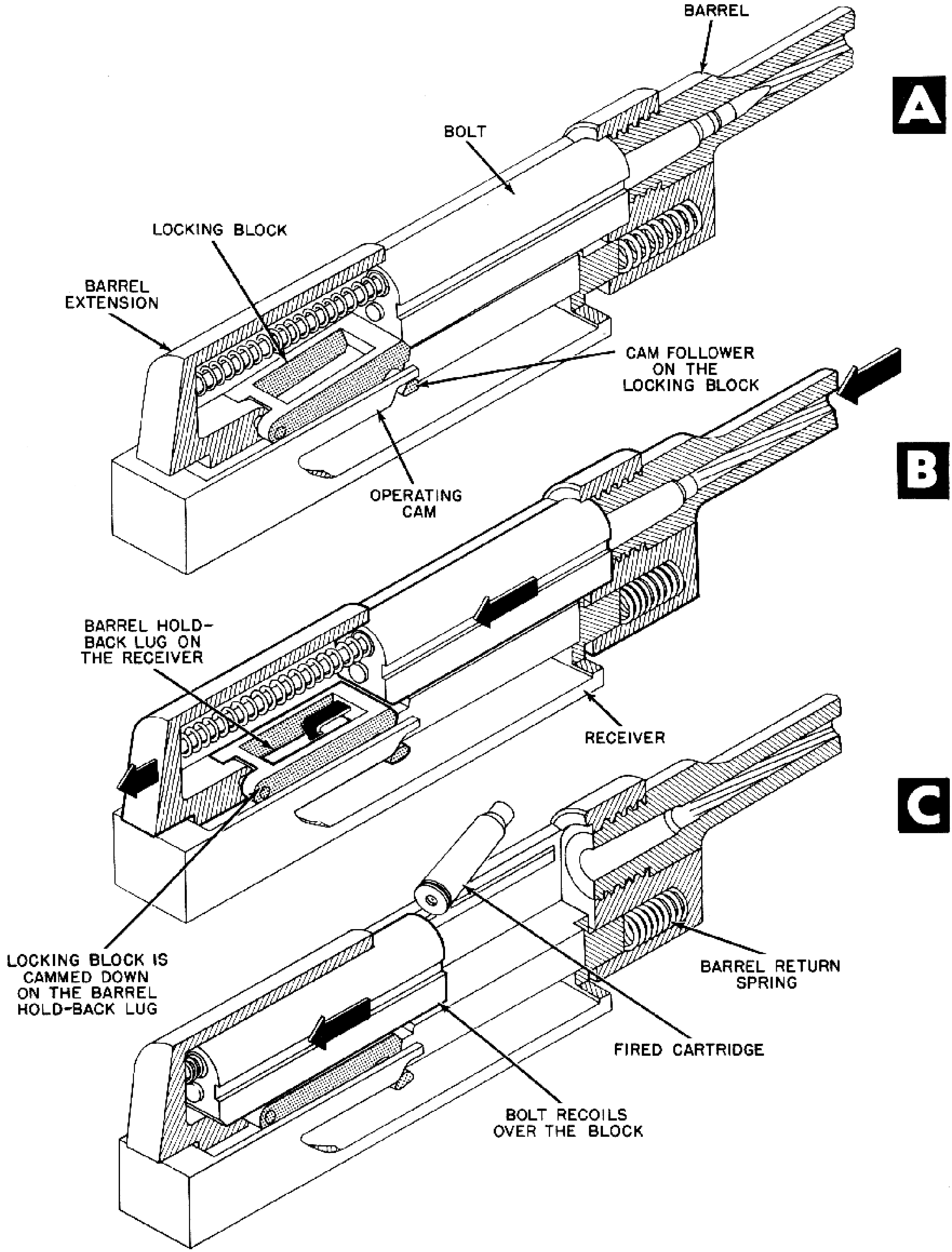


Figure 6-60. Groove in Receiver Cams Locking Block Free of Bolt.

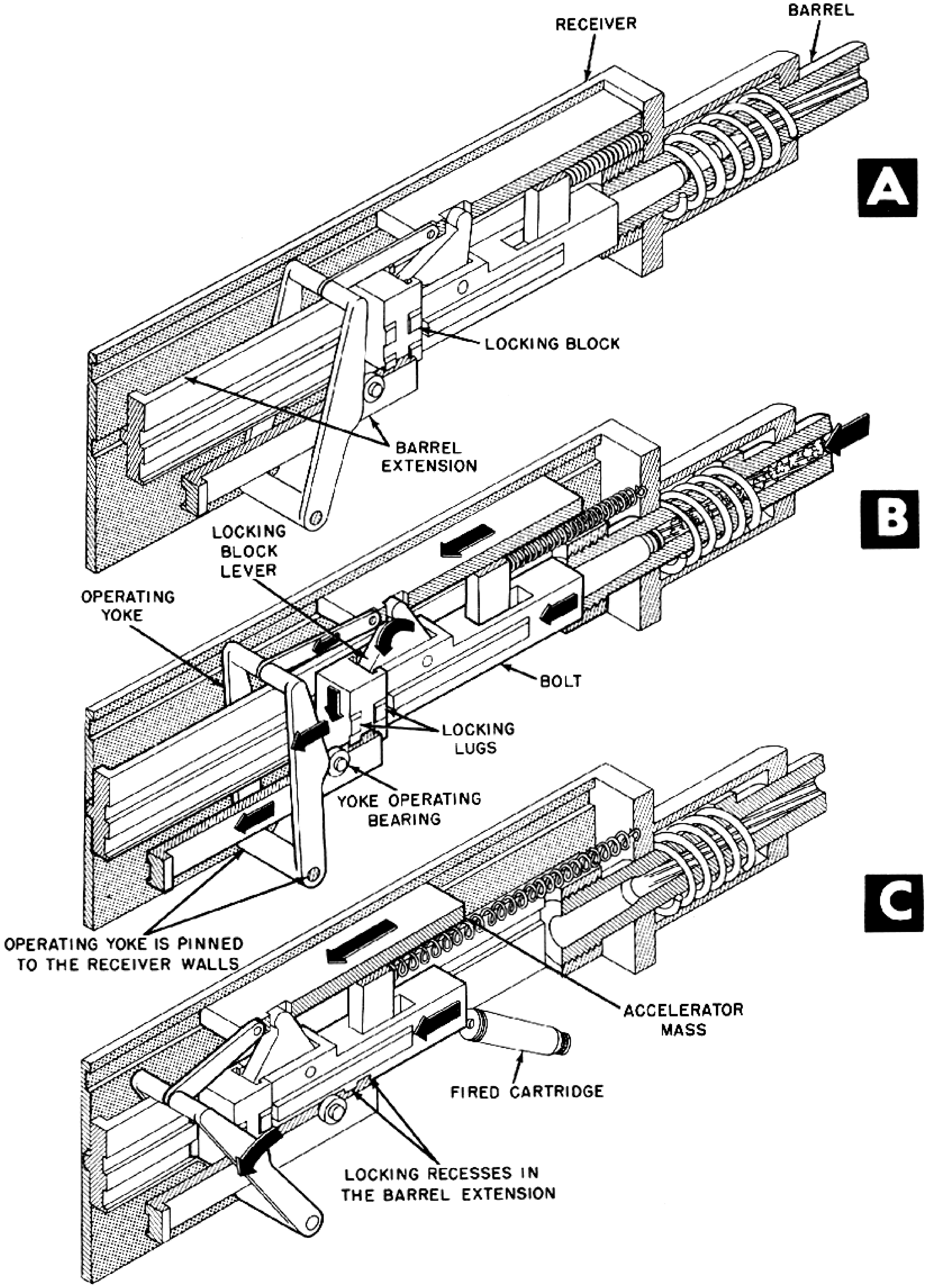


Figure 6–61. Recoiling Mass Cams Locking Block Free of Barrel Extension.

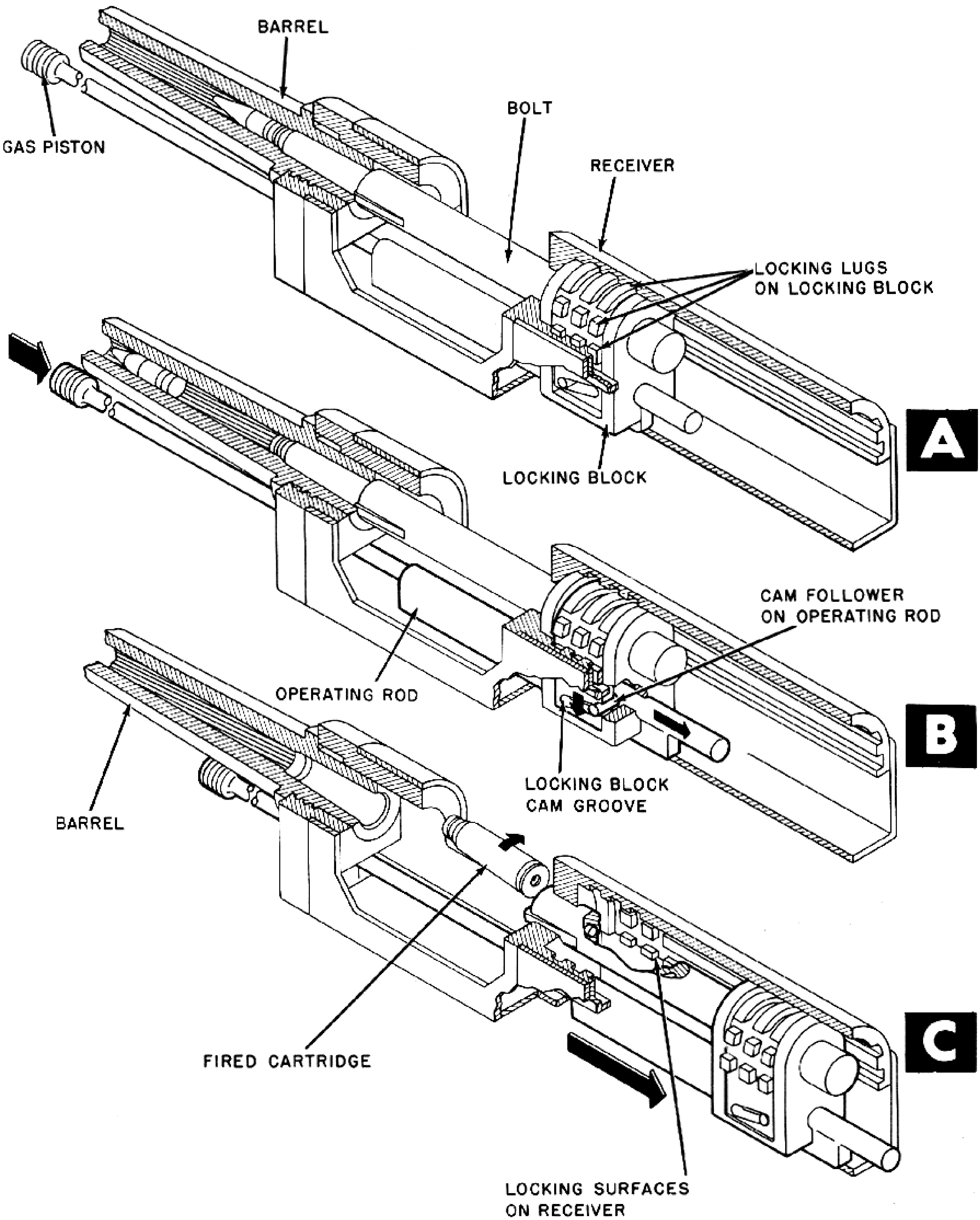


Figure 6-62. Operating Rod Cams Locking Block Free of Receiver.

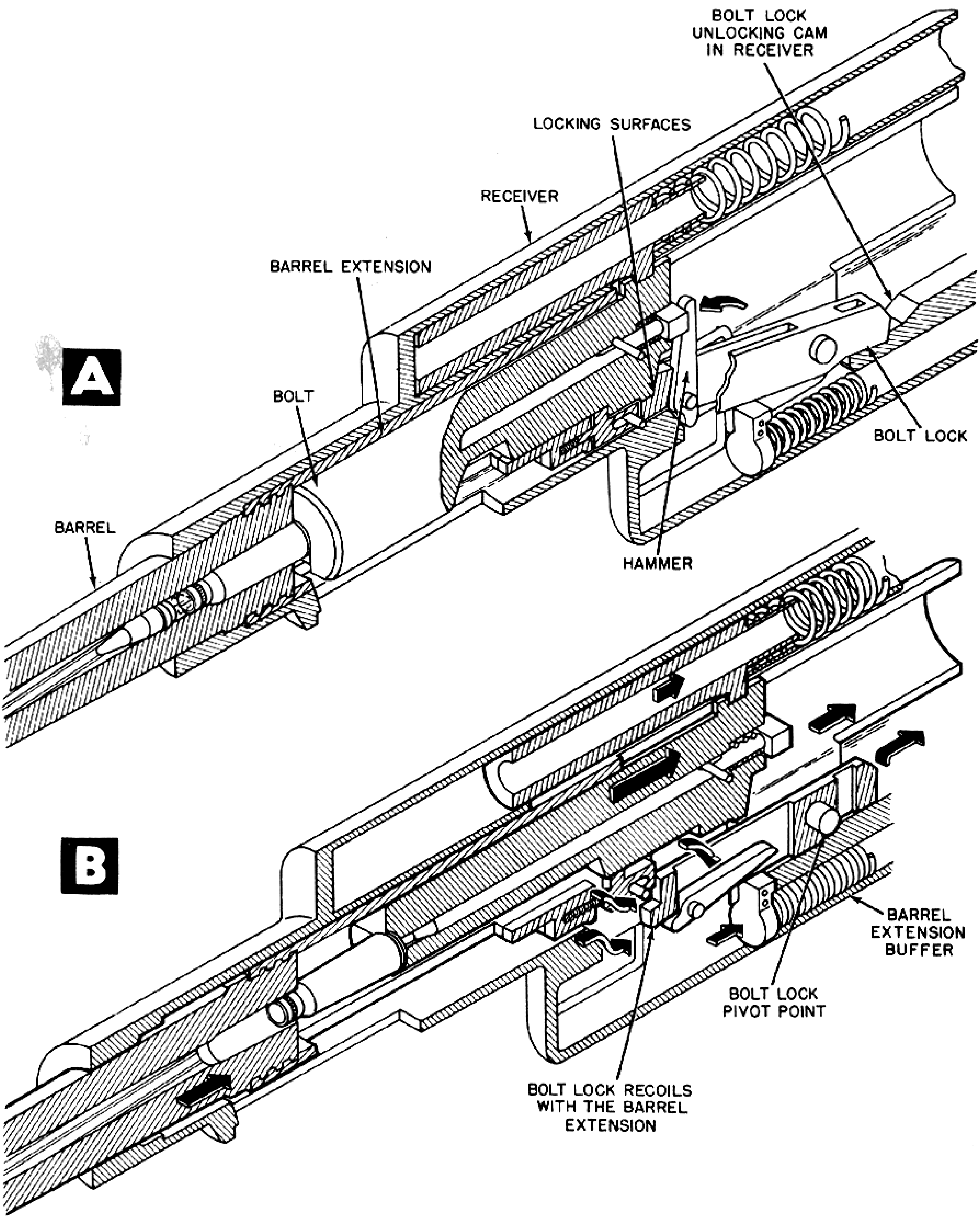
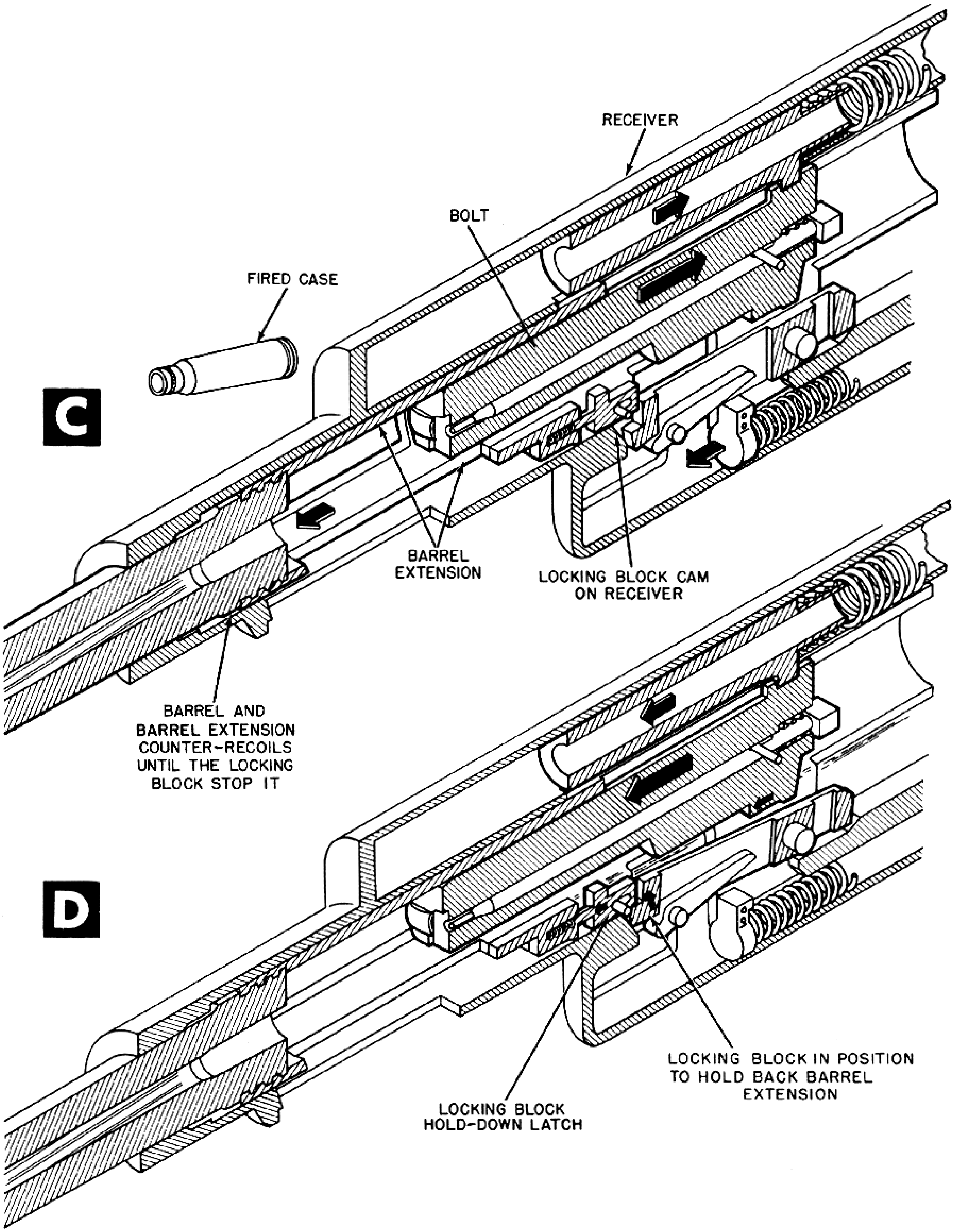


Figure 6–63. Barrel Extension Recoils, Camming



Locking Block Free of Bolt.

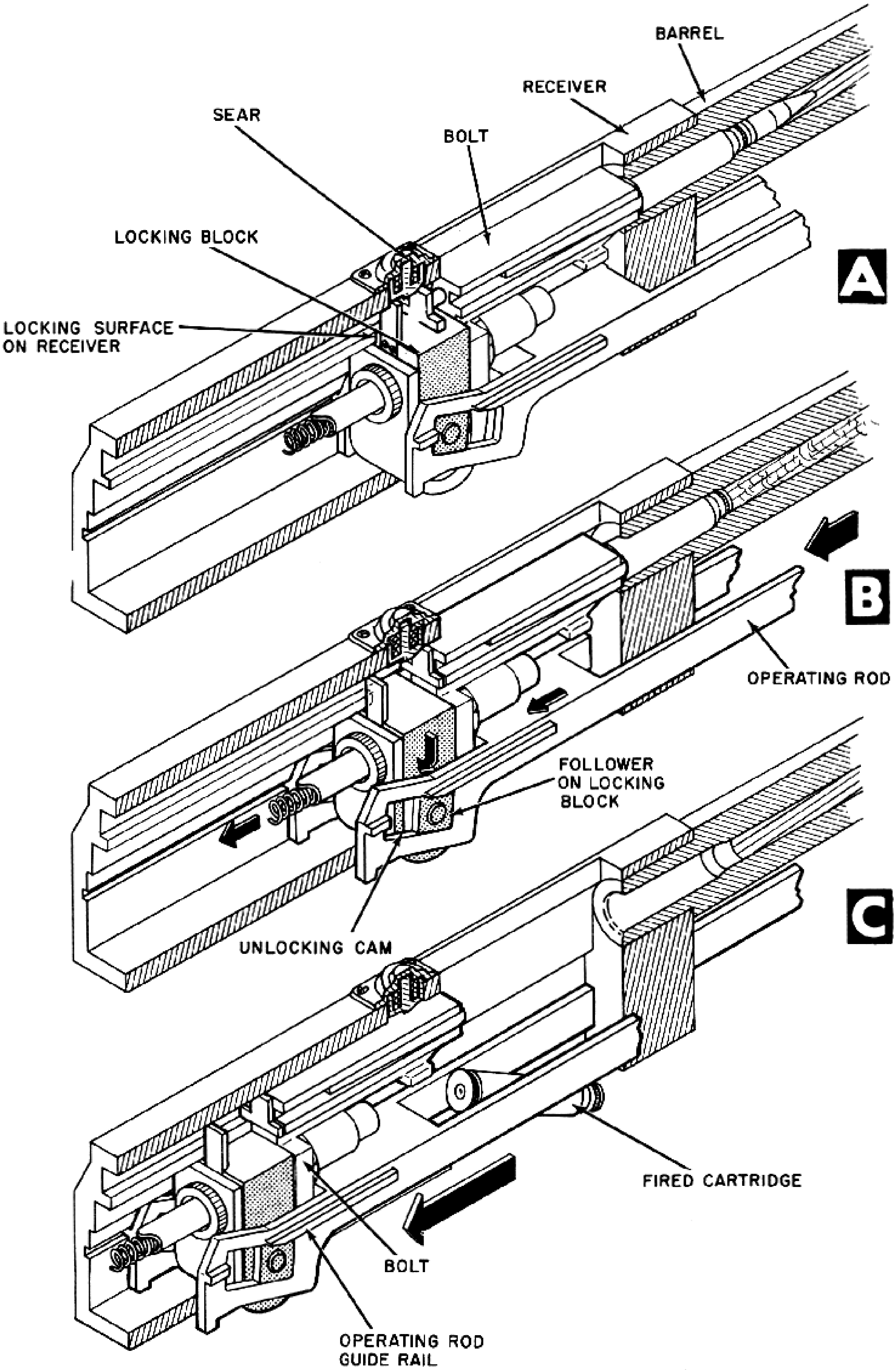


Figure 6–64. Operating Rod Cams Locking Block Free of Receiver.

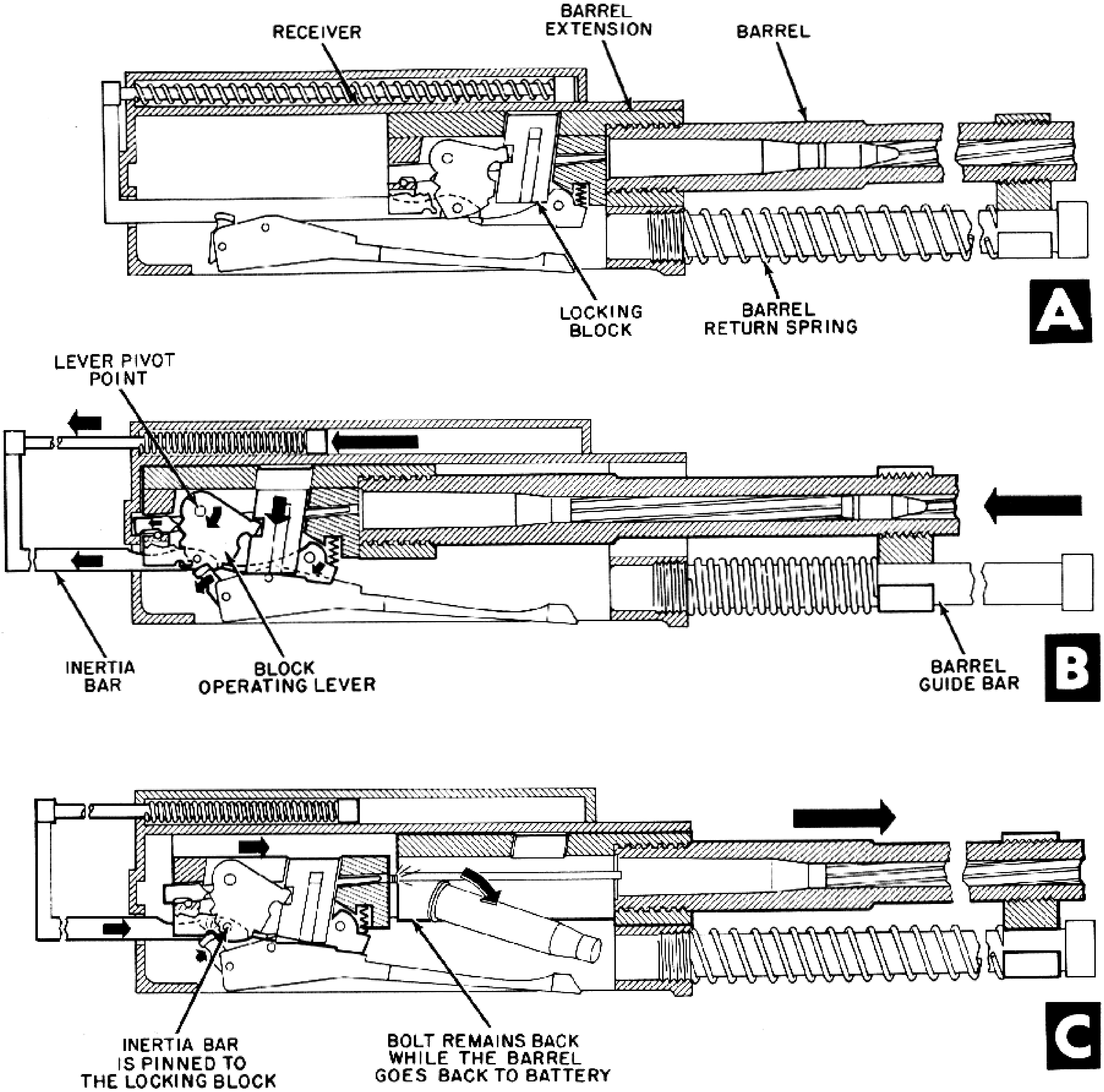


Figure 6–65. Locking Block Is Cammed Free of Barrel Extension by Motion of Inertia Bar.

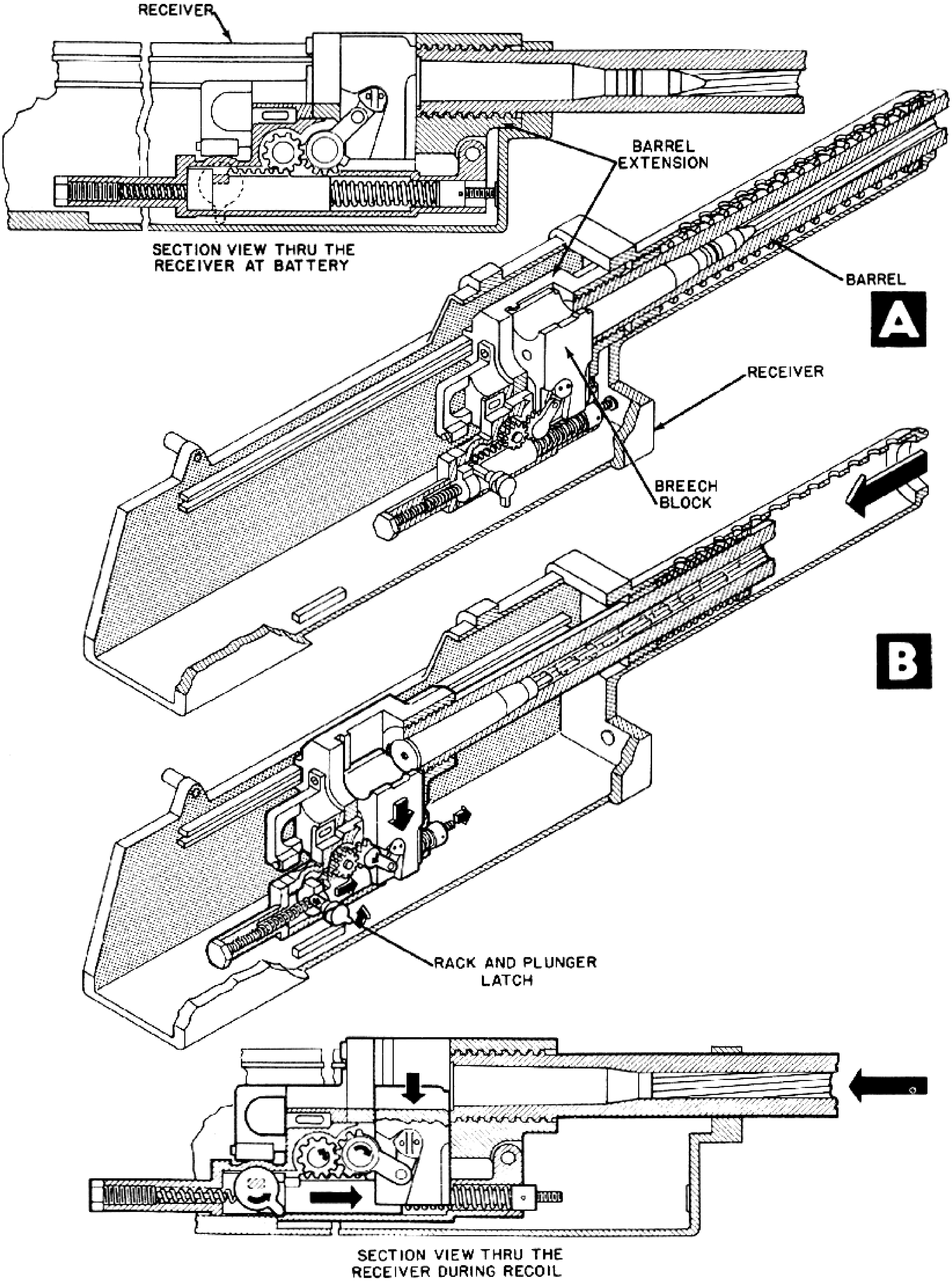
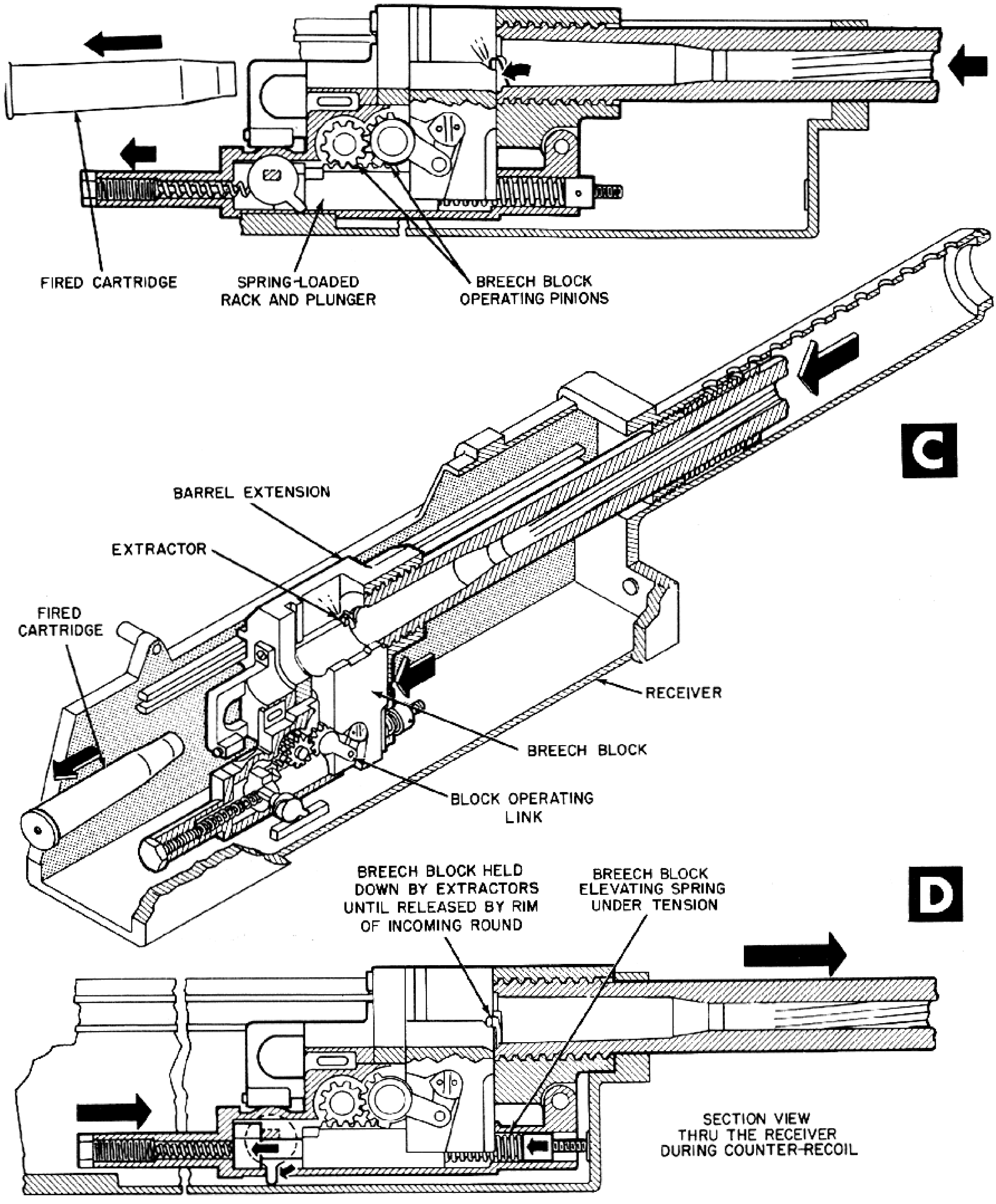


Figure 6–66. Breech Block Is Operated by



Spring-Loaded Rack and Pinion.

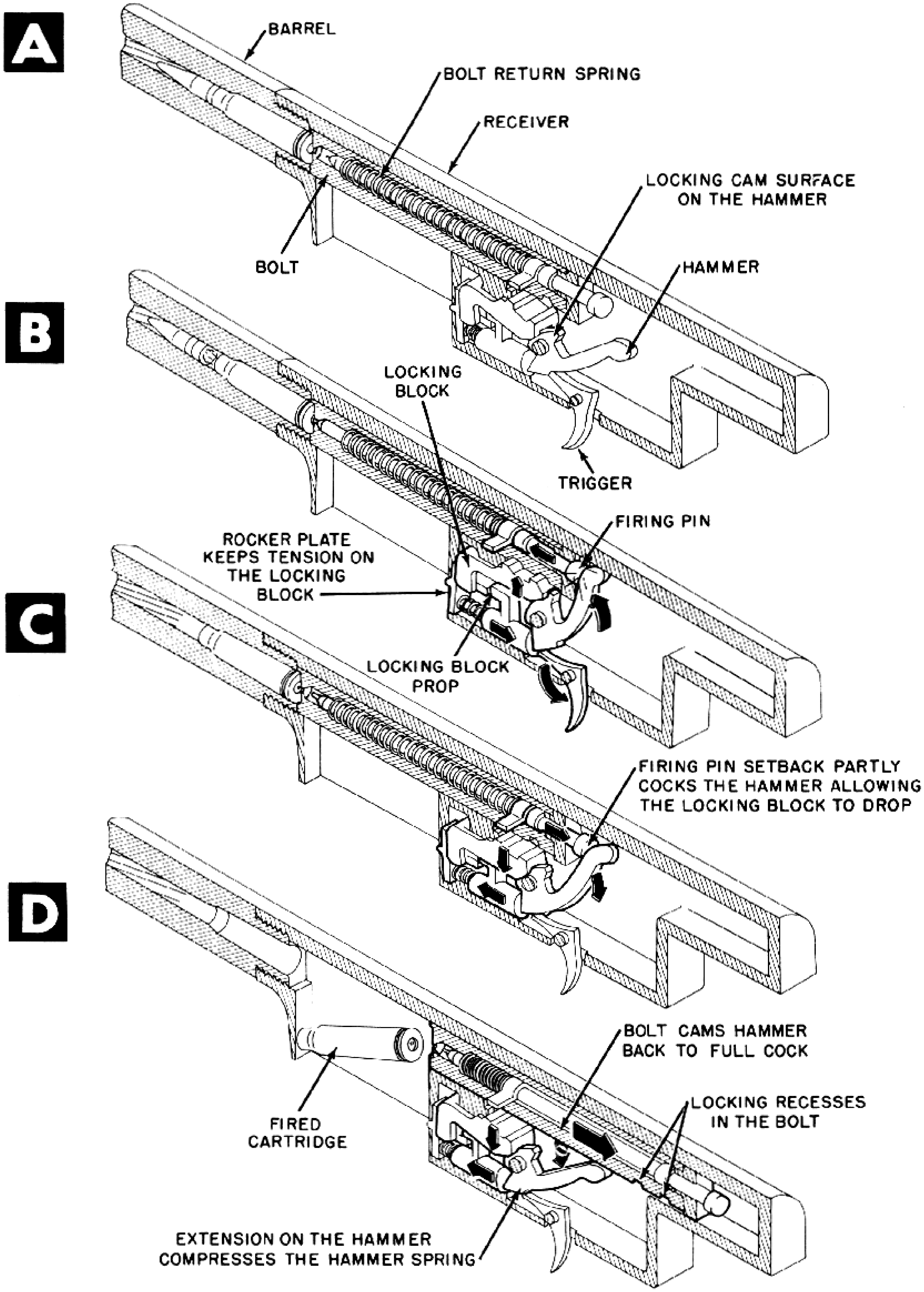


Figure 6–67. Bolt Is Locked by Action of Hammer on Locking Block.

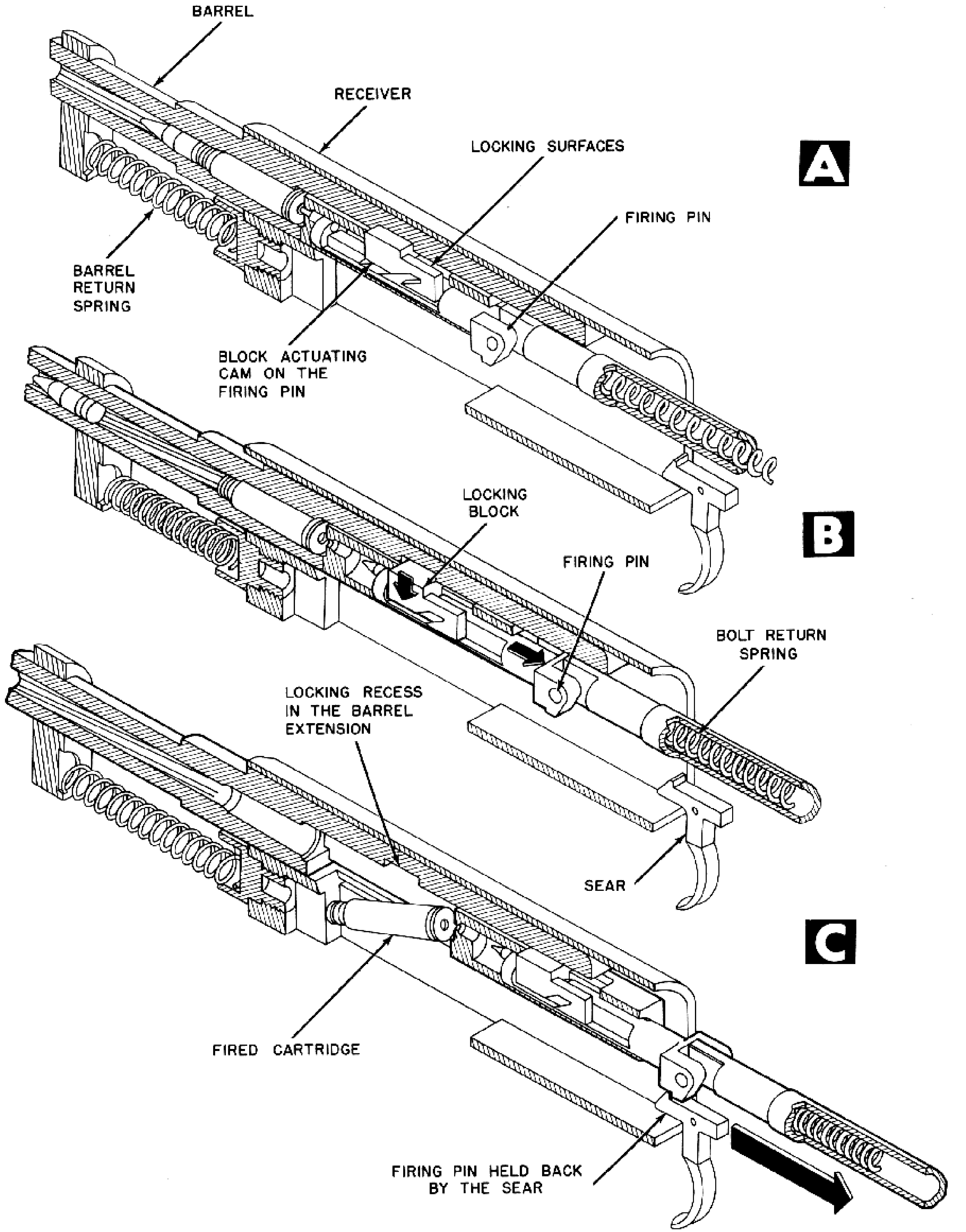


Figure 6–68. Firing Pin Recoils, Camming Locking Block Free of Barrel Extension.

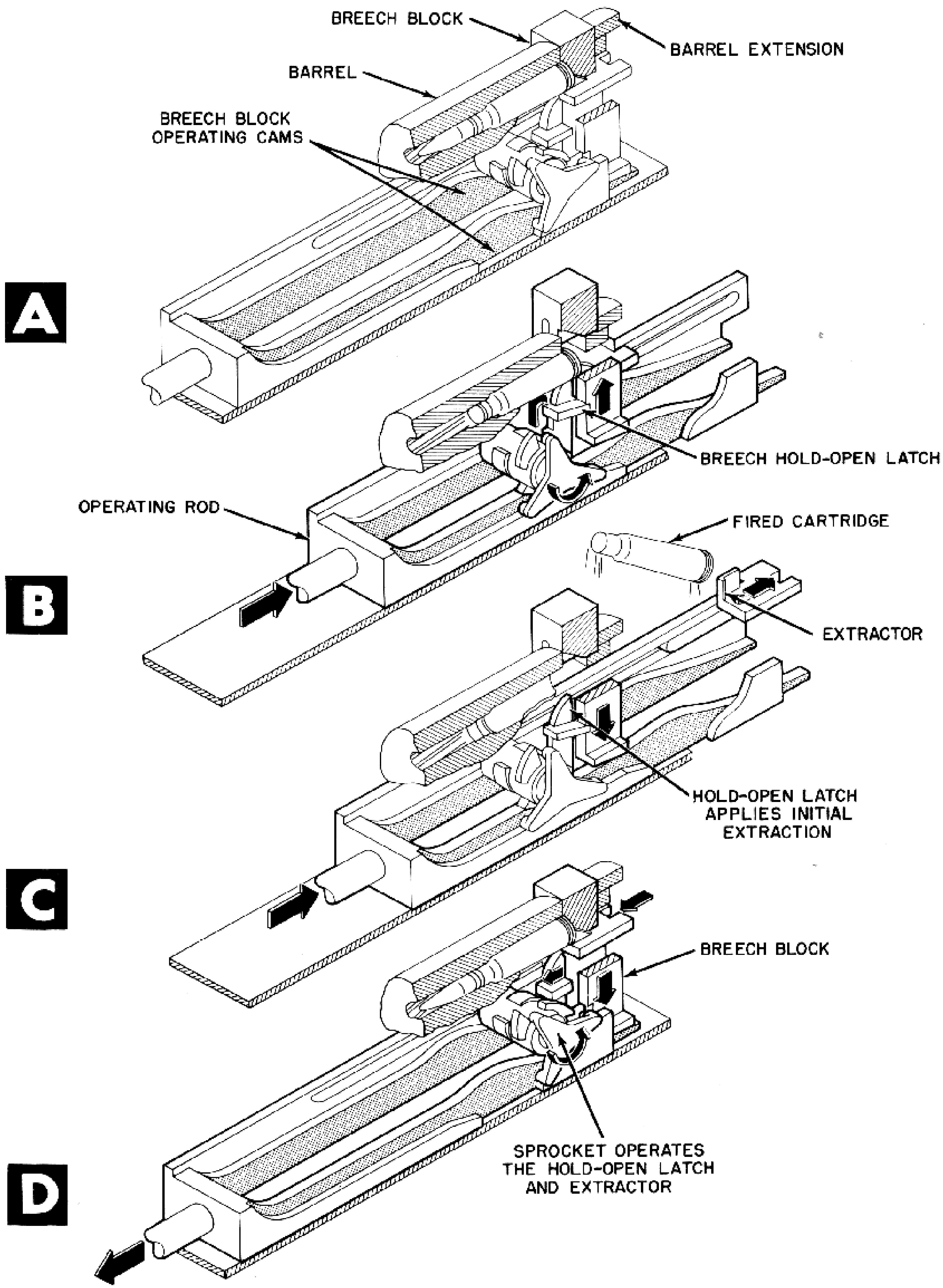


Figure 6–69. Cams on Operating Rod Actuate Breech Block.

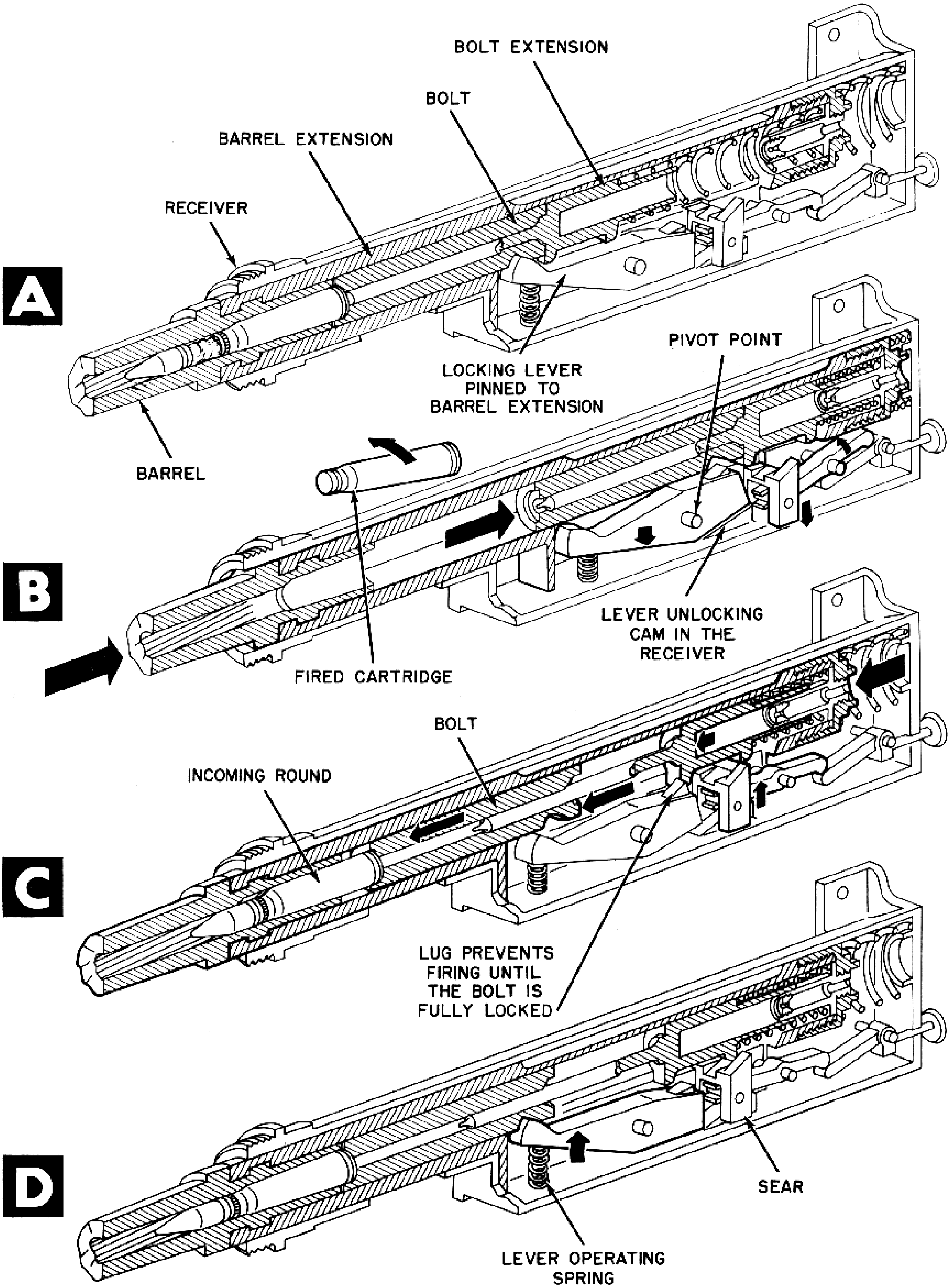


Figure 6–70. Barrel Extension Recoils, Camming Locking Lever Free of the Bolt.

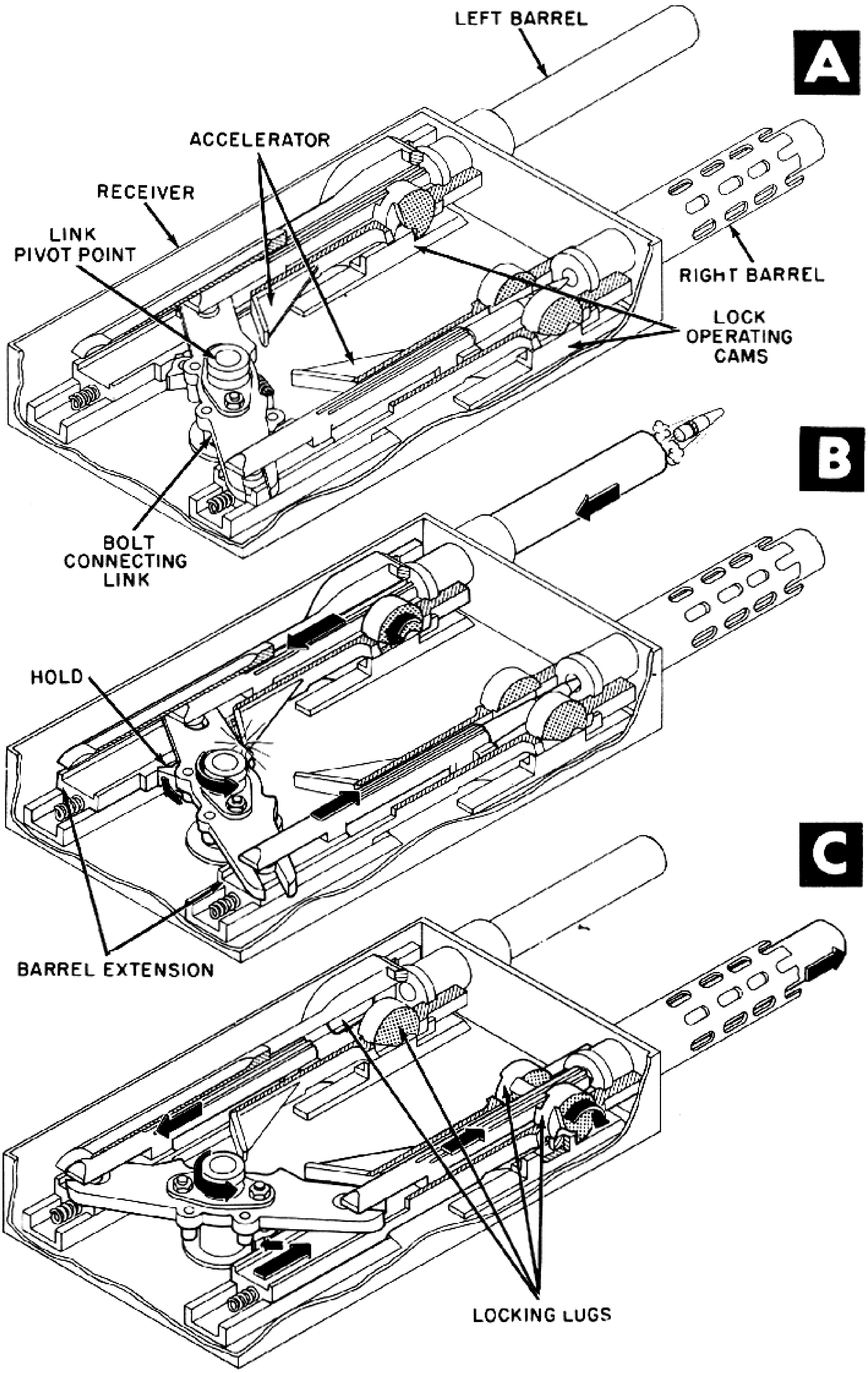


Figure 6–71. Double Barrel Gun. Barrel Extension Recoils, Unlocking Rotary Locking Blocks.

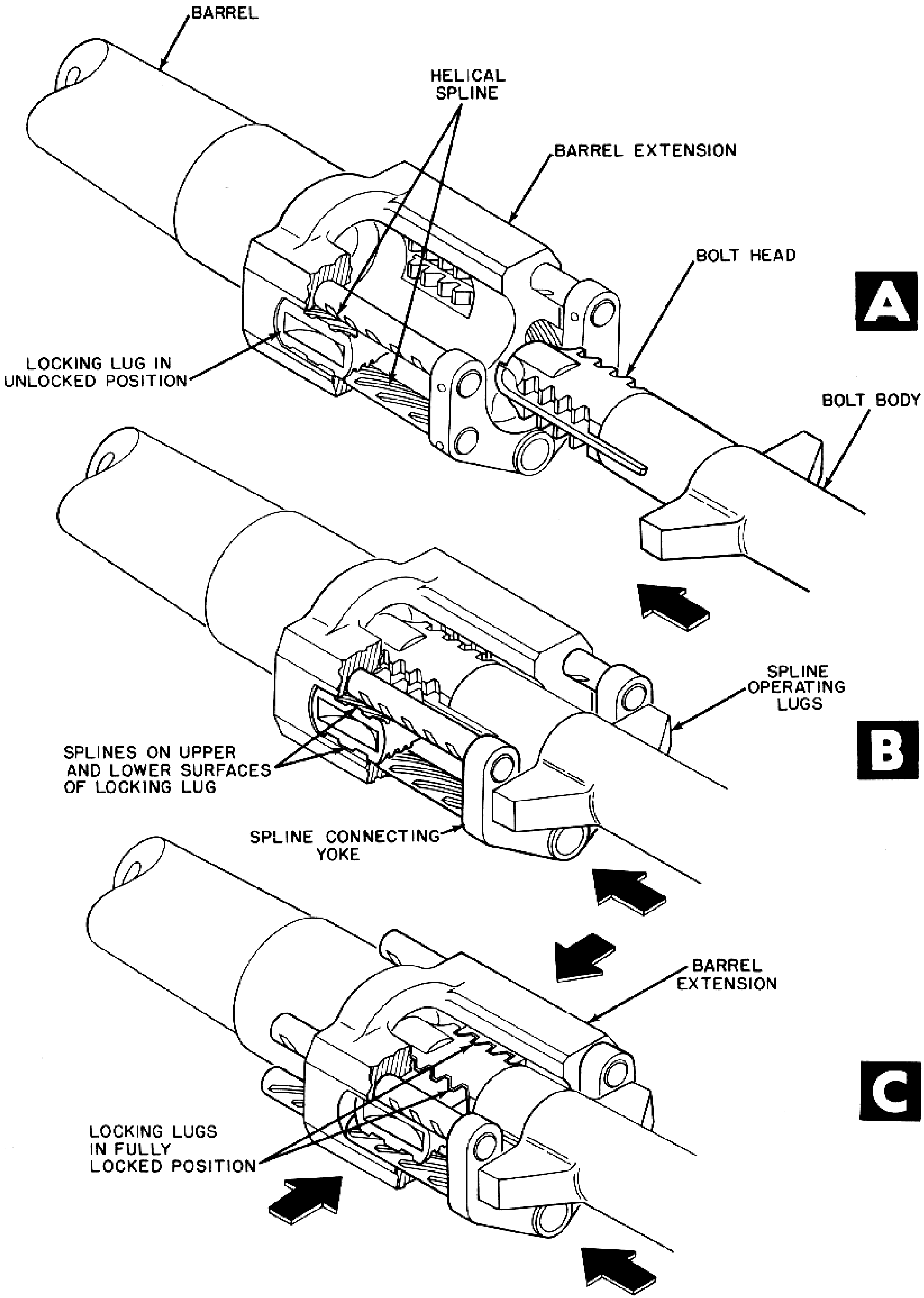


Figure 6–72. Helical Splines in Barrel Extension Lock Bolt by Pressure of Bolt Extension.

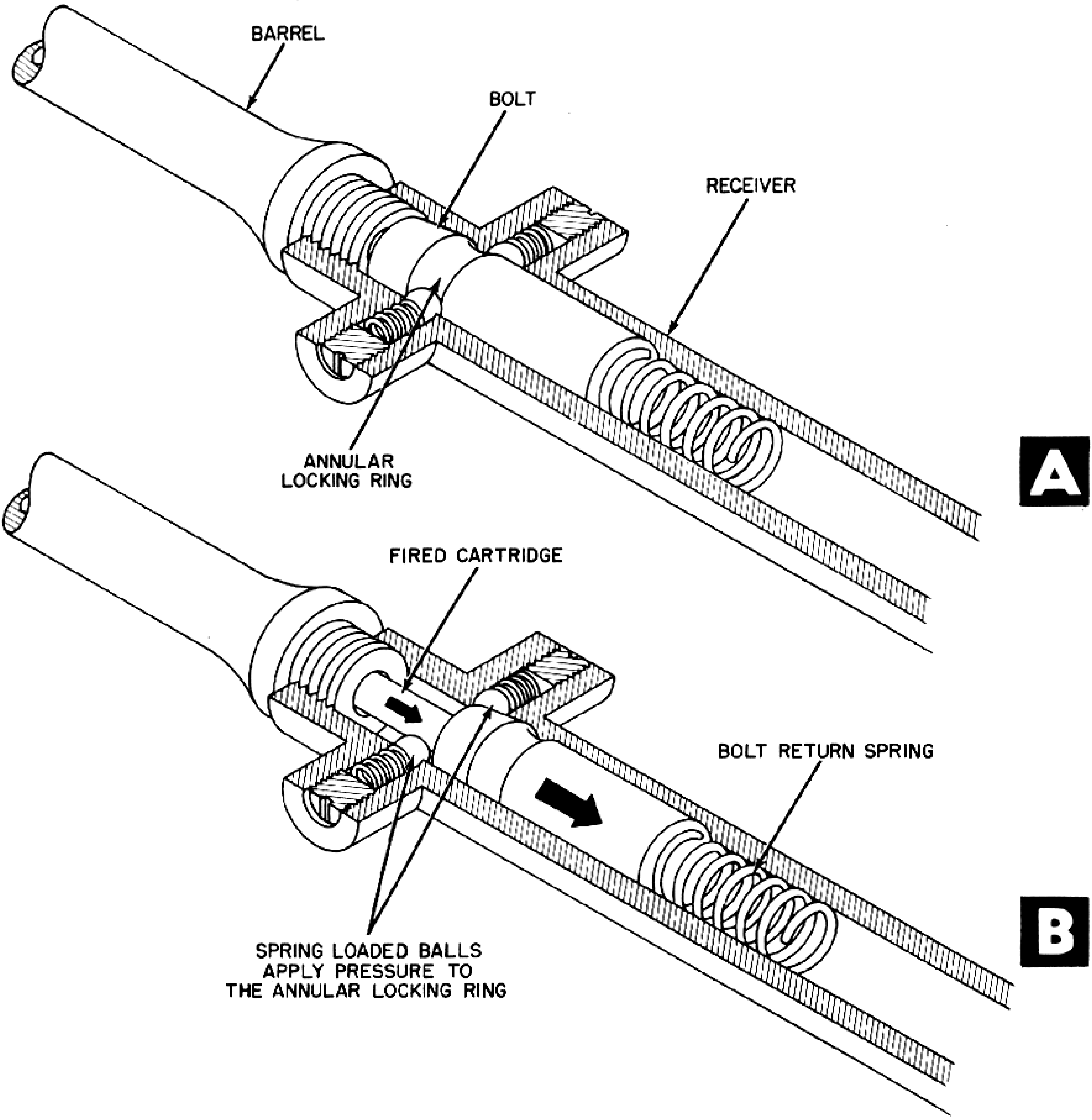


Figure 6–73. Spring-Loaded Balls Retard Recoil of Bolt.

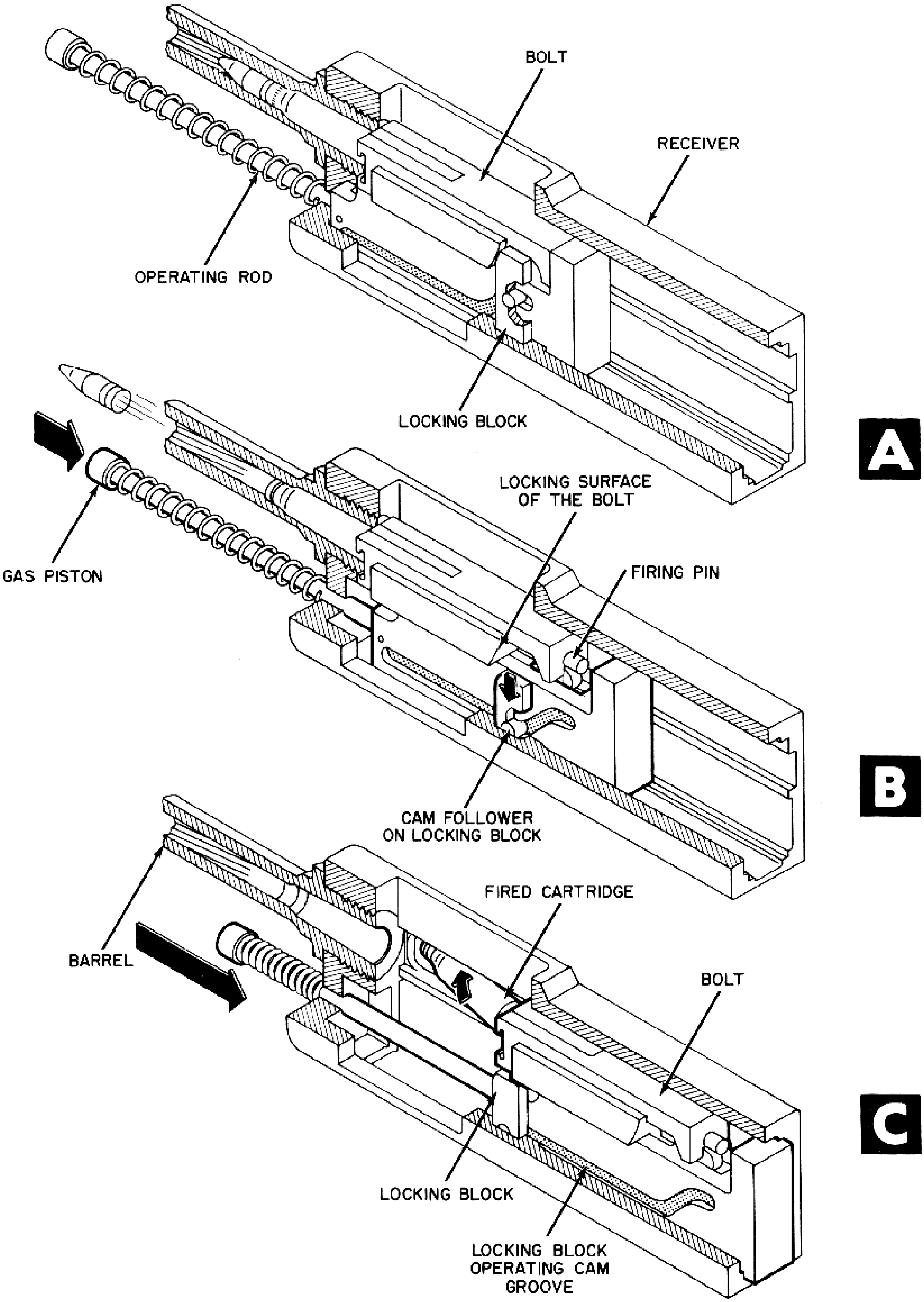


Figure 6-74. Cam on Operating Rod Actuates Locking Block.

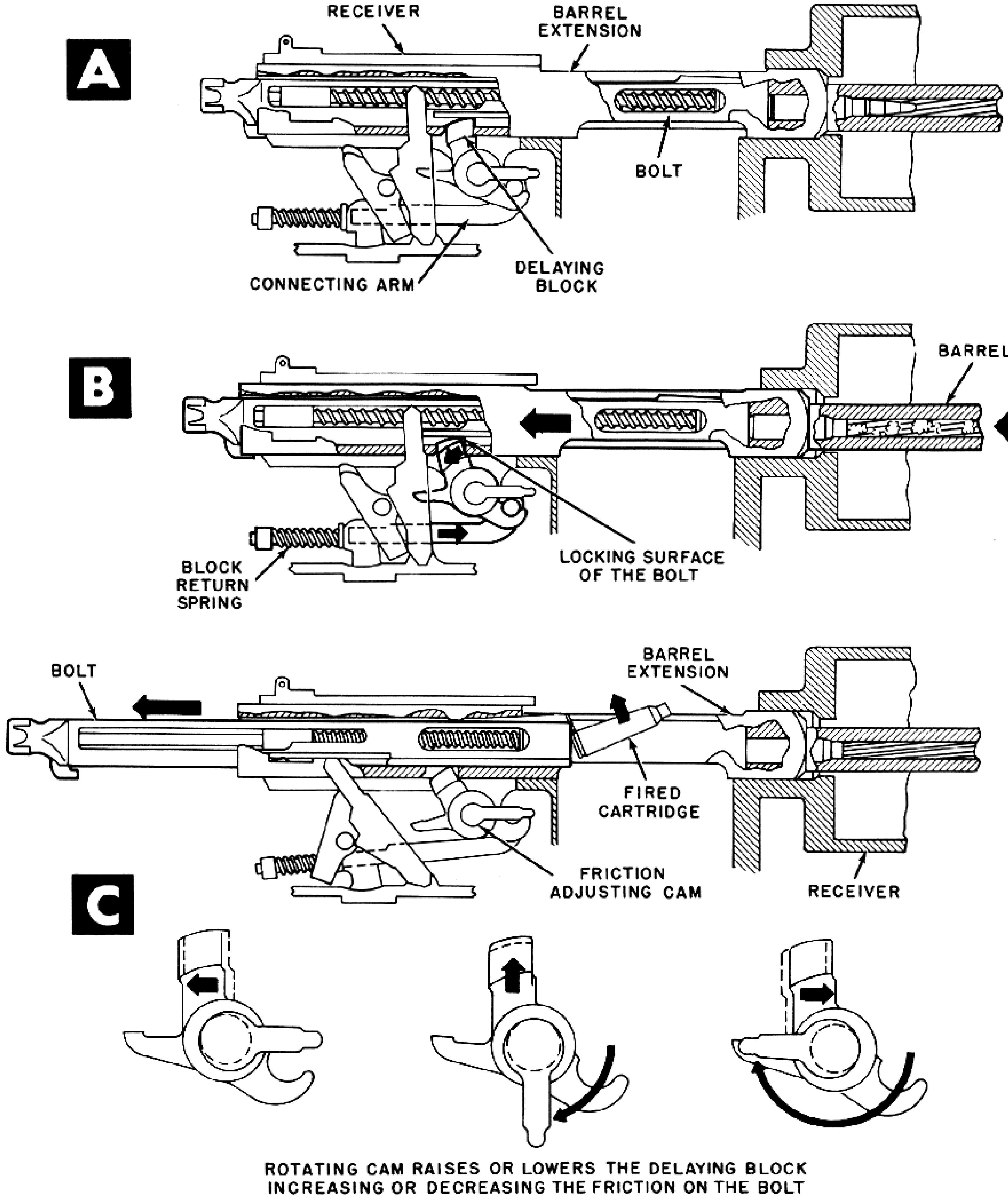


Figure 6–75. Spring-Loaded Locking Block Retards Recoil of Bolt.

F. Cammed Locking Lug

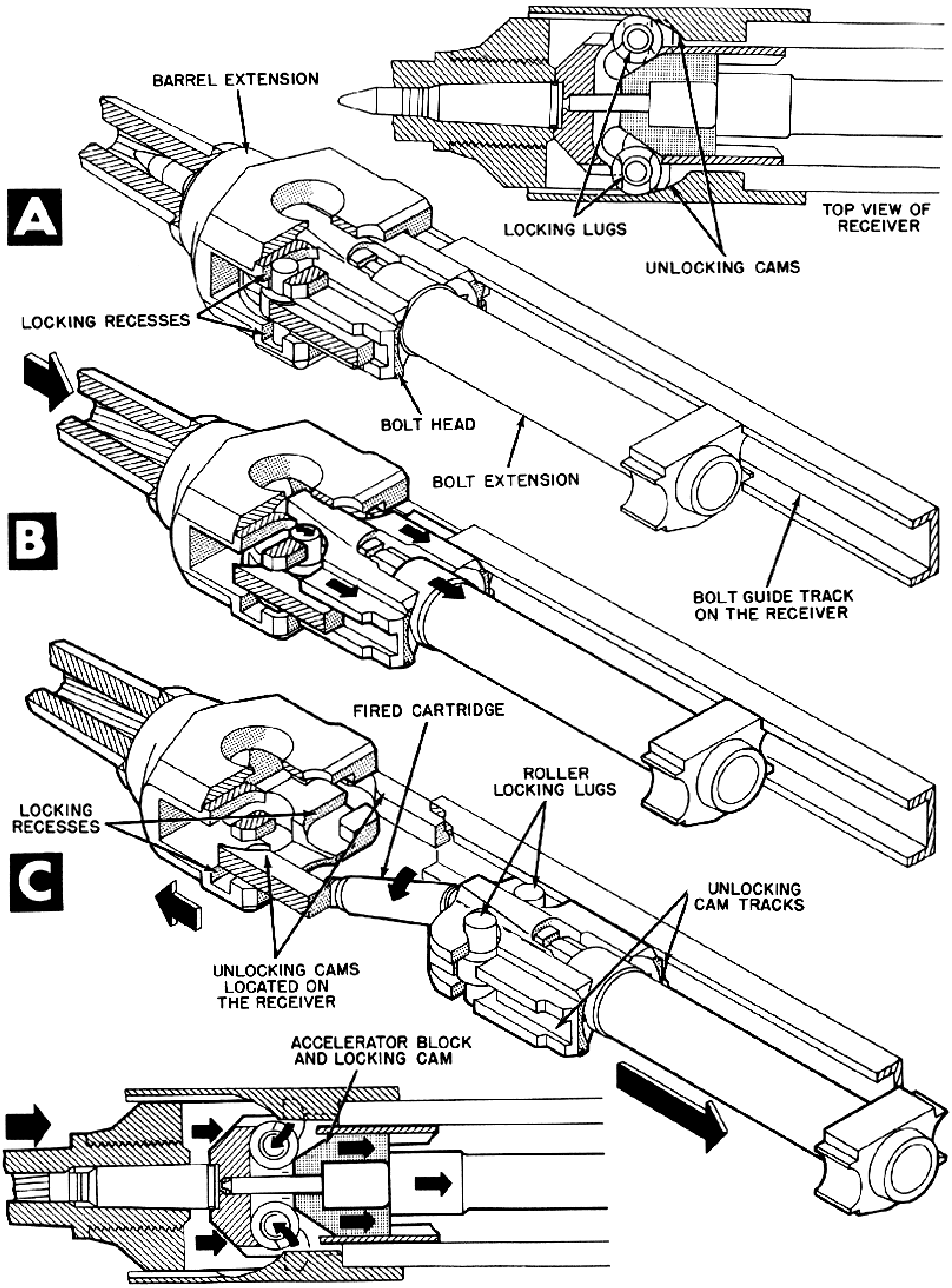


Figure 6–76. Locking Rollers Are Cammed Free of Barrel Extension by Rails in Receiver.

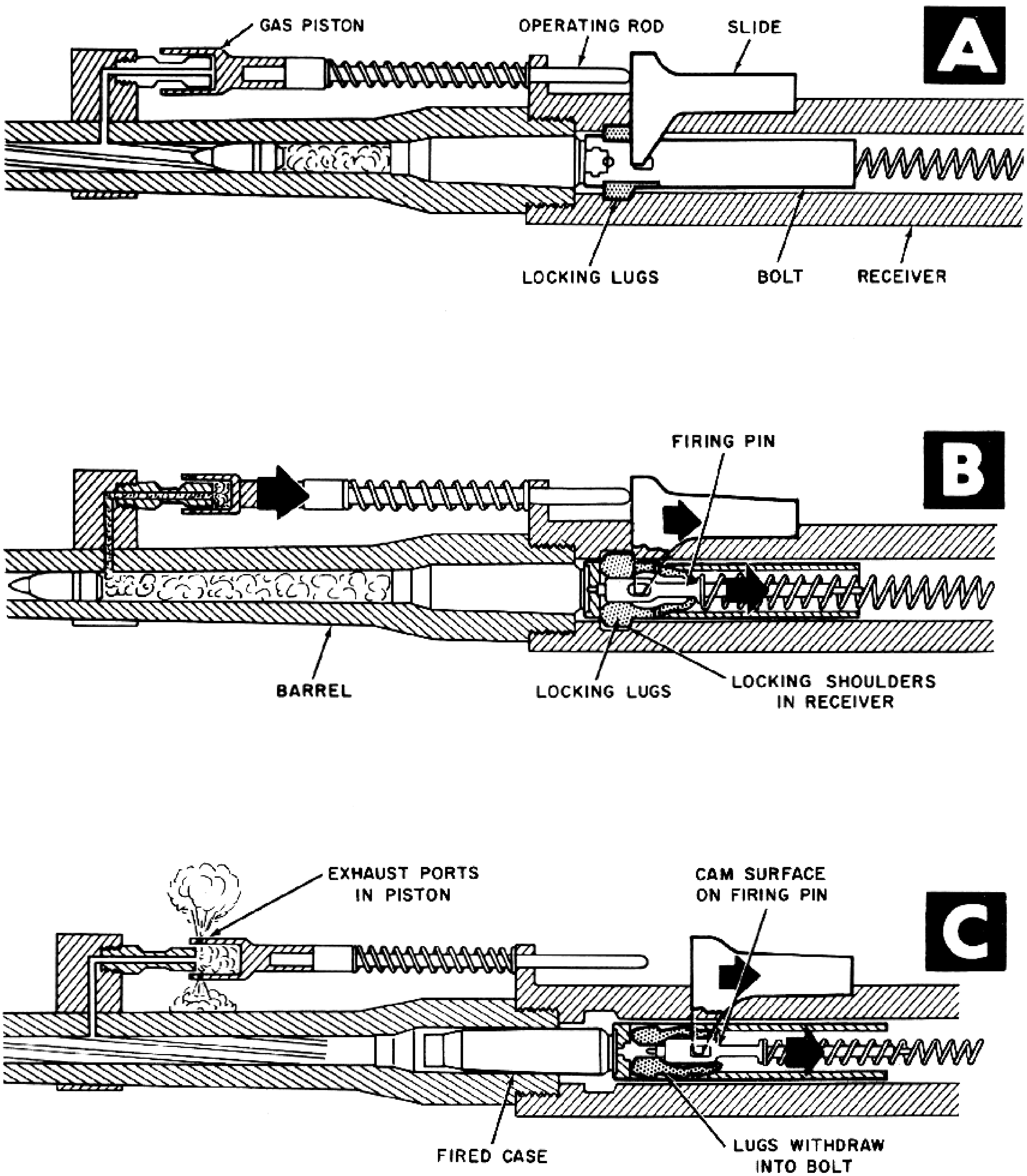


Figure 6–77. Cammed Surface on Firing Pin Unlocks Lugs From Receiver.

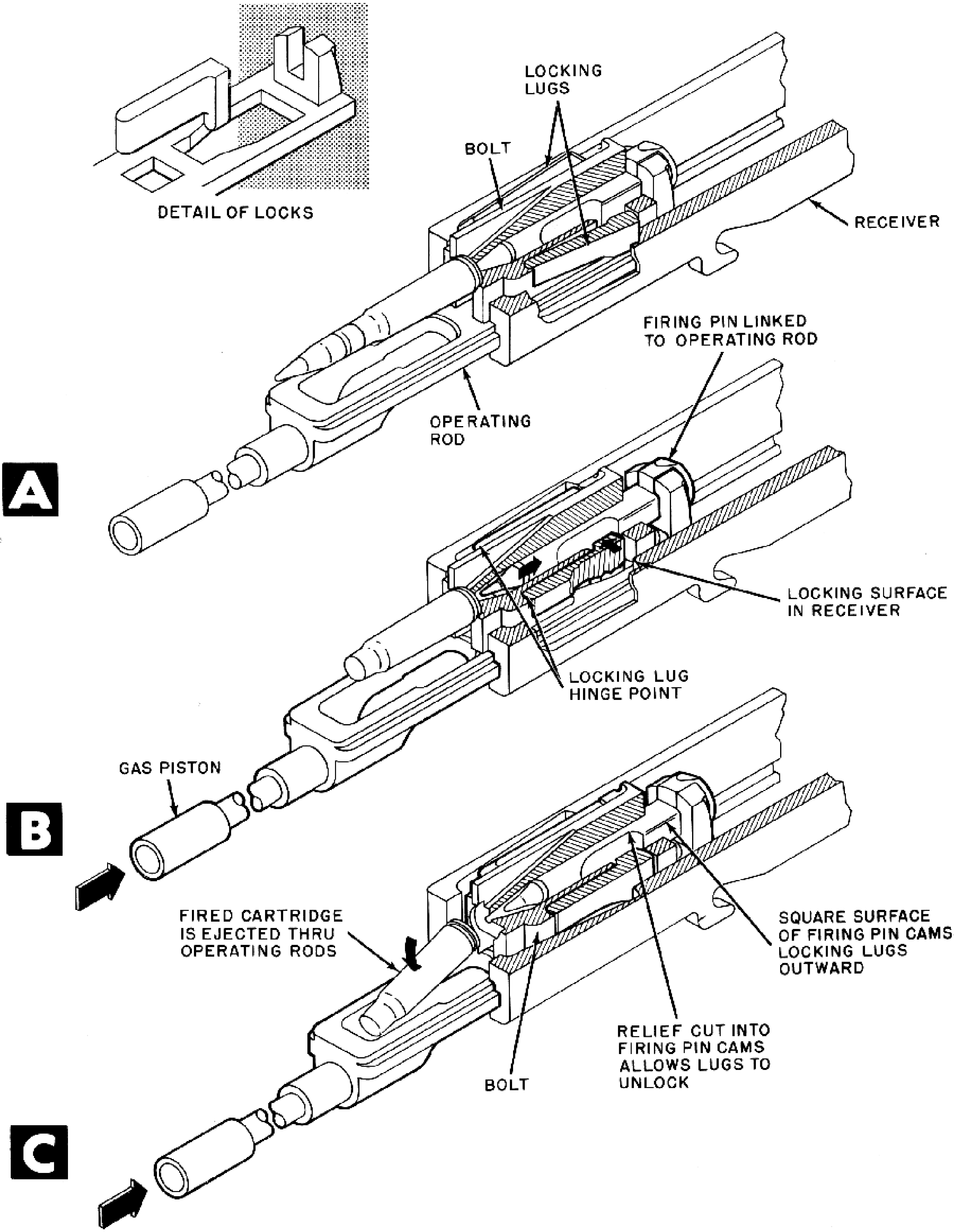


Figure 6–78. Cammed Surface on Operating Rod Unlocks Lugs From Receiver.

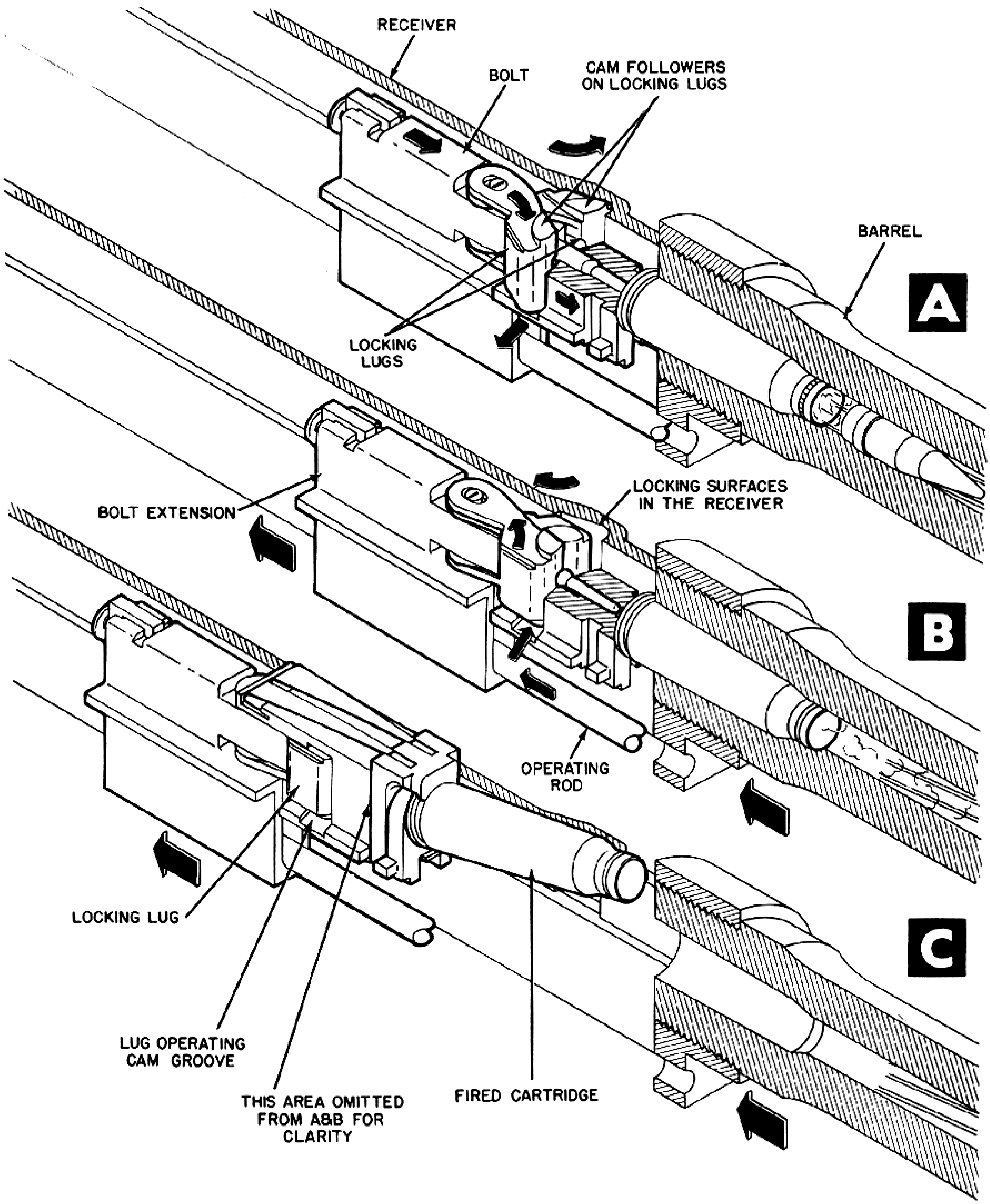


Figure 6–79. Recoiling Bolt Extension Cams Locking Lugs Free of Receiver.

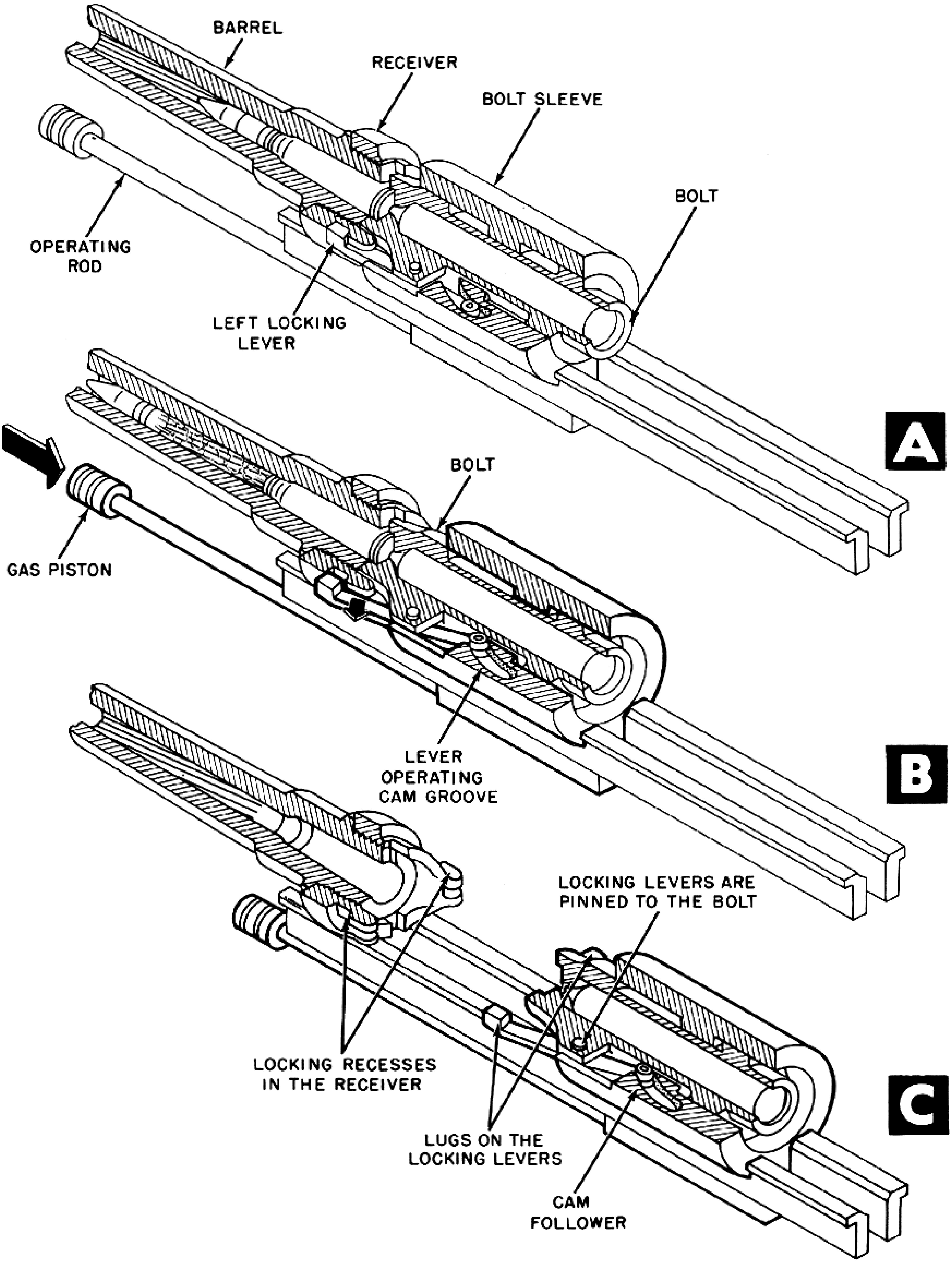


Figure 6–80. Recoiling Bolt Sleeve Cams Pivoted Locking Levers Free of Receiver.

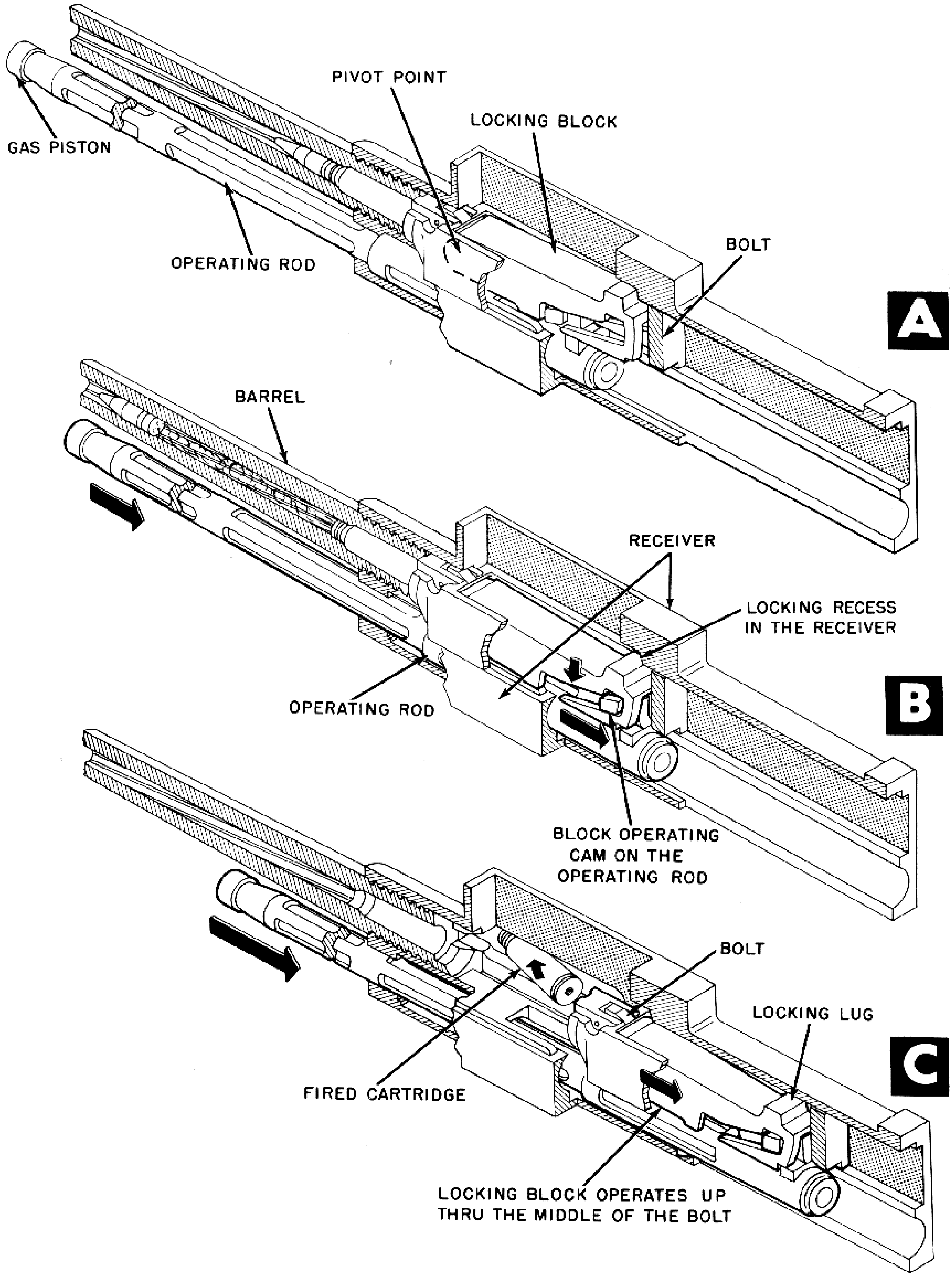


Figure 6–81. Lug on Operating Rod Cams Locking Block Free of Receiver.

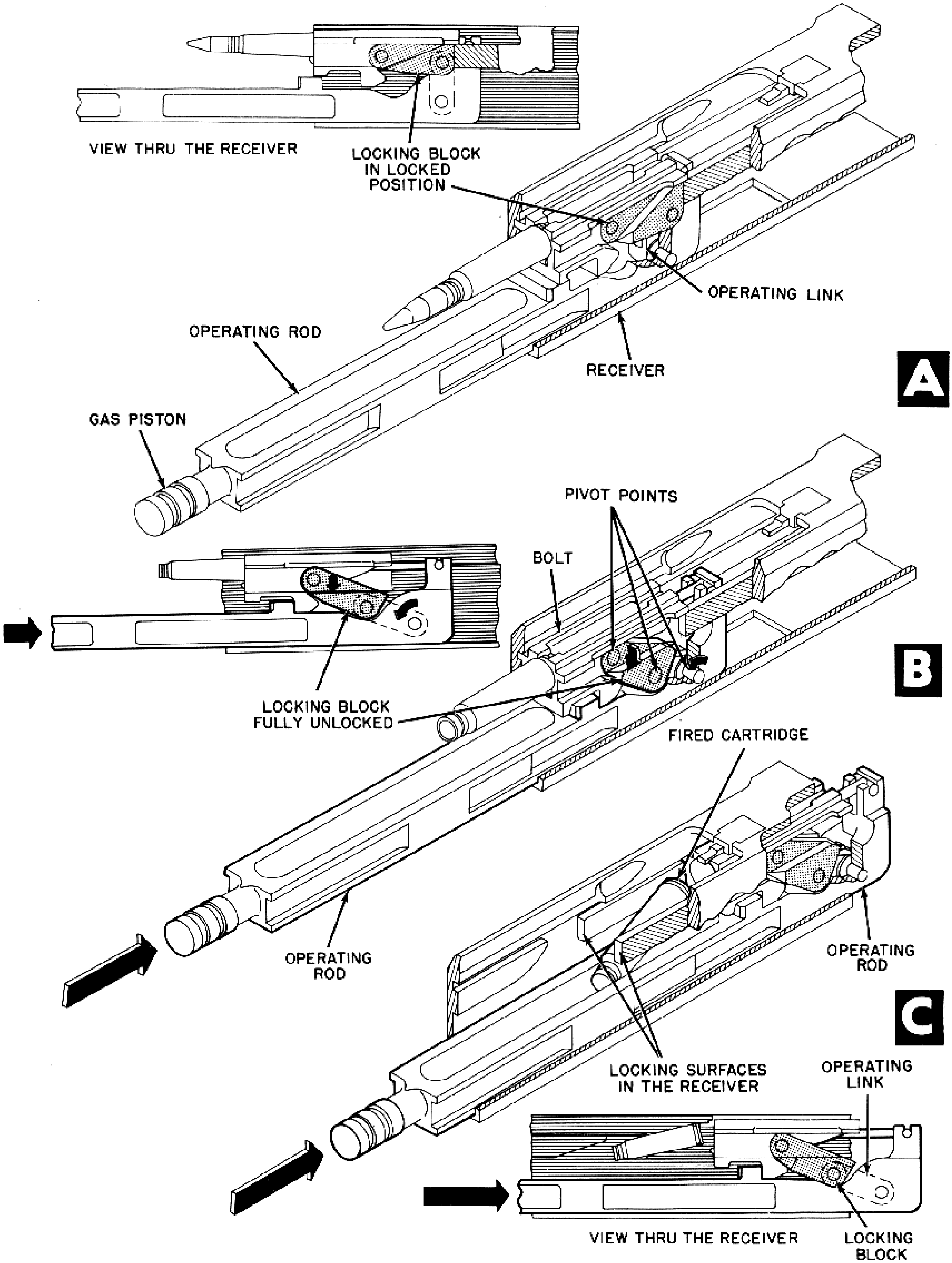


Figure 6–82. Link on Operating Rod Pulls Locking Block Free of Receiver.

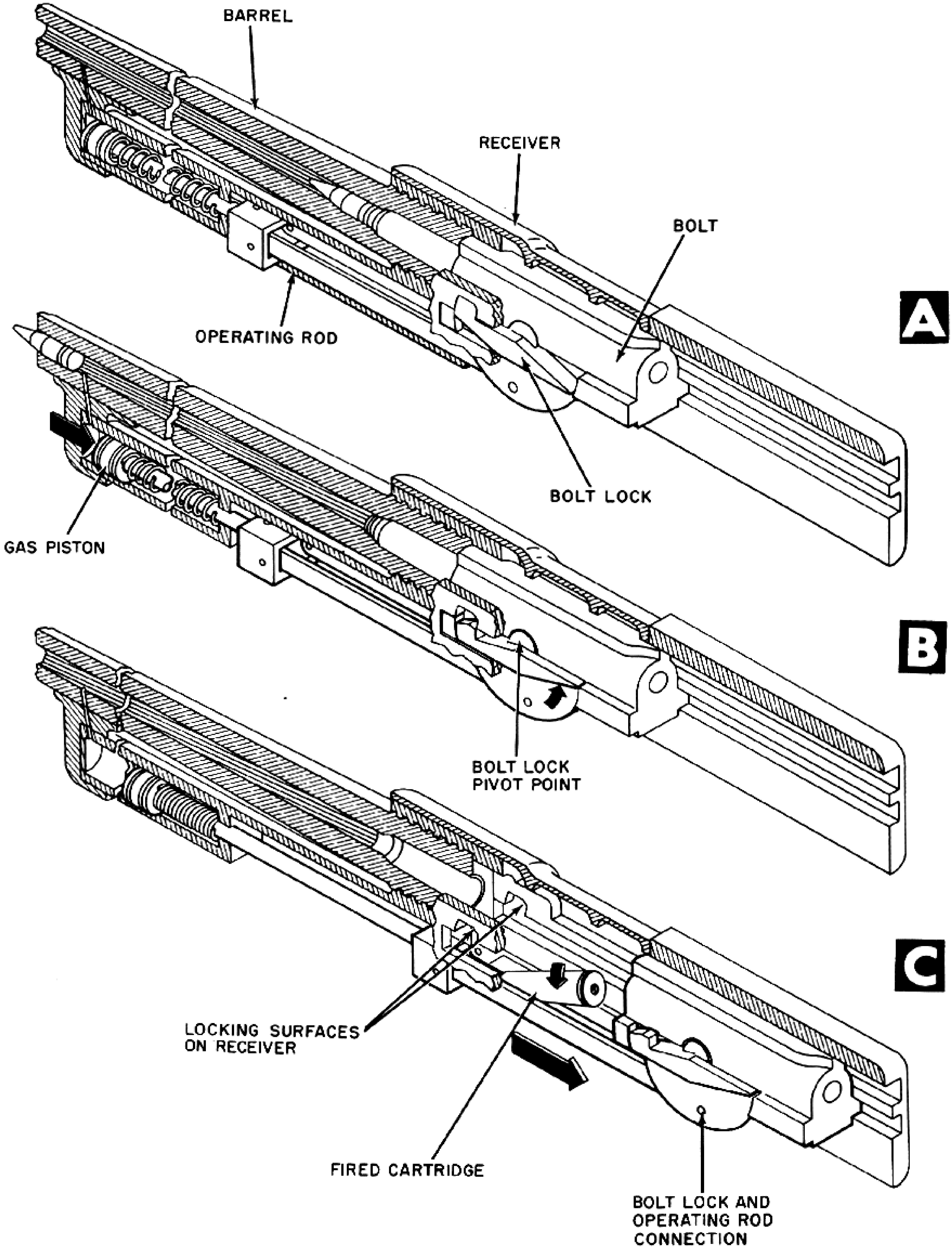


Figure 6–83. Operating Rod Rotates Pivoted Locking Block Free of Receiver.

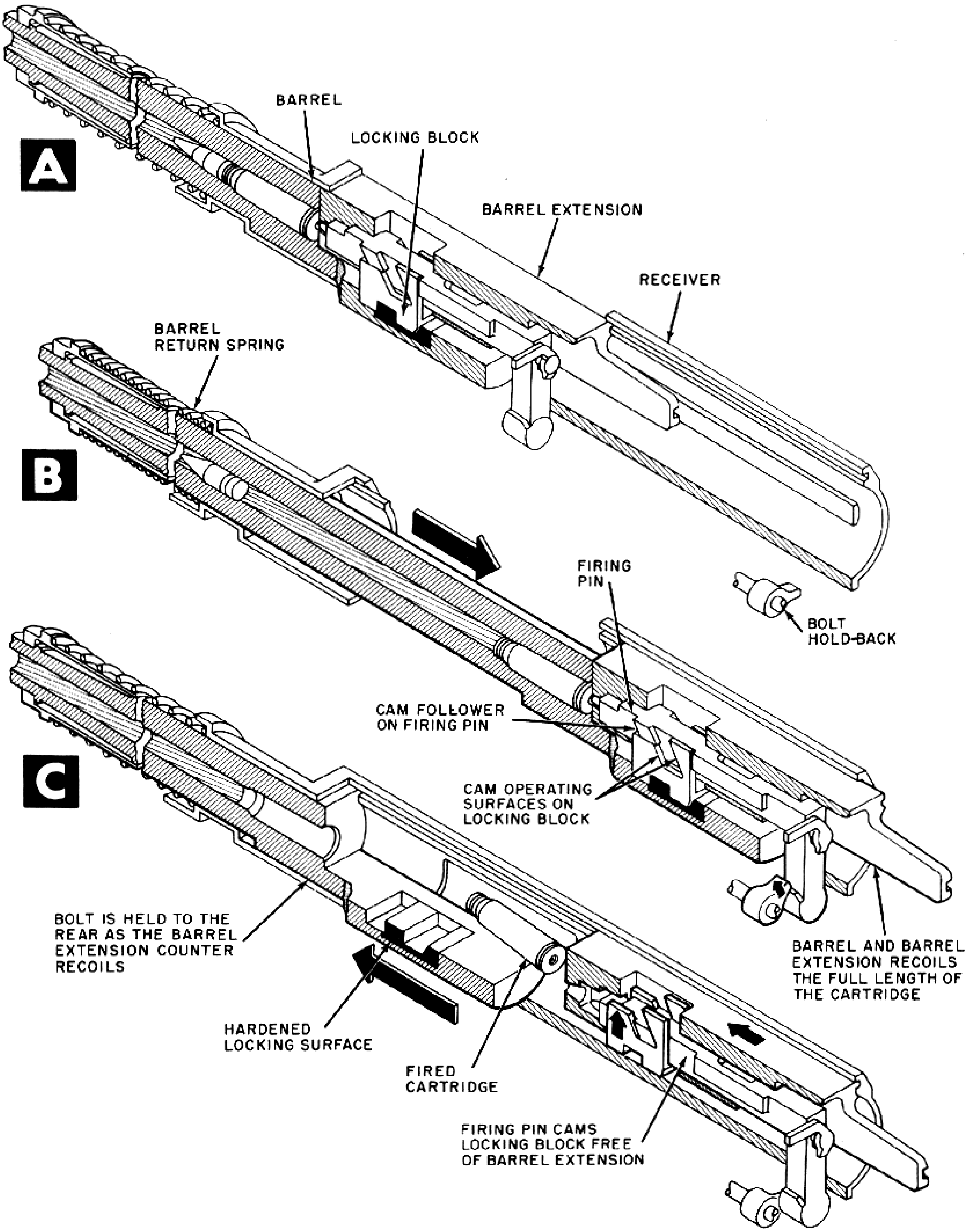


Figure 6–84. At End of Recoil Stroke, Firing Pin Is Held to the Rear. Barrel and Bolt Counter-Recoil Until Locking Block Is Cammed Free of Barrel Extension.

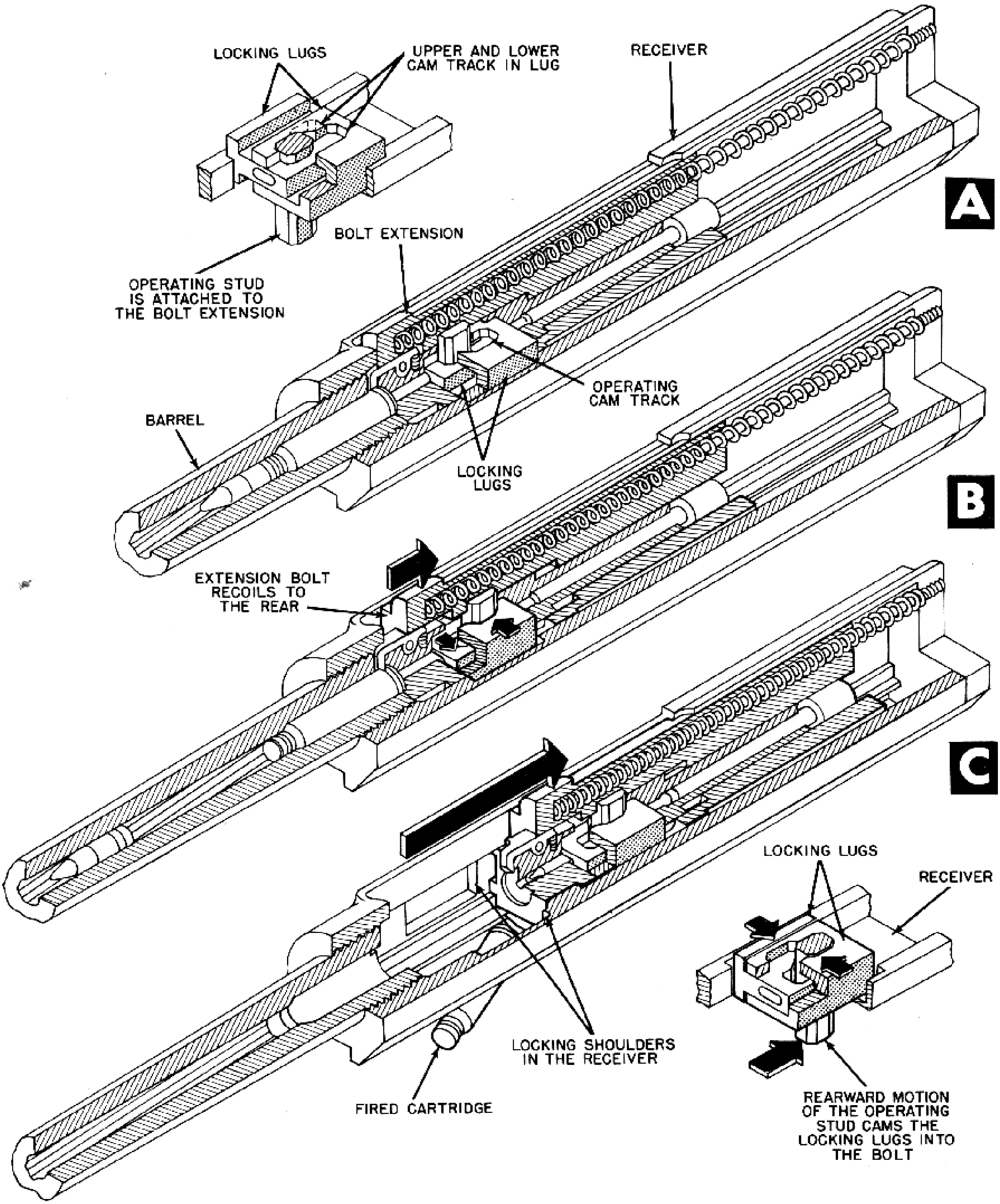


Figure 6–85. Recoiling Bolt Extension Cams Locking Lugs Free of Receiver.

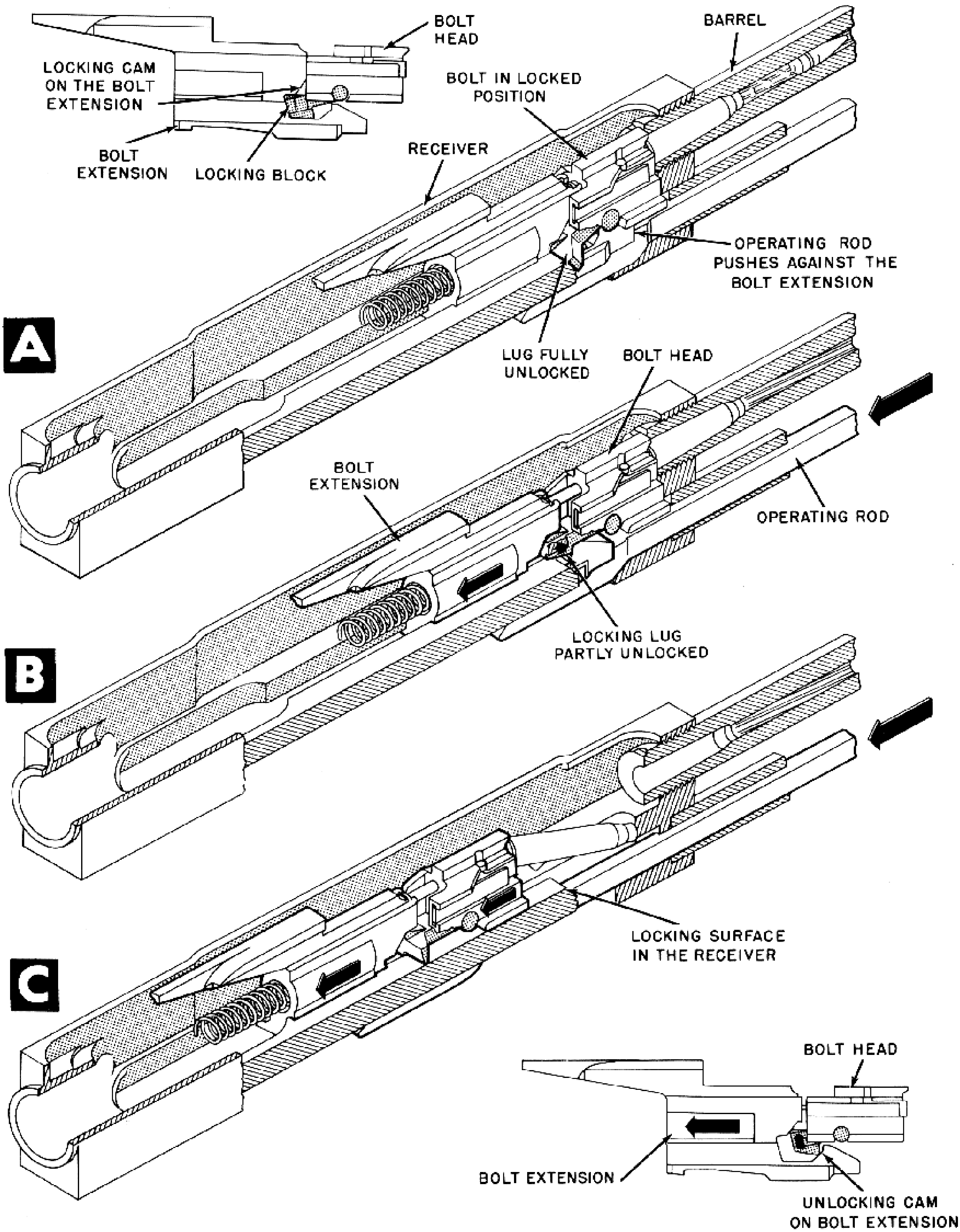


Figure 6–86. Recoiling Bolt Extension Lifts Locking Block Free of Receiver.

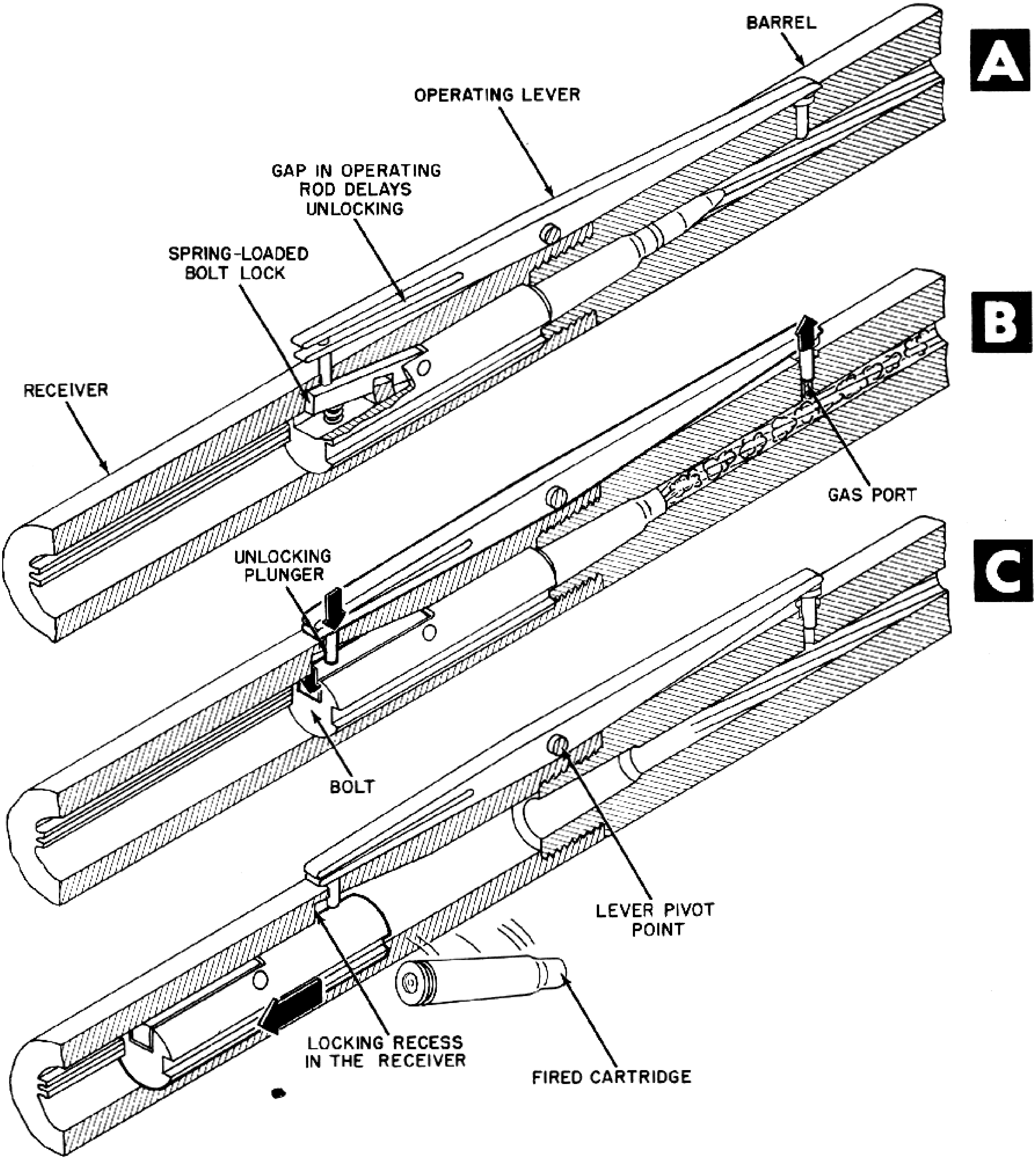


Figure 6-87. Gas-Operated Lever Unlocks Spring-Loaded Bolt Lock.

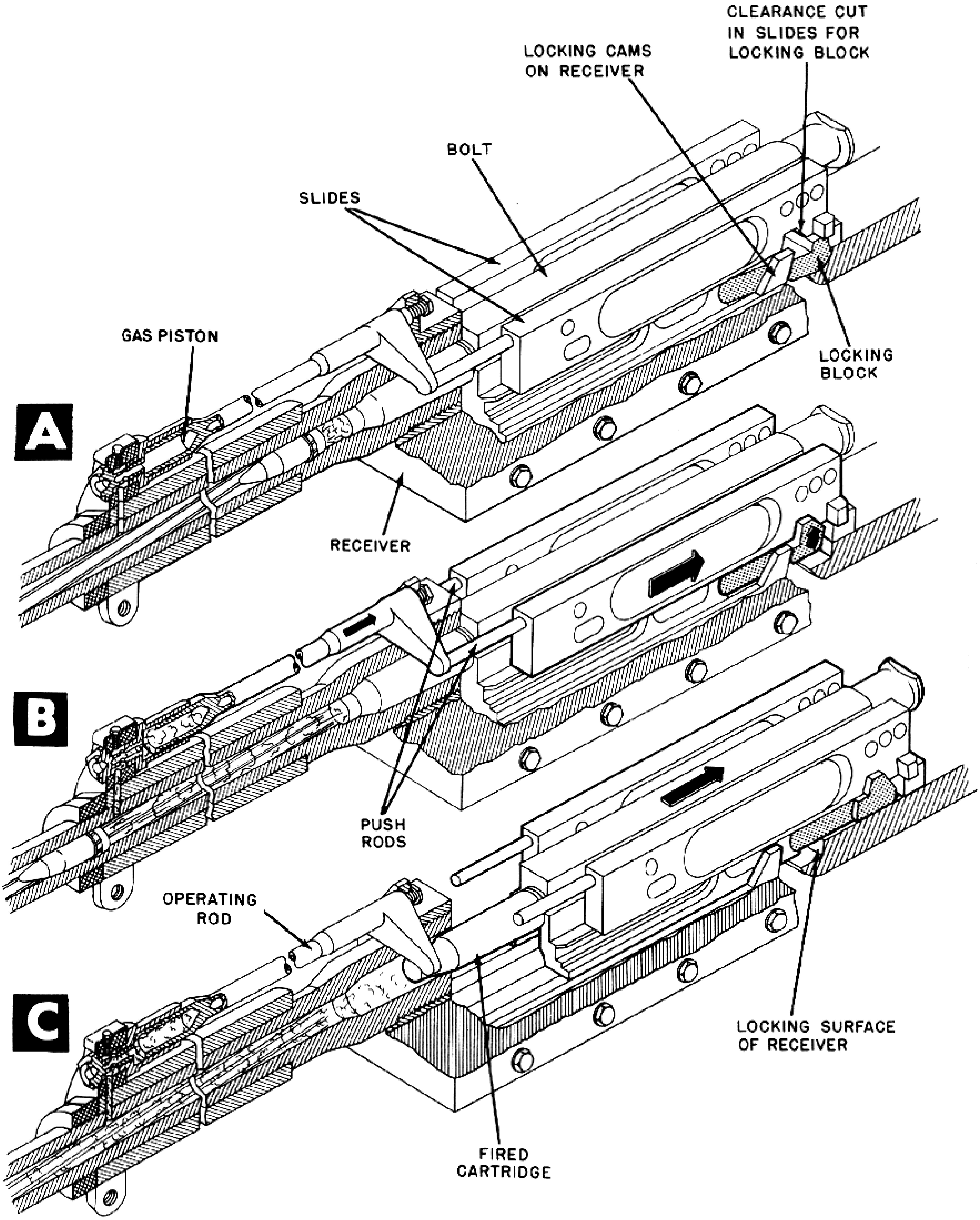


Figure 6–88. Slides Recoil Far Enough To Permit Locking Block To Cam Free of Receiver.

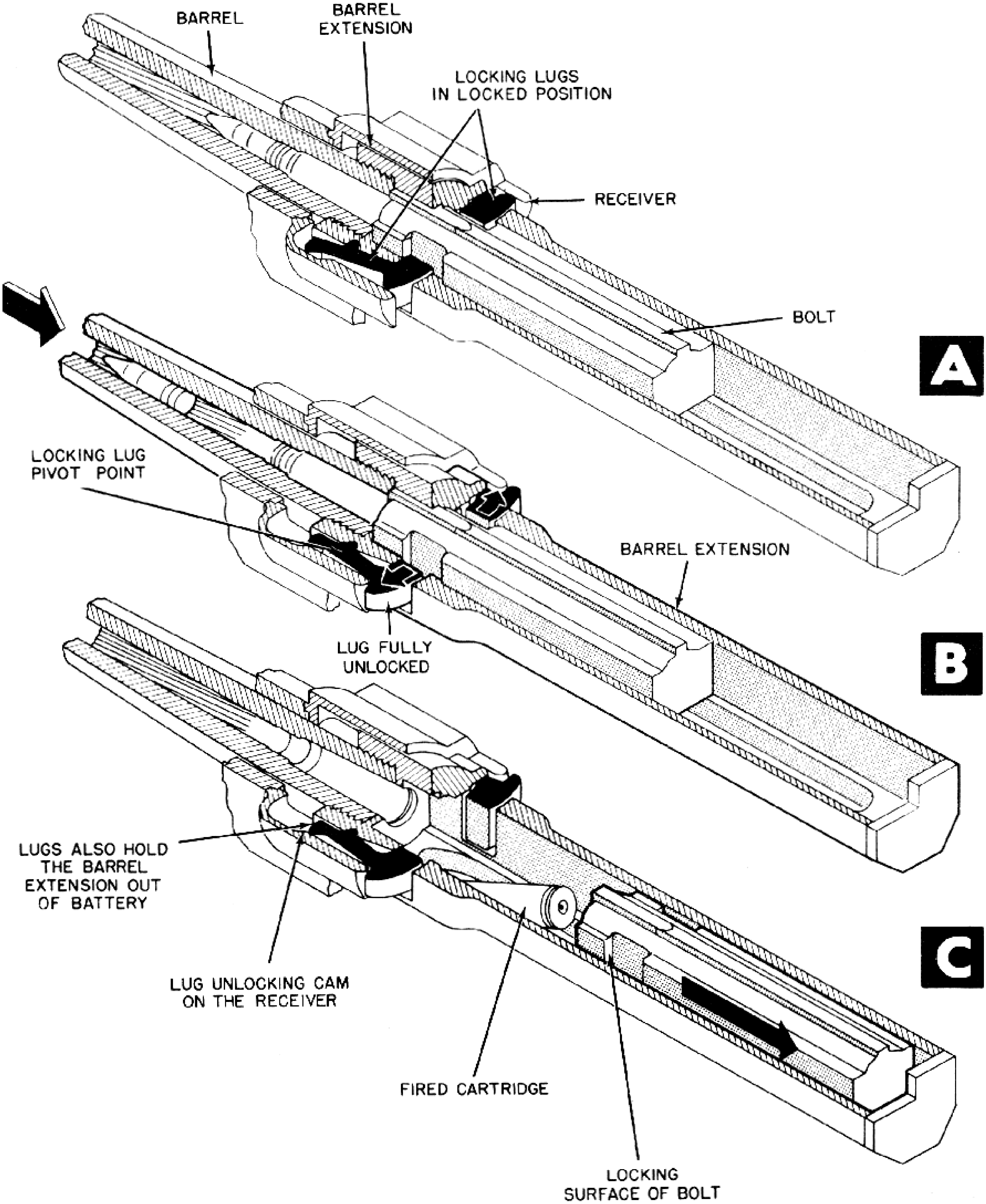


Figure 6–89. Recoiling Barrel Extension Cams Lugs Free of Bolt.

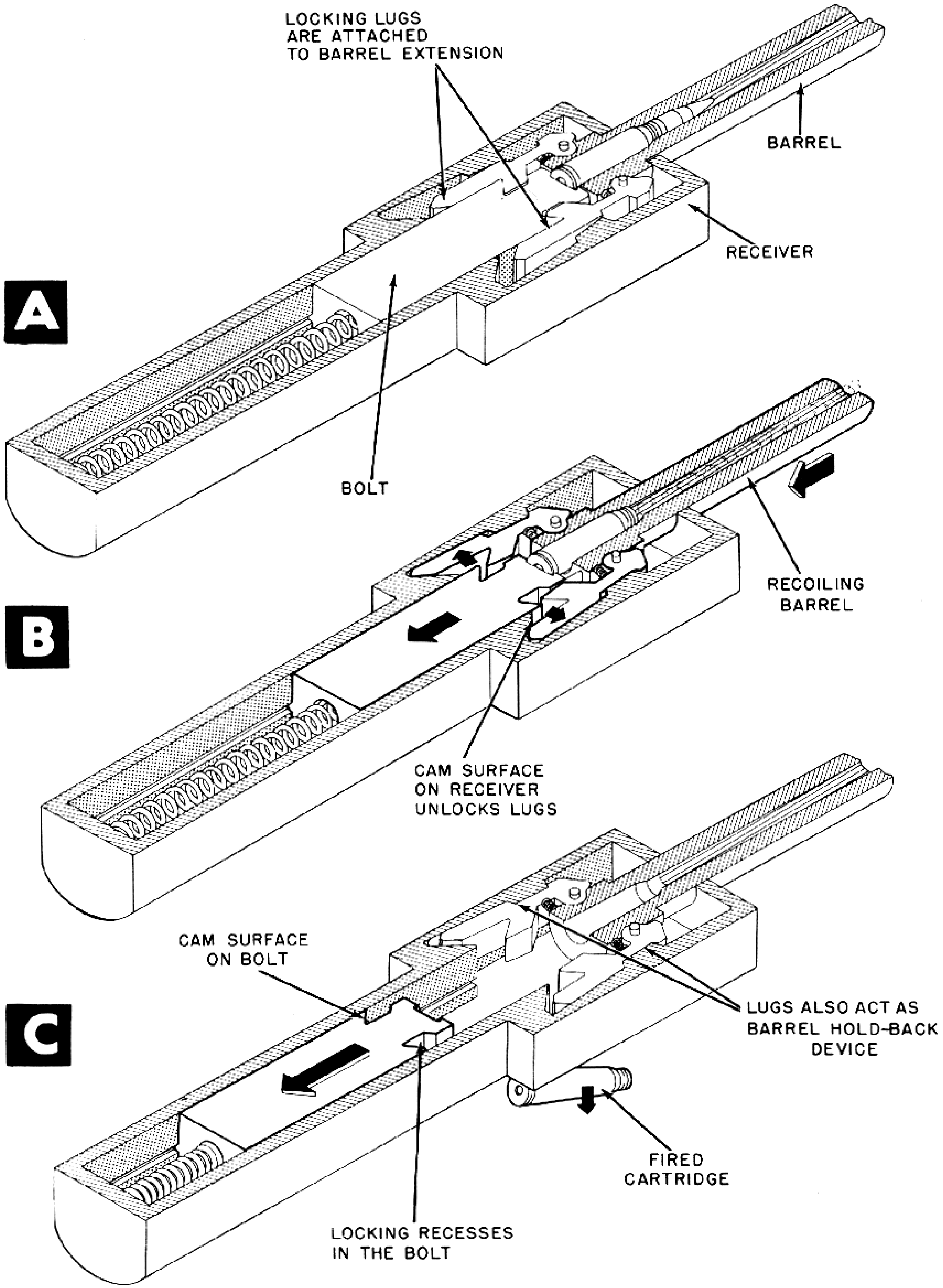


Figure 6–90. Recoiling Barrel Extension Cams Locking Lugs Free of Bolt.

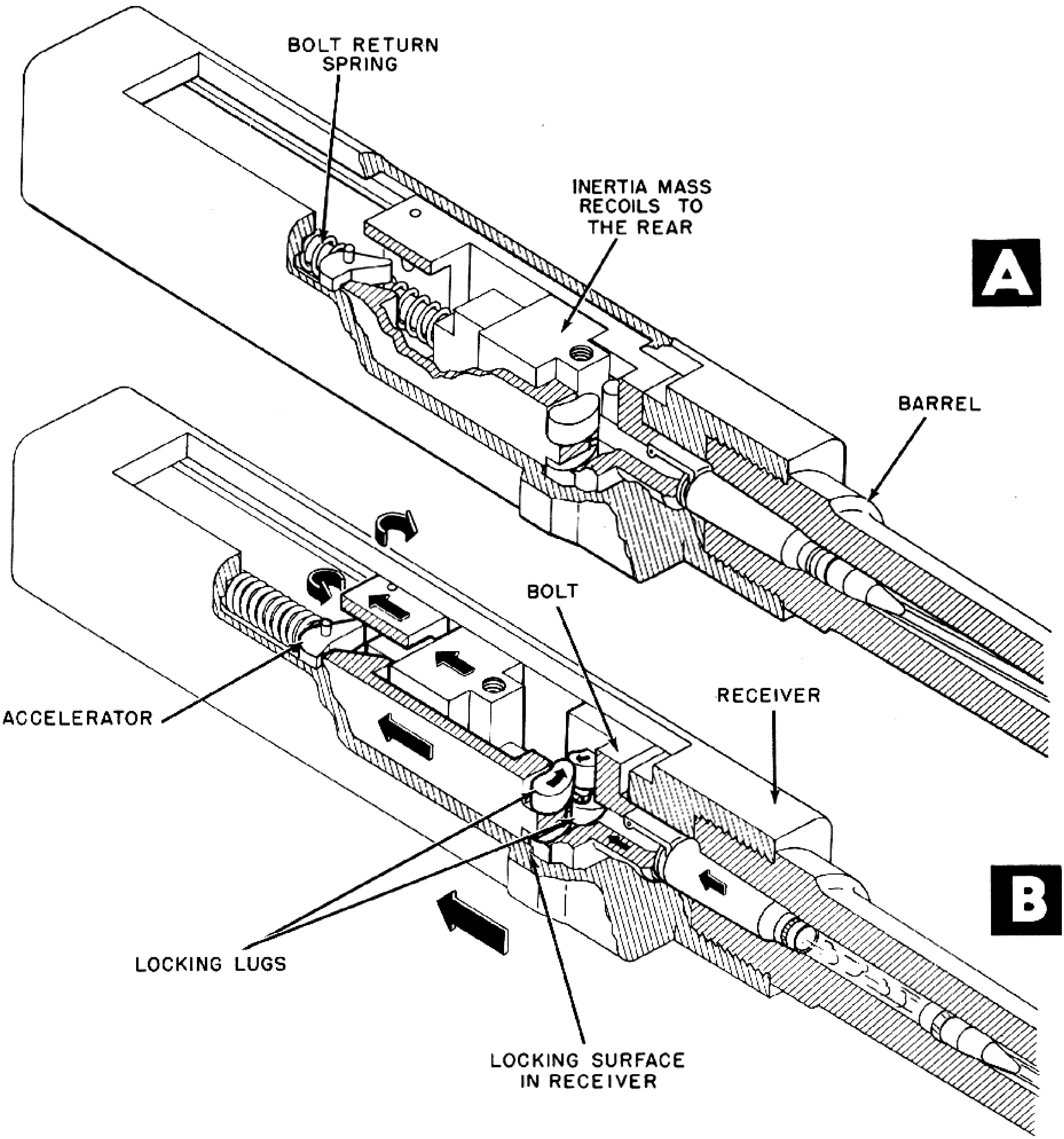


Figure 6–91. Recoiling Mass Unlocks Bolt.

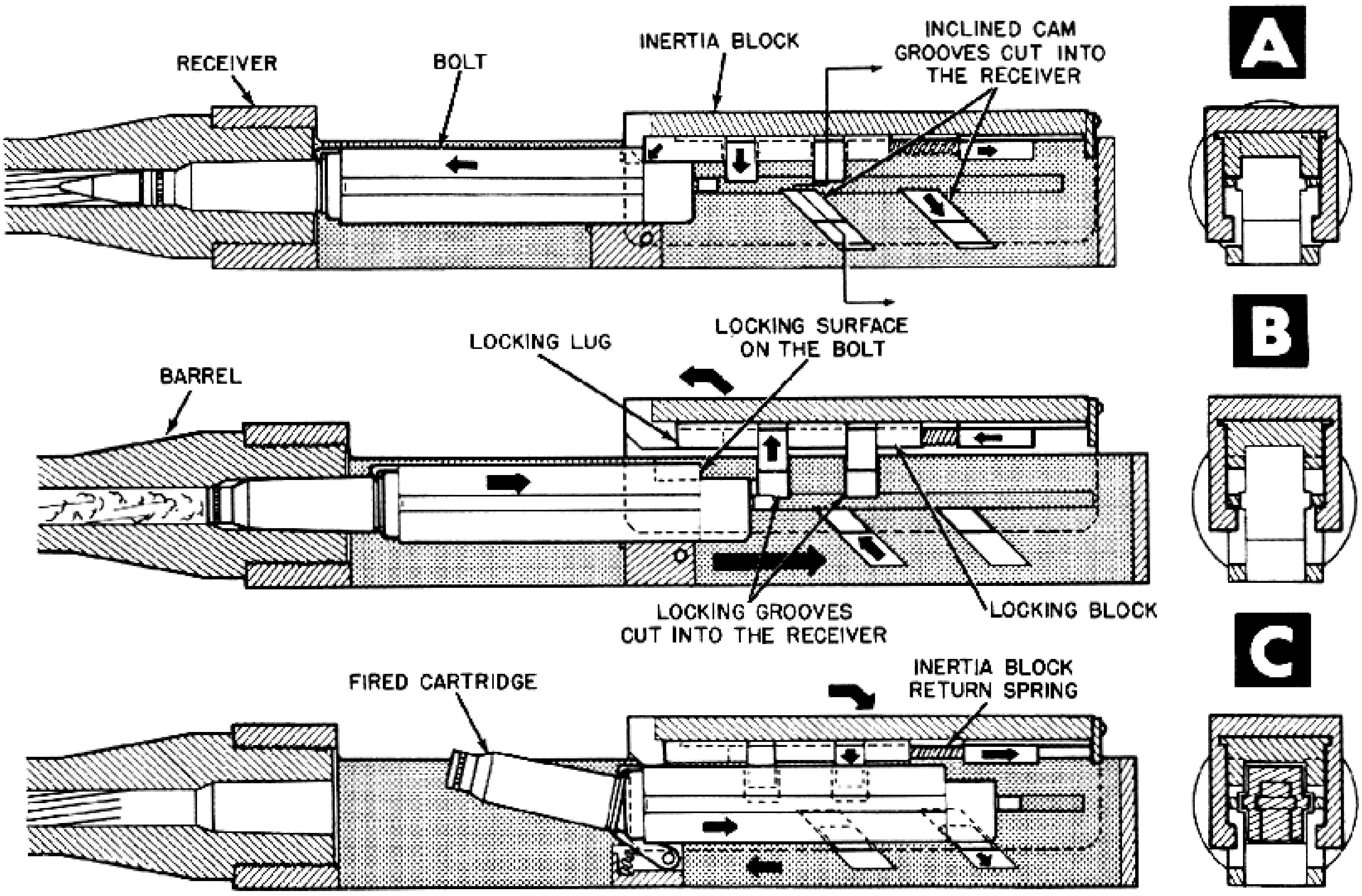


Figure 6–92. Recoiling Mass Unlocks Bolt.

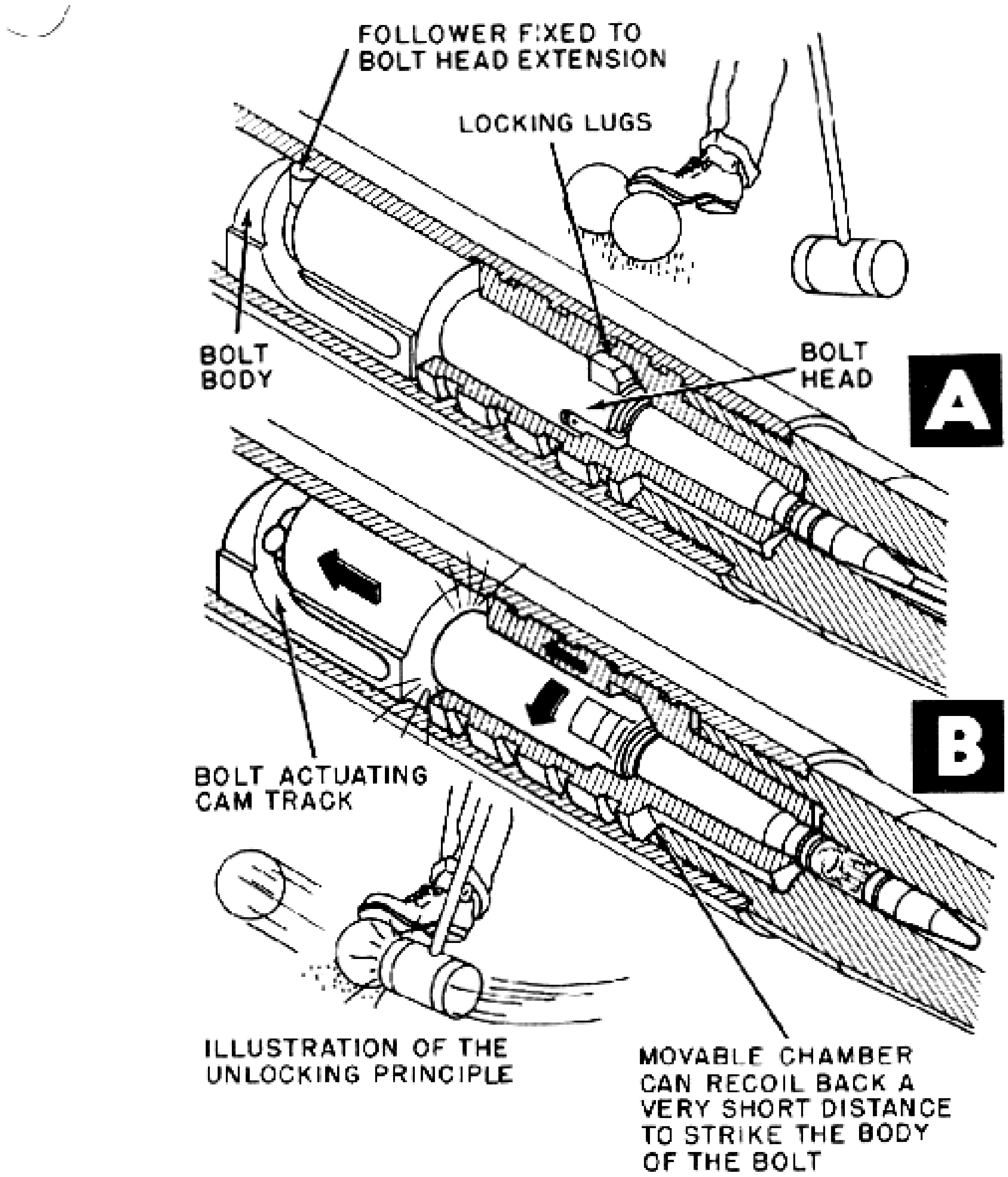


Figure 6–93. Impact of Recoiling Chamber Unlocks Bolt.

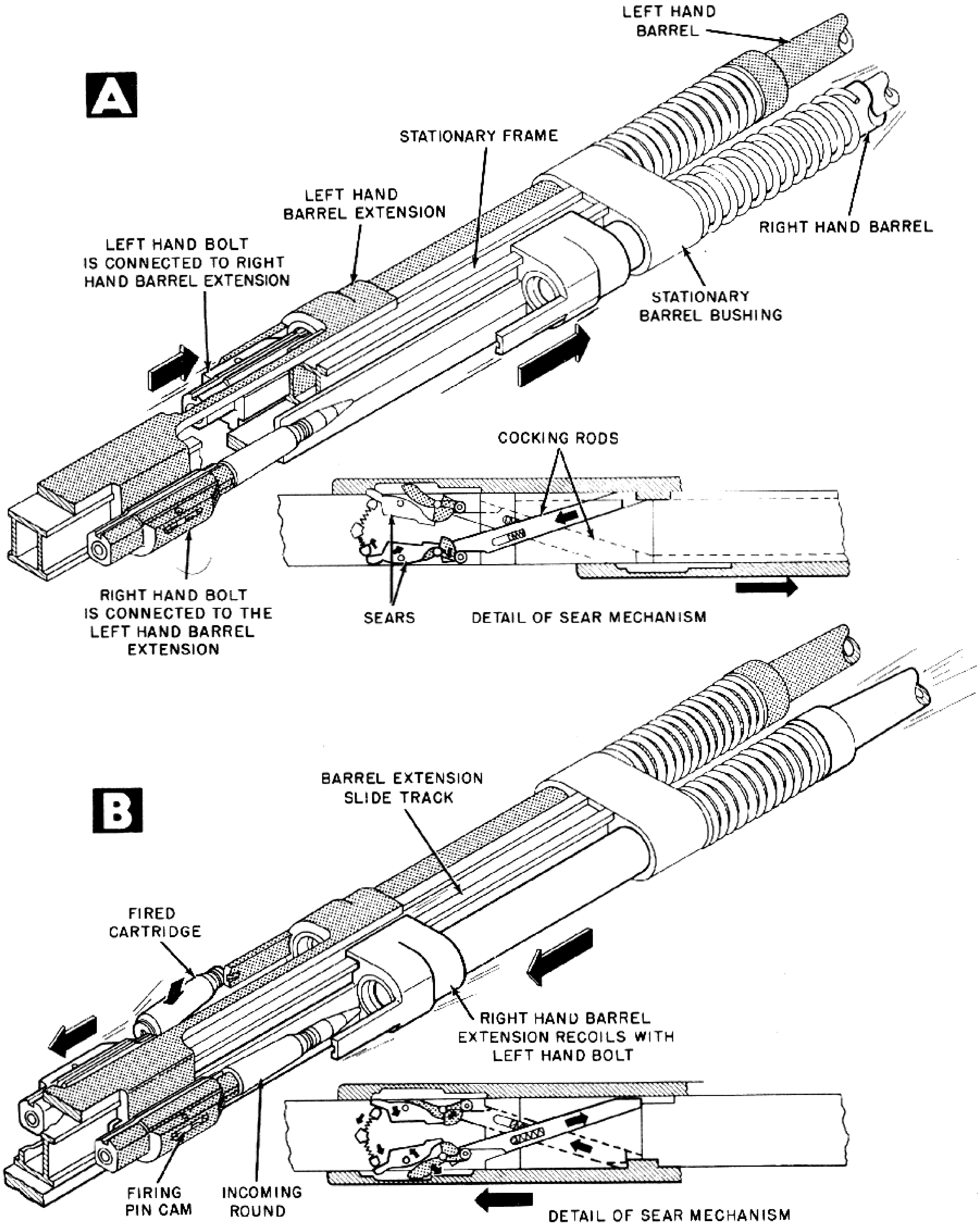
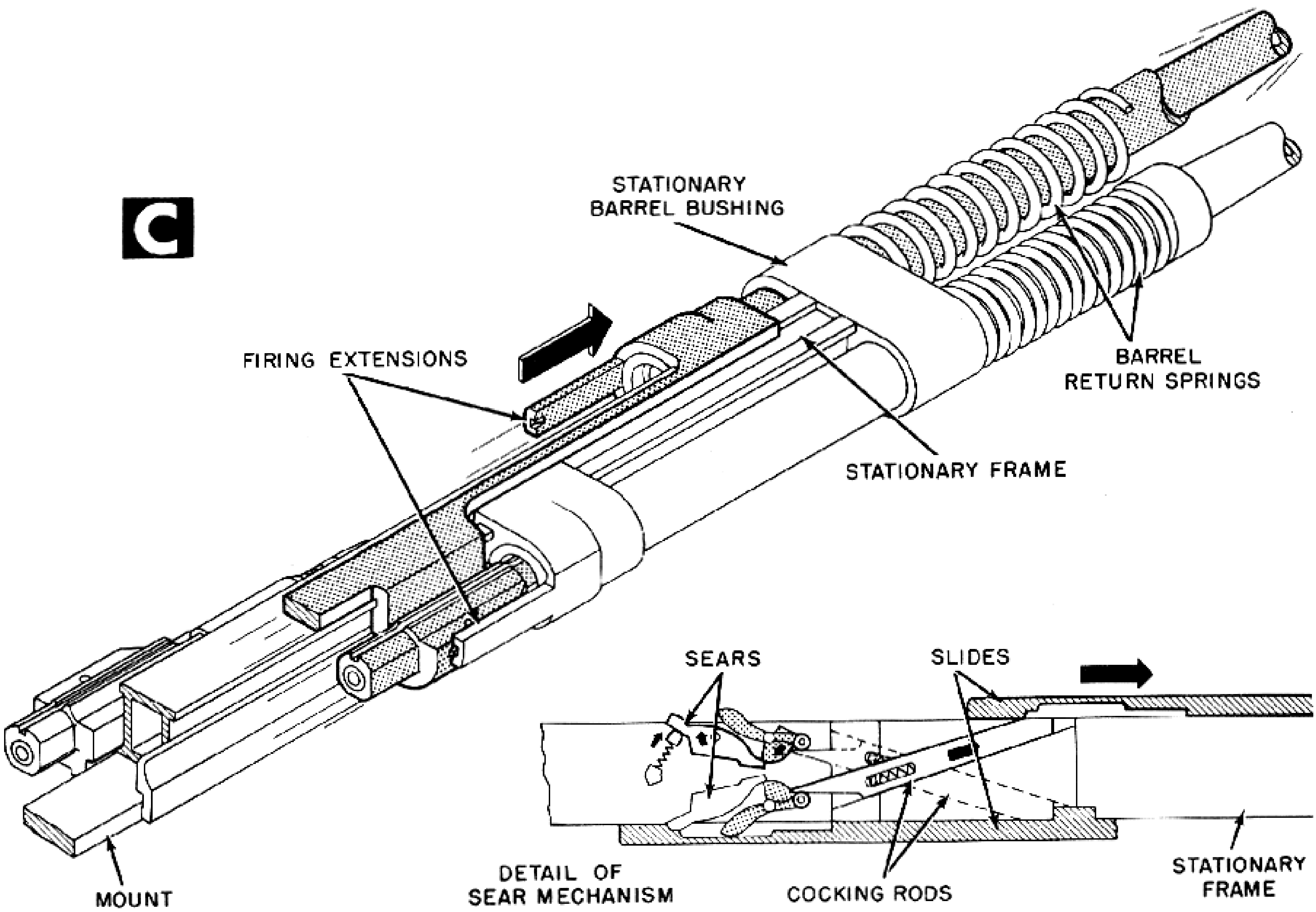


Figure 6–94. Double Barrel



Retarded Blowback Gun.

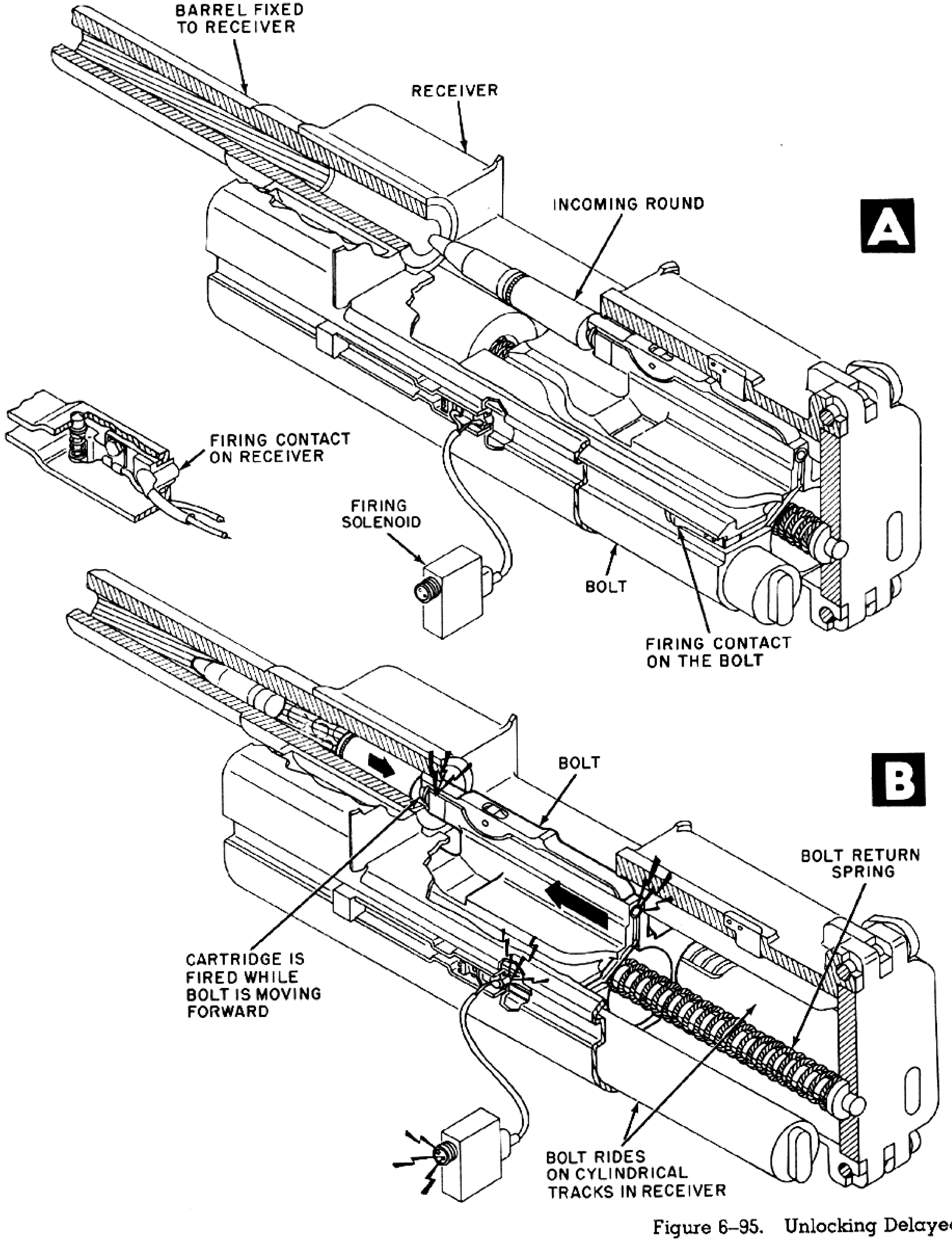
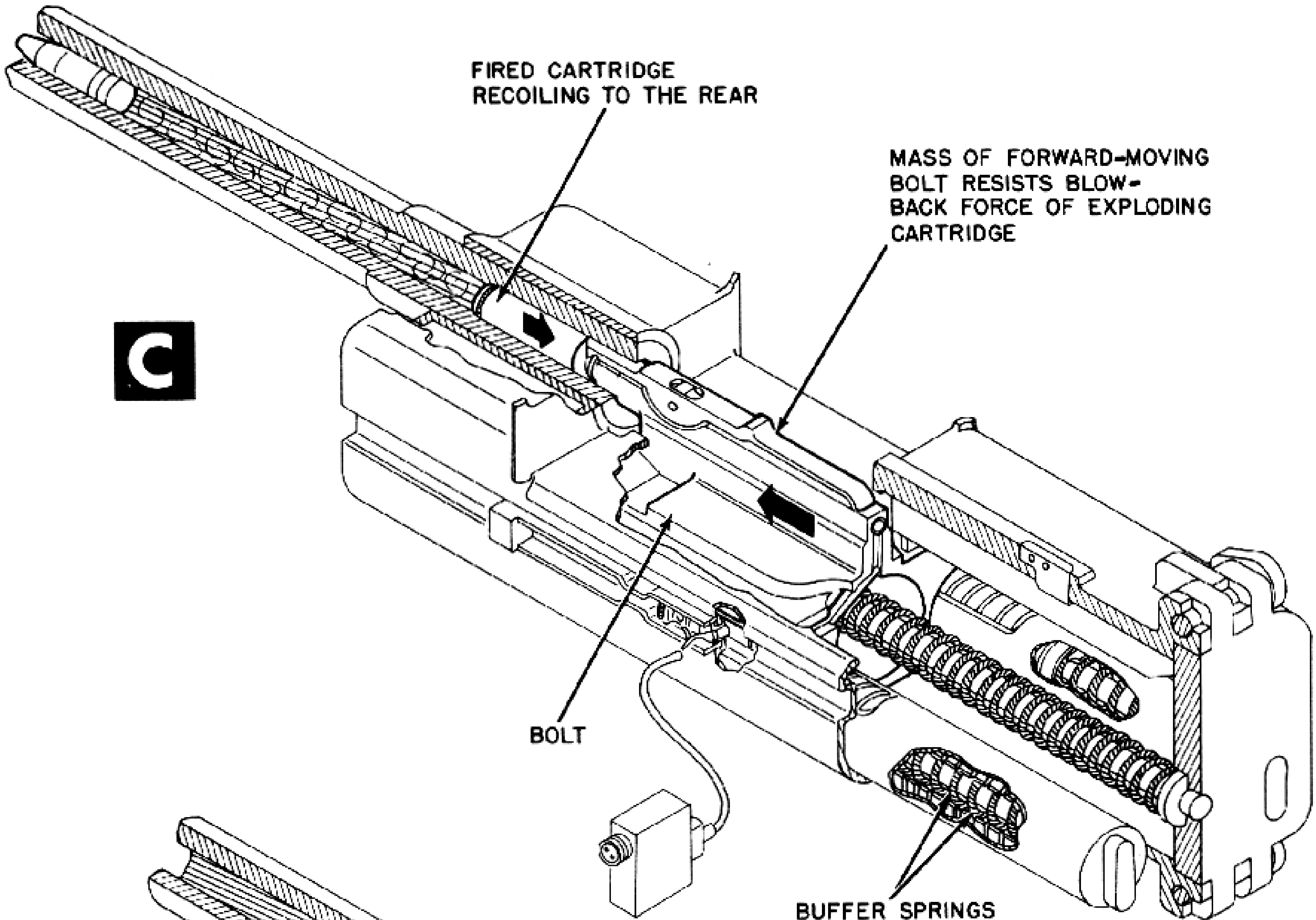
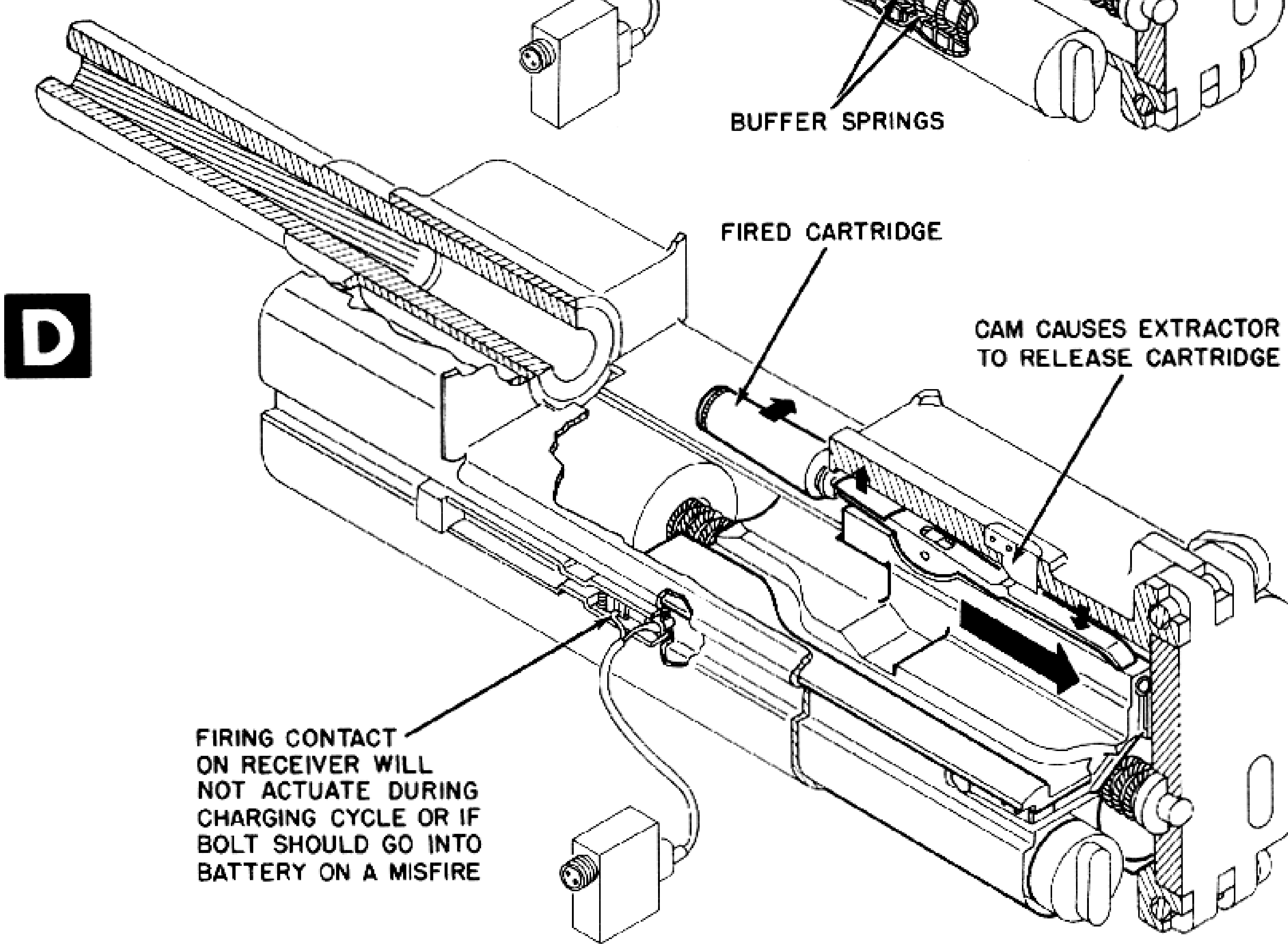


Figure 6–95. Unlocking Delayed





by Inertia of Moving Bolt.

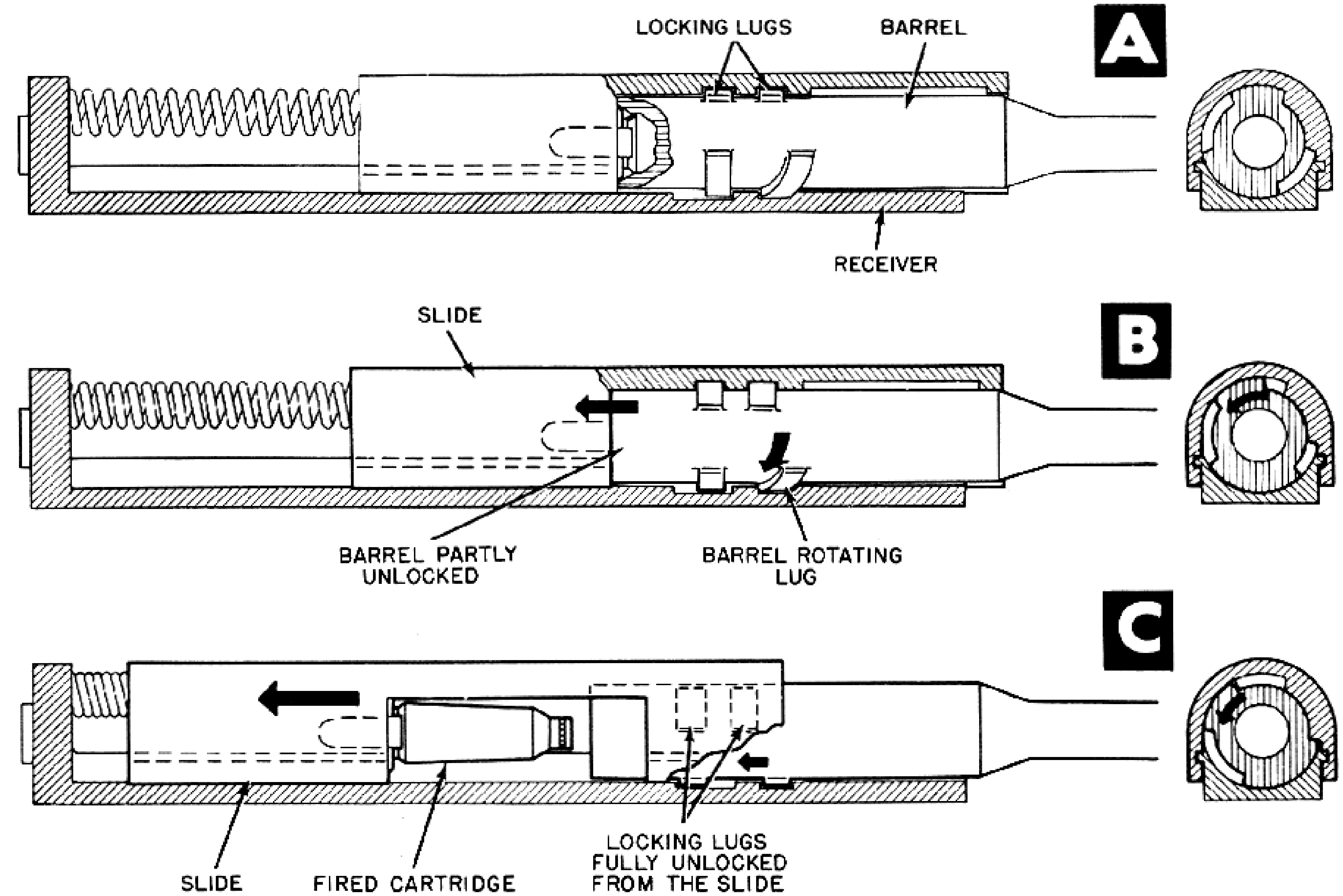


Figure 6–96. Recoiling Barrel Is Rotated Free of the Slide.

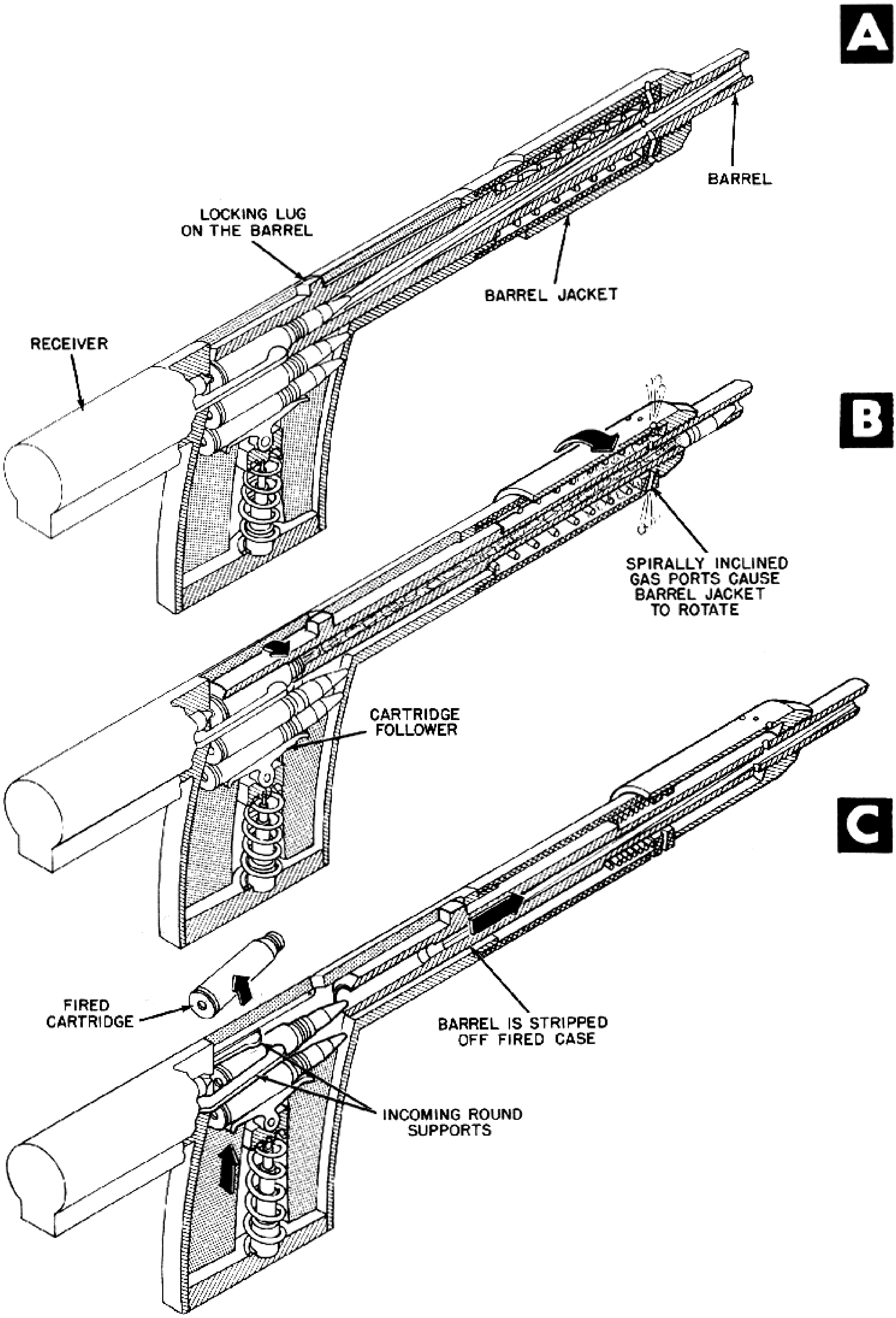


Figure 6–97. Rotating Gases Unlock and Blow Barrel Forward.

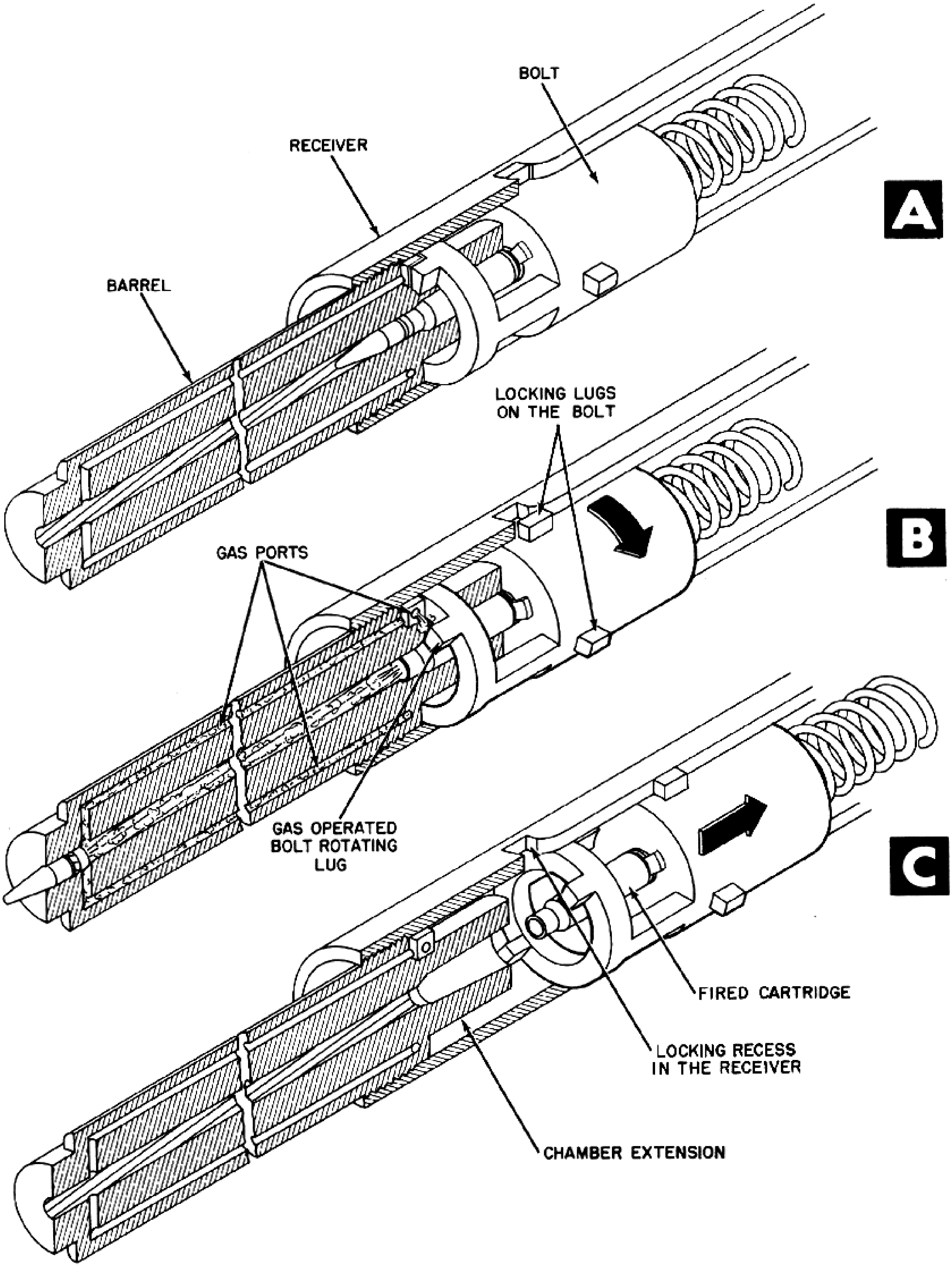


Figure 6–98. Gas Pressure Rotates Bolt to Unlocked Position.

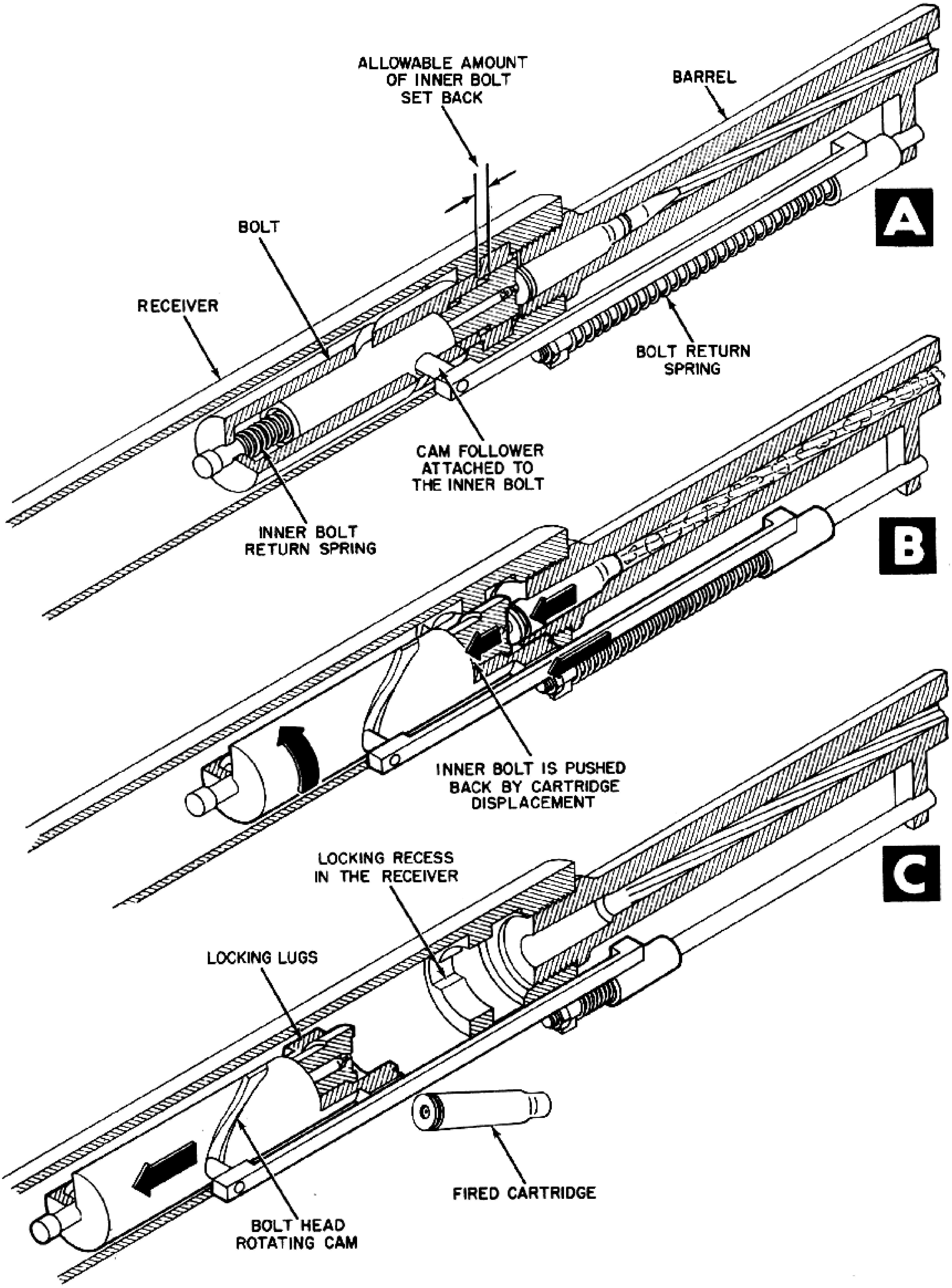


Figure 6–99. Recoiling Cartridge Case Unlocks Bolt.

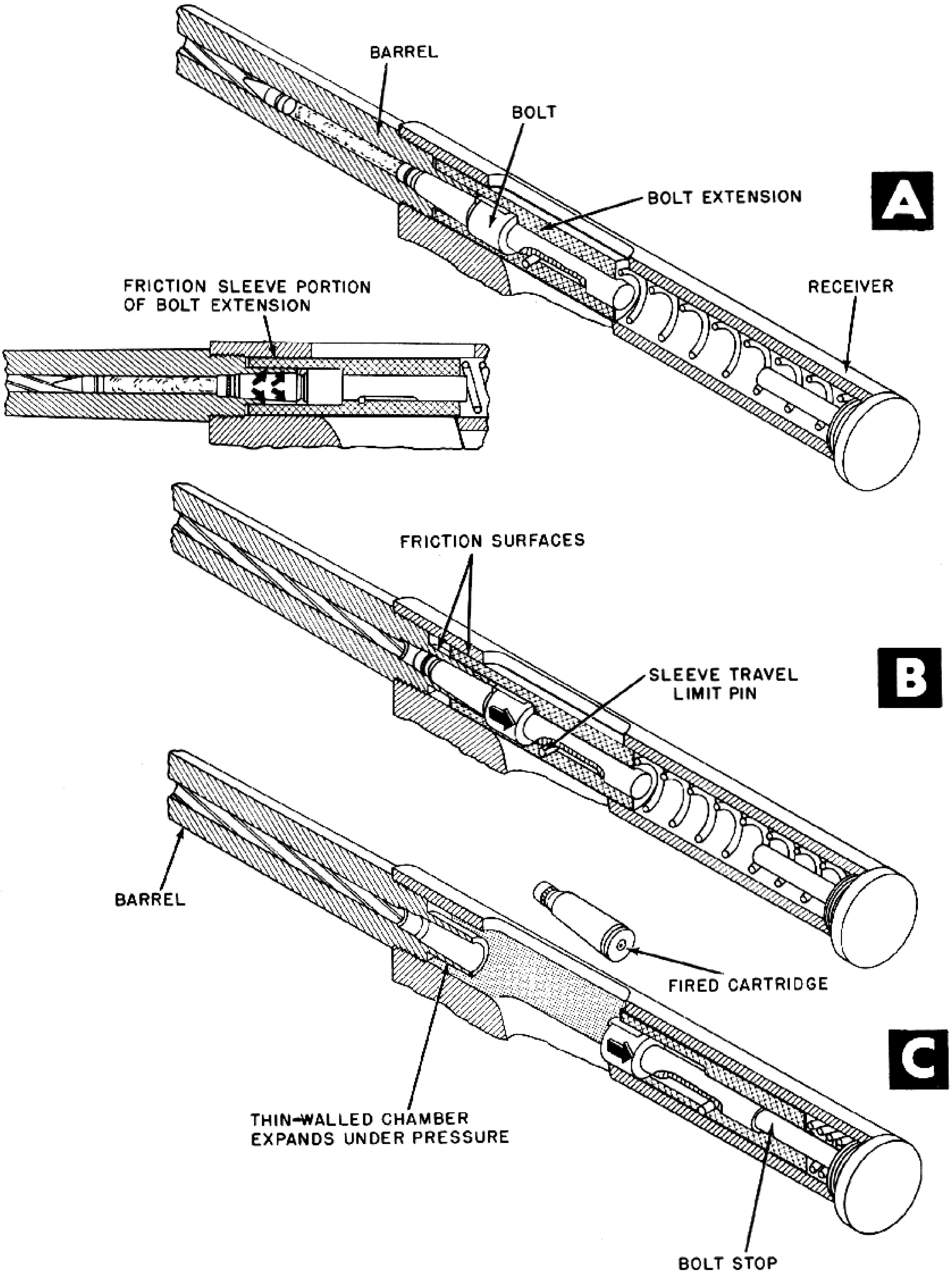


Figure 6–100. Expansion of Chamber Locks Bolt to Barrel.

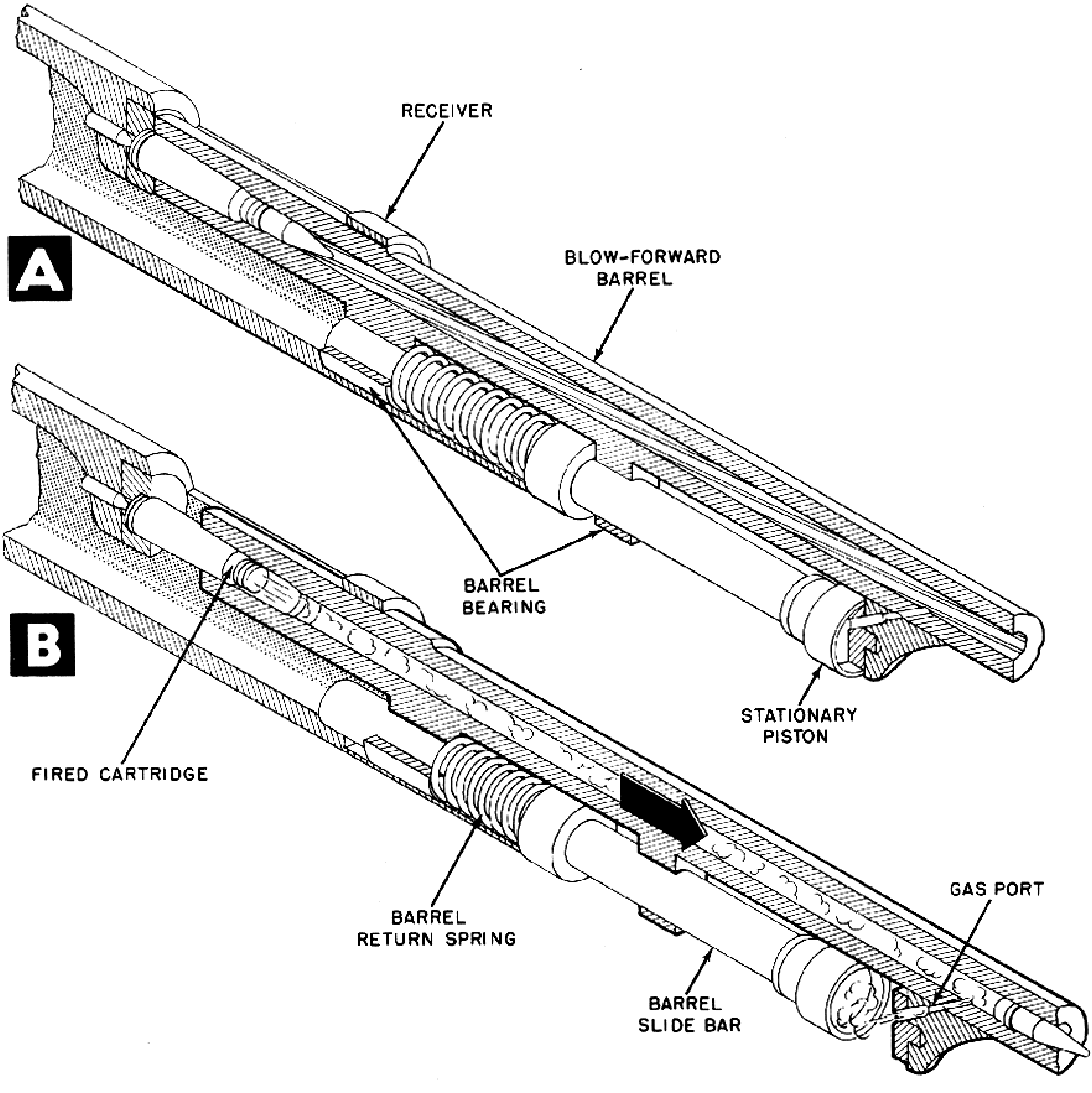


Figure 6–101. Barrel Is Blown Forward by Gases Acting on a Solid Piston.

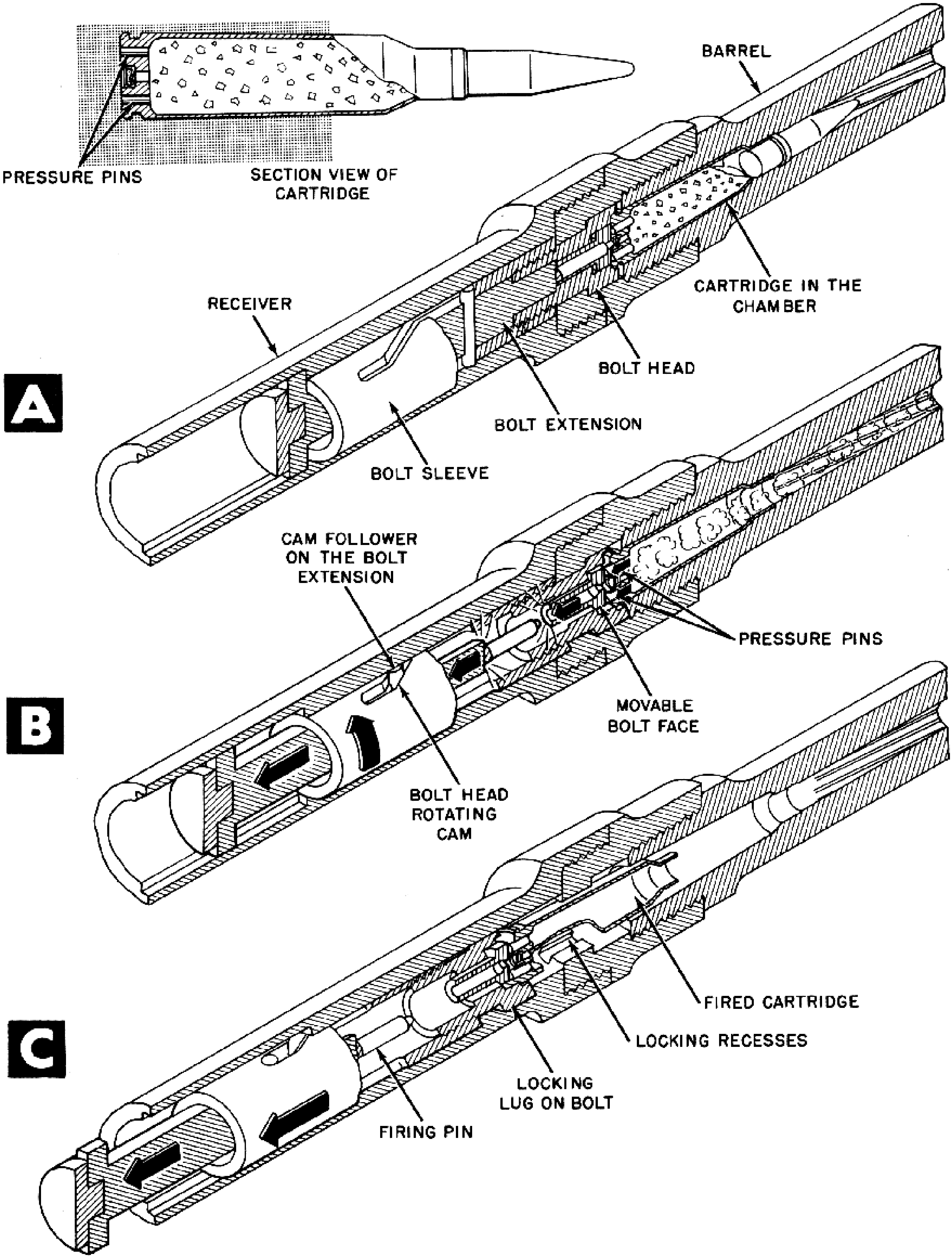


Figure 6–102. Pins in Base of Cartridge Unlock Bolt.

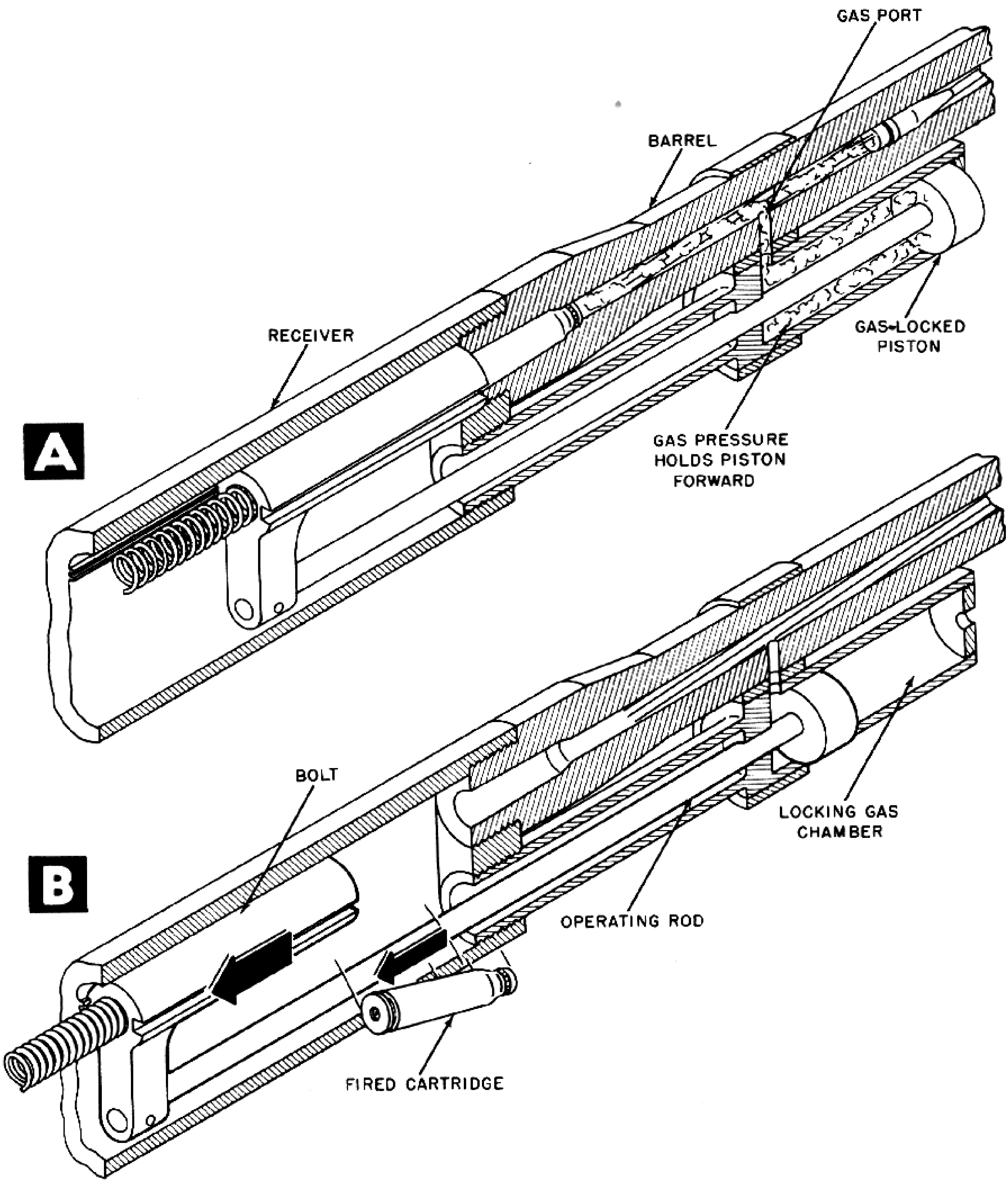


Figure 6–103. Bolt Is Locked to Barrel by Gas Pressure.

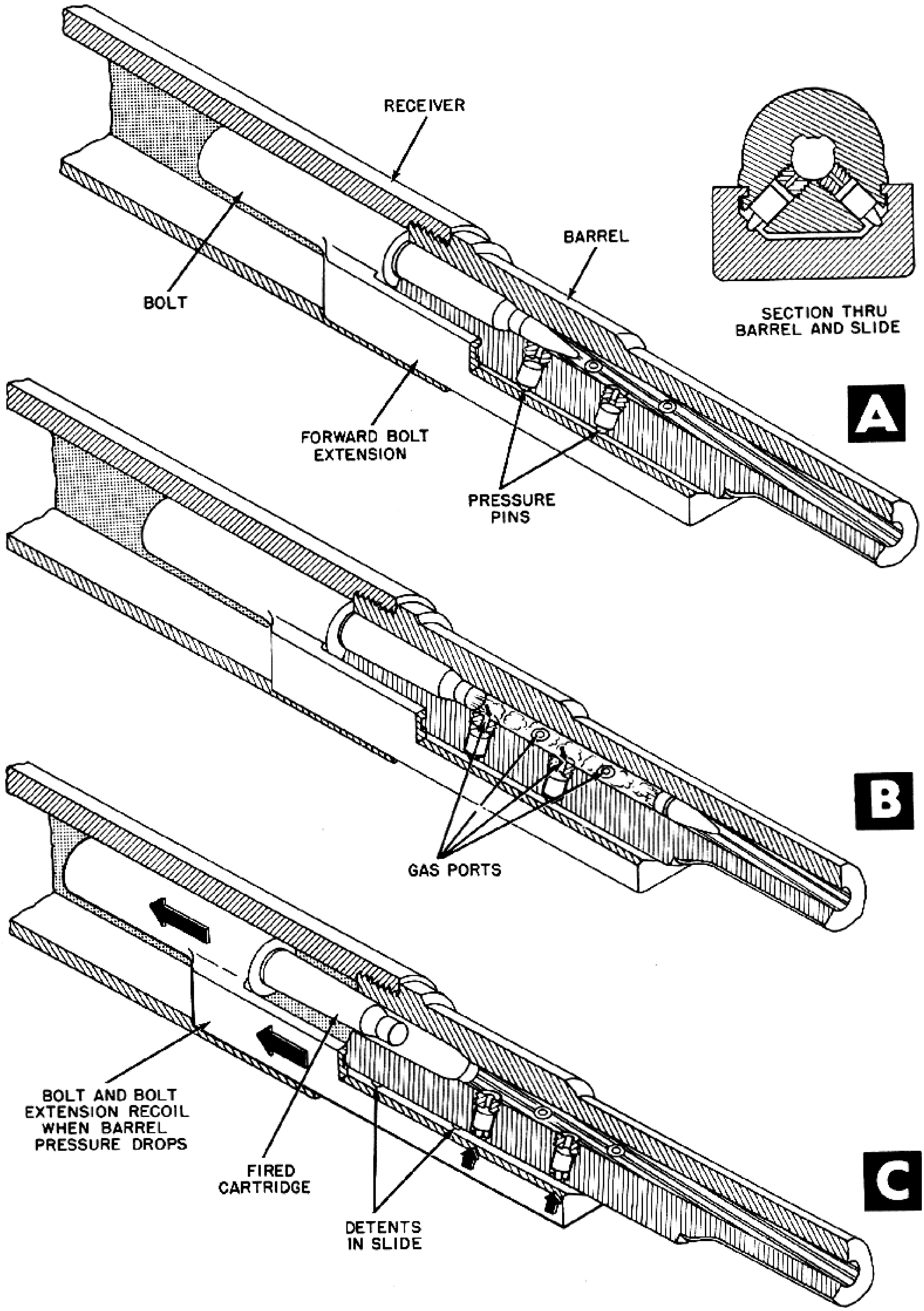


Figure 6–104. Bolt Is Locked to Barrel by Gas Pressure.

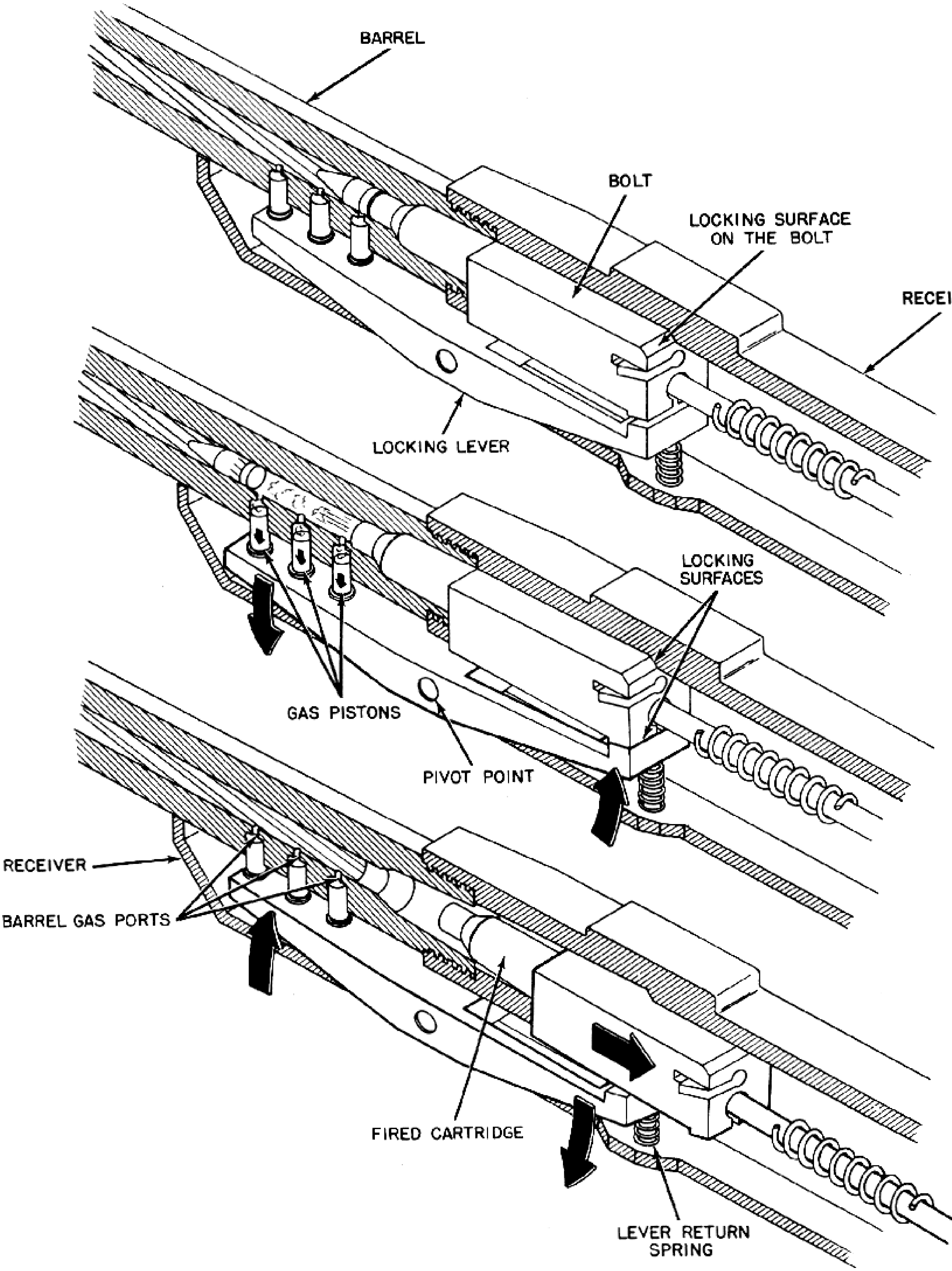


Figure 6–105. Gas Pressure Acting on Lever Locks Bolt.

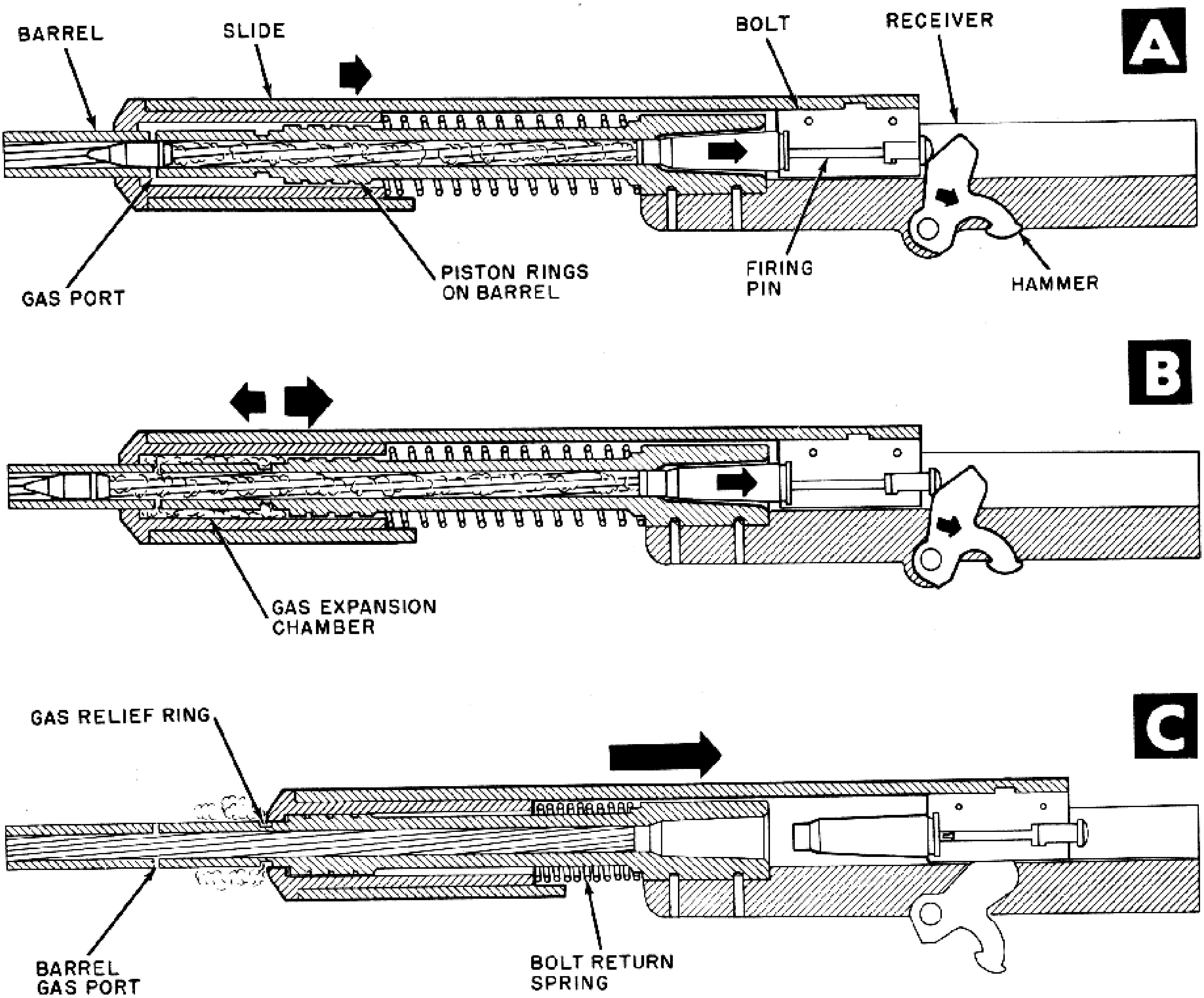


Figure 6–106. Gas Pressure Acting on Slide Retards Unlocking.

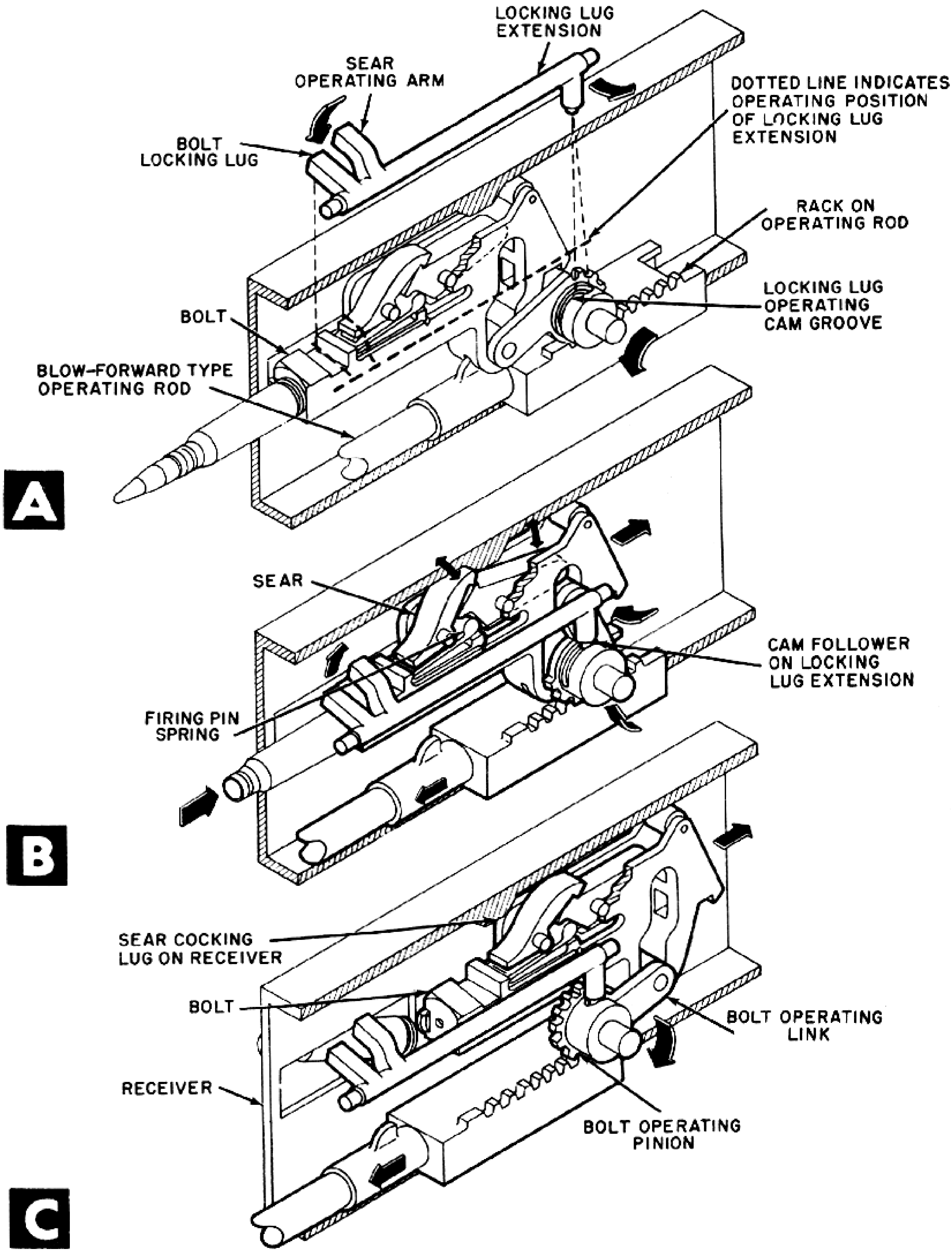


Figure 6–107. Cam Groove on Pinion Unlocks Bolt.

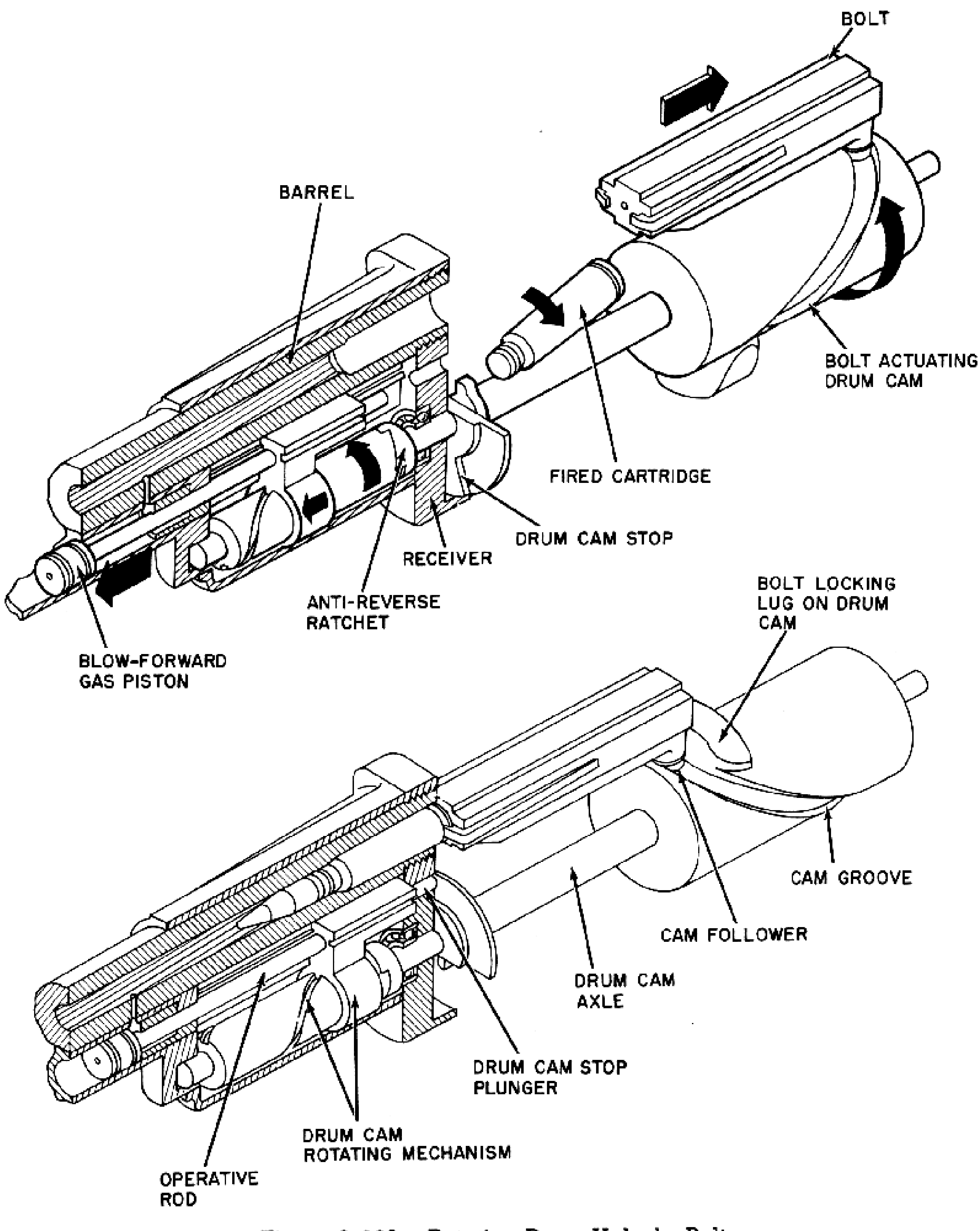


Figure 6–108. Rotating Drum Unlocks Bolt.

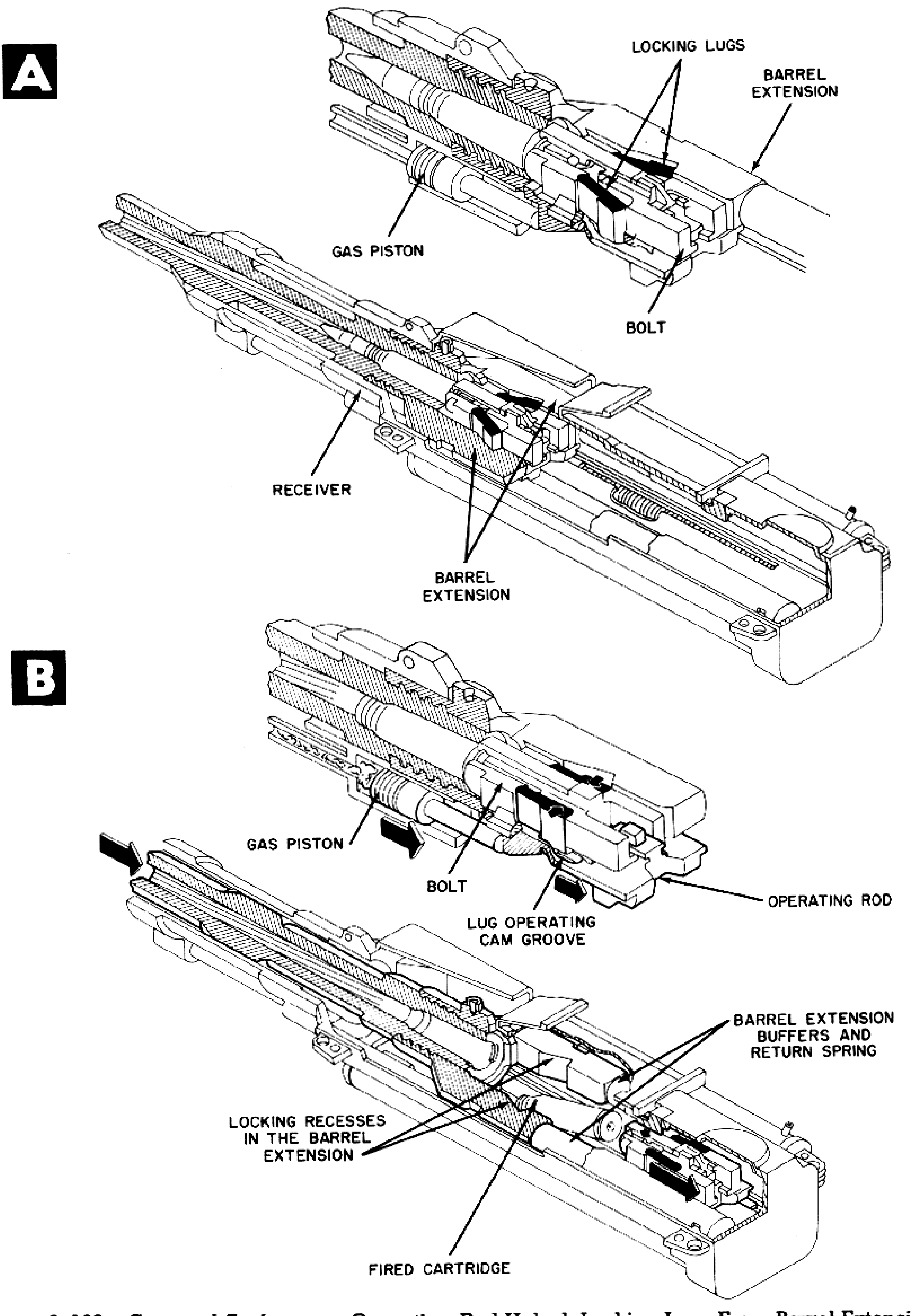


Figure 6–109. Cammed Surfaces on Operating Rod Unlock Locking Lugs From Barrel Extension.

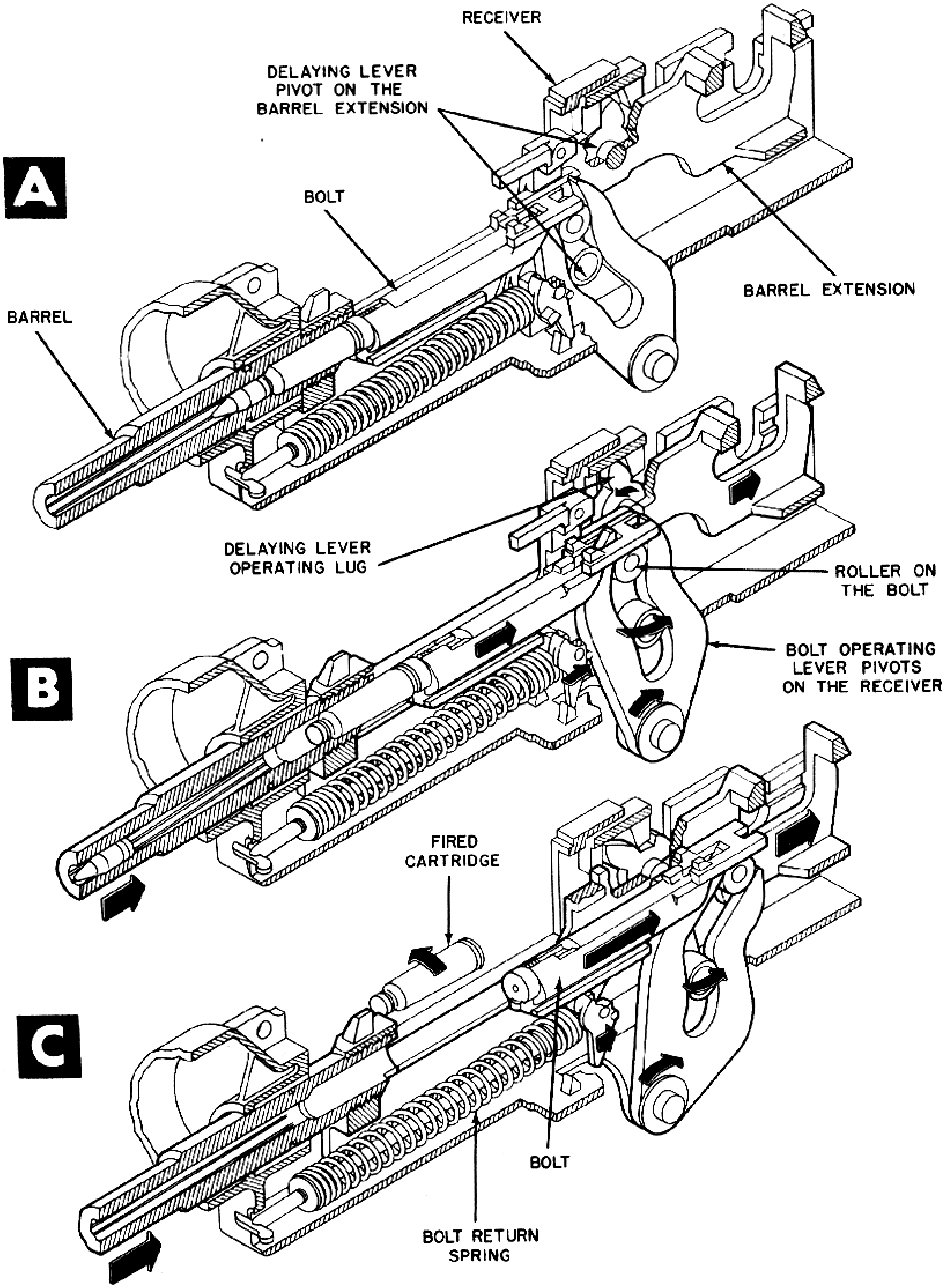


Figure 6–110. Unlocking Is Delayed by Action of Cams and Springs.

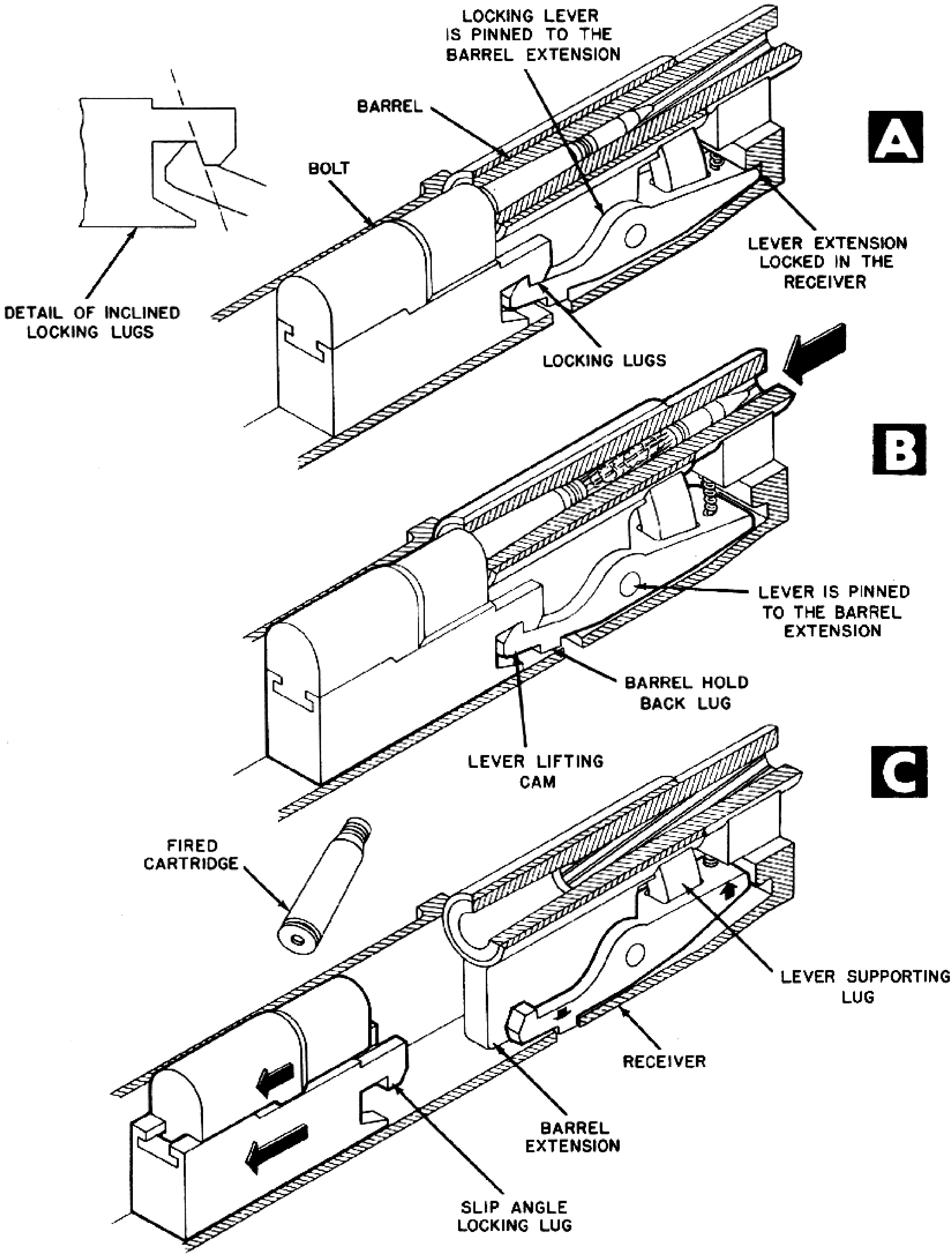


Figure 6-111. Lever on Barrel Extension Locks Bolt to Barrel.

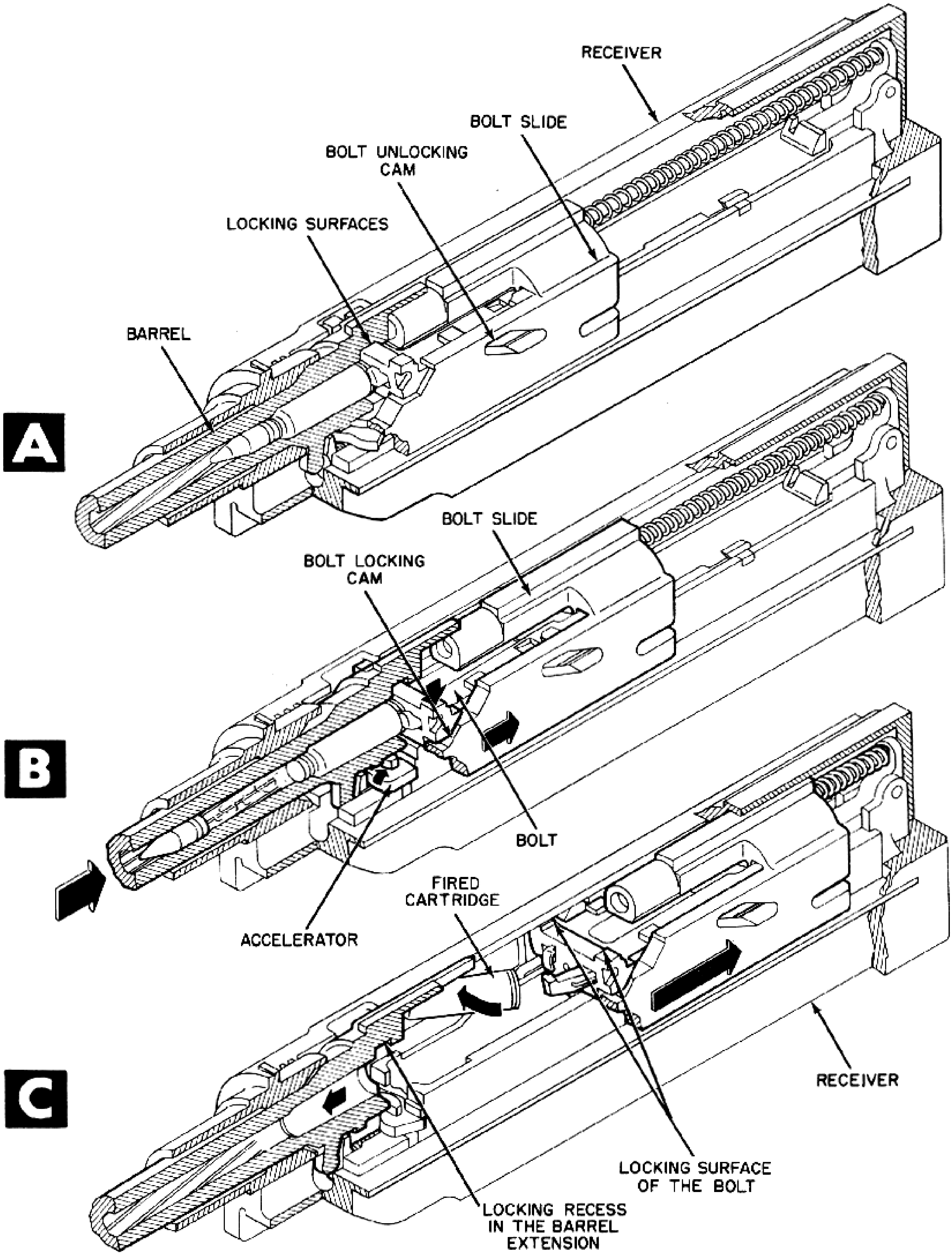


Figure 6–112. Recoiling Slide Cams Locking Lug Free of Barrel Extension.

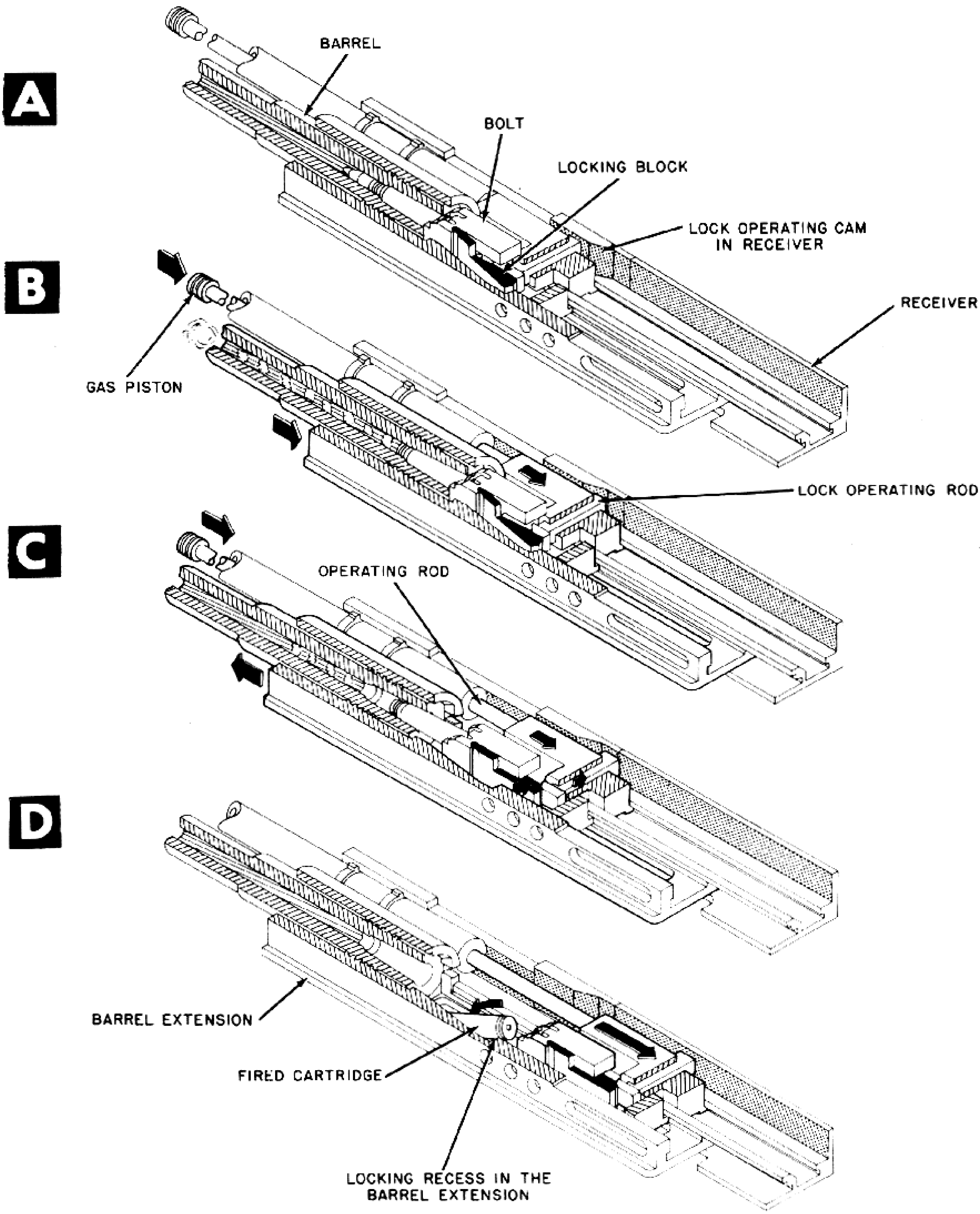


Figure 6–113. Operating Rod Removes Prop From Locking Lug. Gas Pressure Forces Locking Lug Free of Receiver.

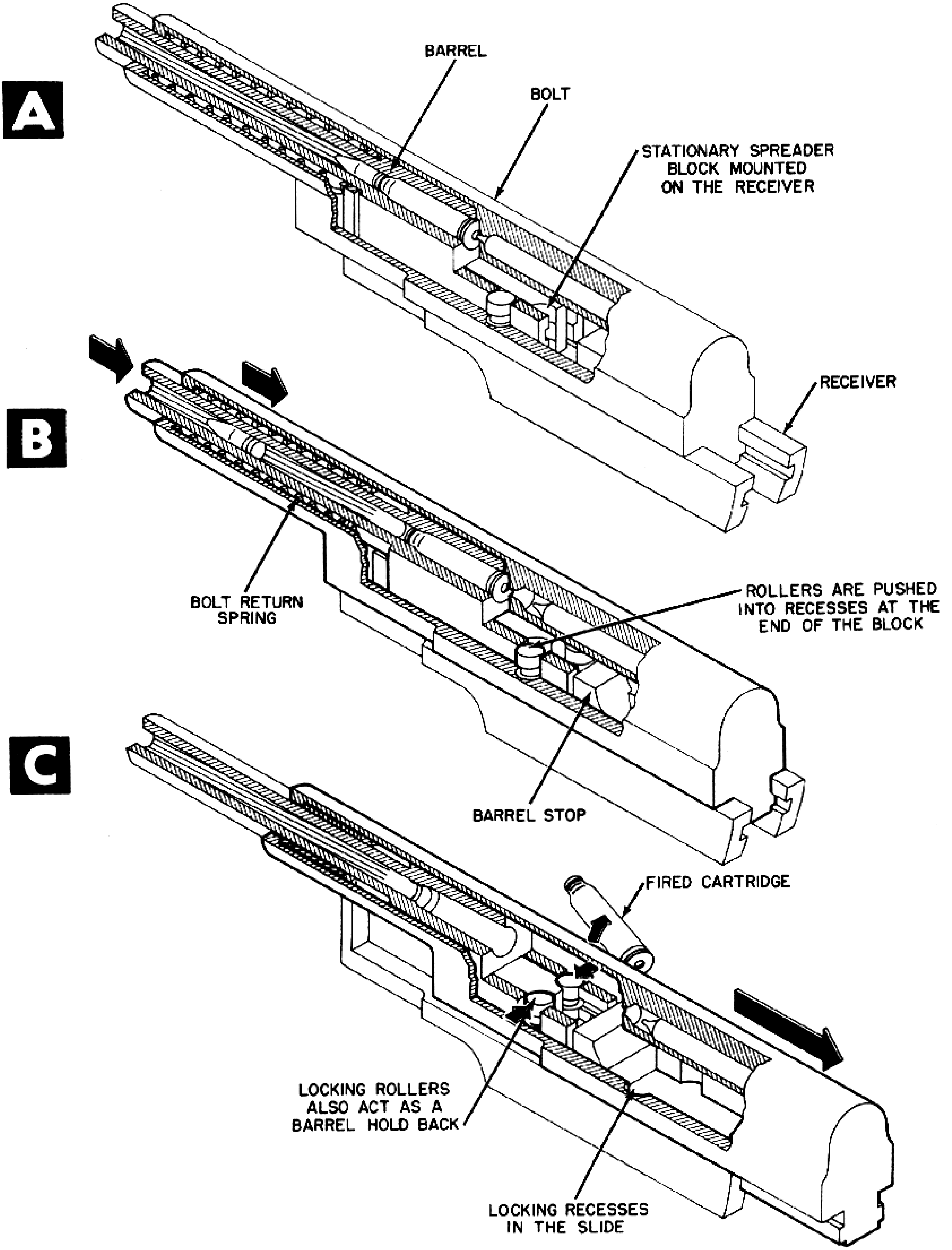


Figure 6–114. Bolt and Barrel Recoil to a Point Where Locking Rollers Are Forced Free of Bolt.

G. Caseless Cartridges

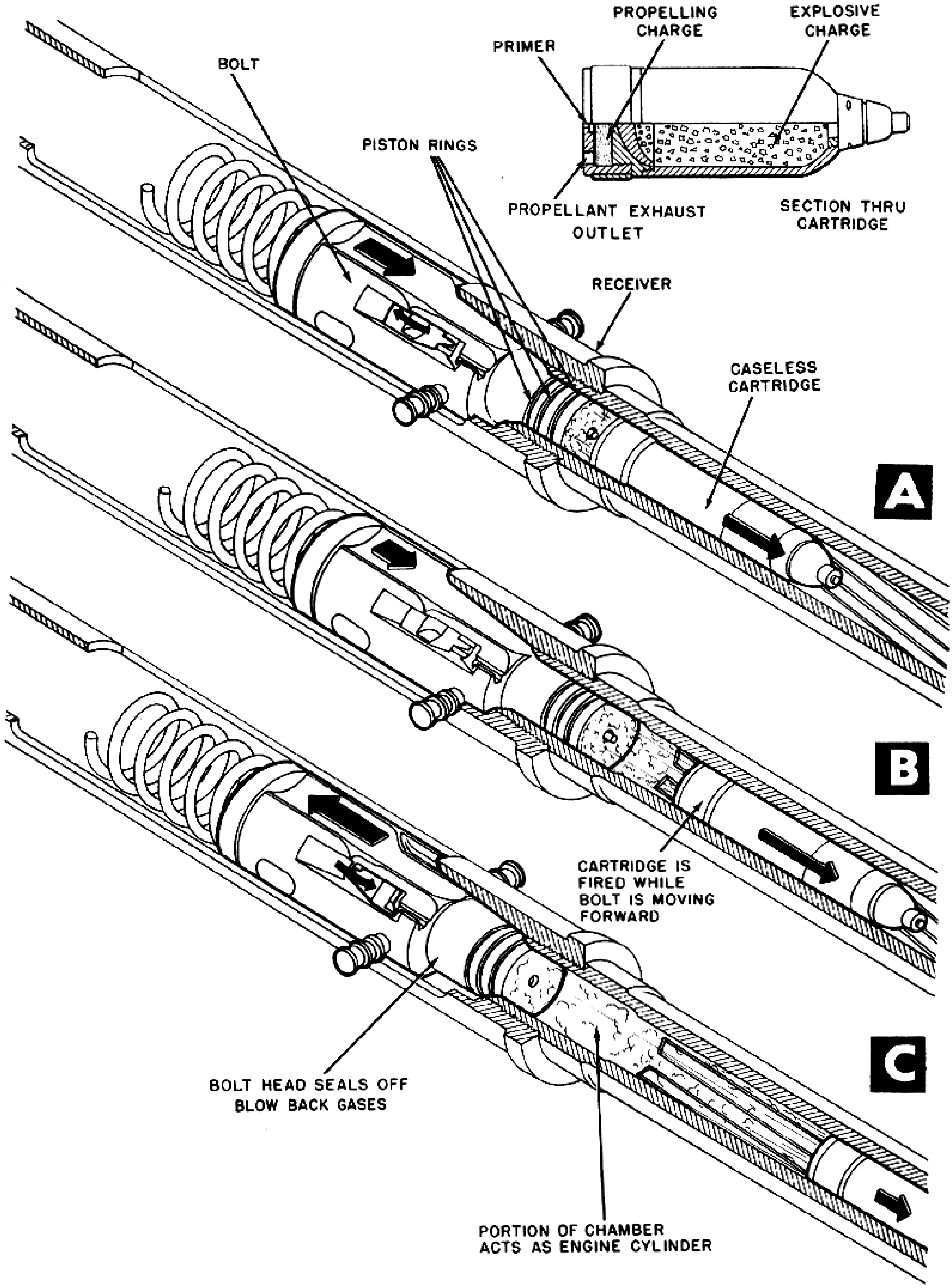


Figure 6–115. Piston Rings on Bolt Seal Bore. Complete Round Fired From Gun, Eliminating Extraction and Ejection.

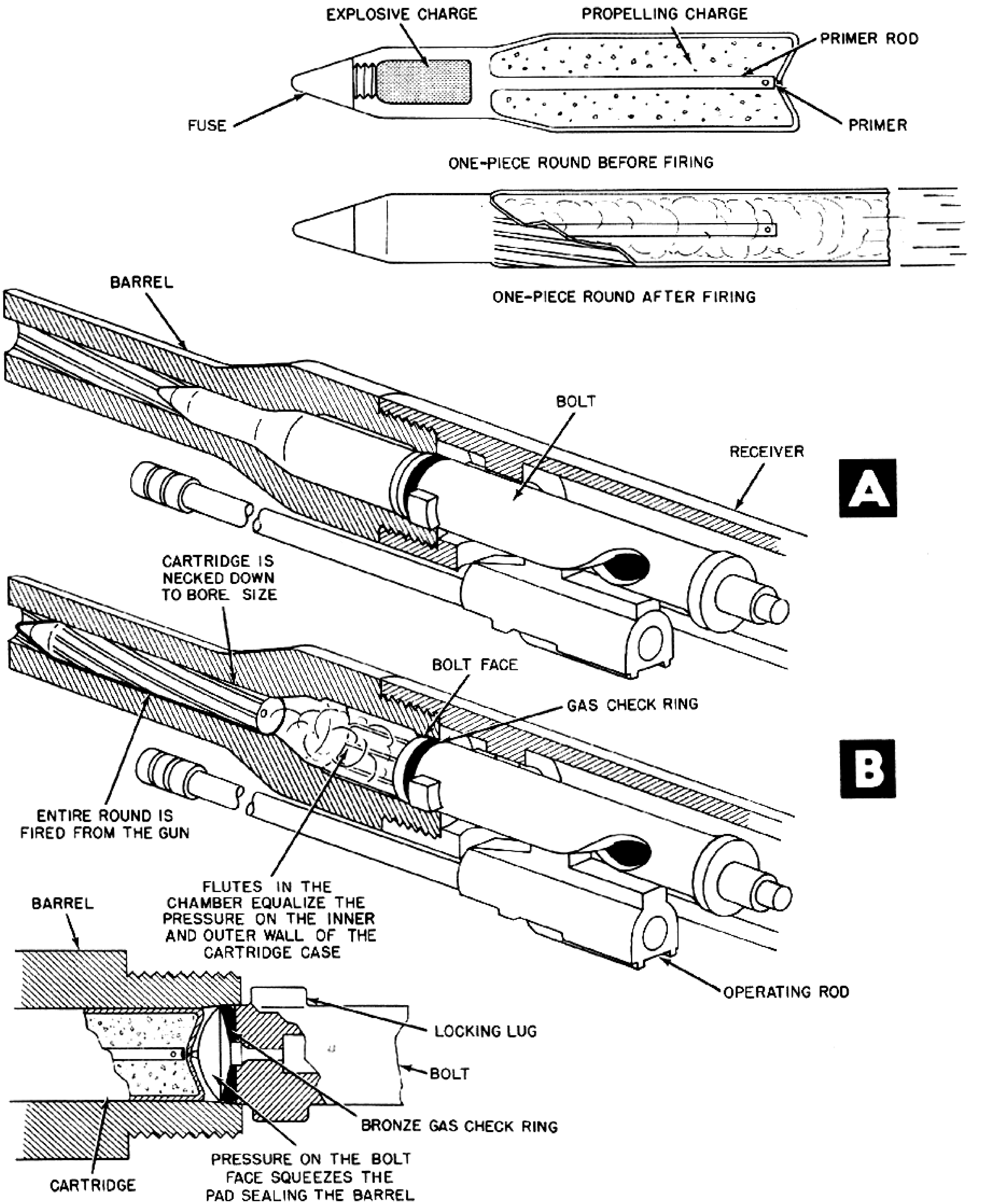


Figure 6–116. Gas Check Ring Seals Bore. Complete Round Fired From Gun, Eliminating Extraction and Ejection.

Chapter 7

ROTARY CHAMBER GUNS

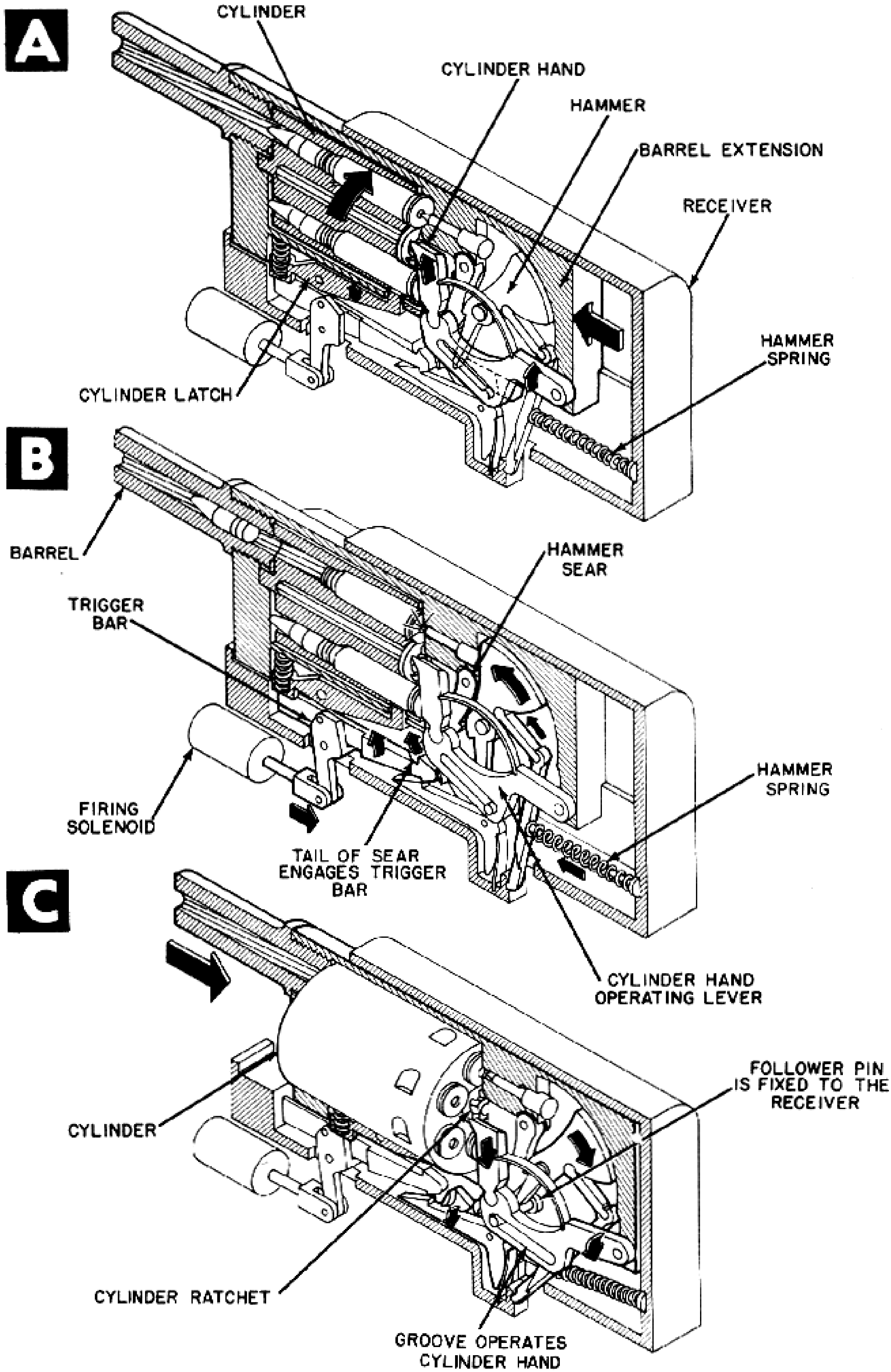


Figure 7–1. Operating Cycle of Recoil-Actuated Single-Barrel Rotary Cannon.

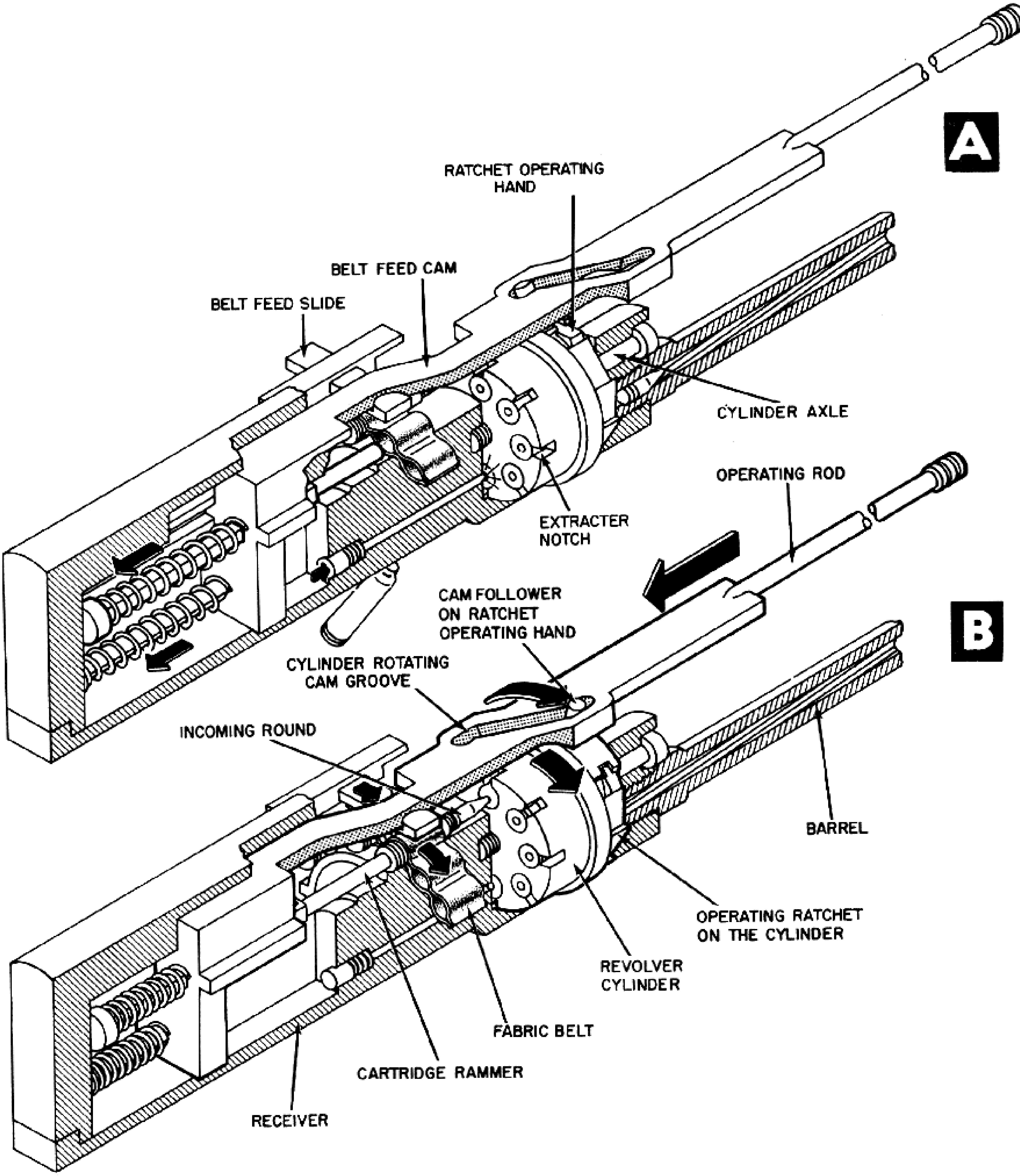
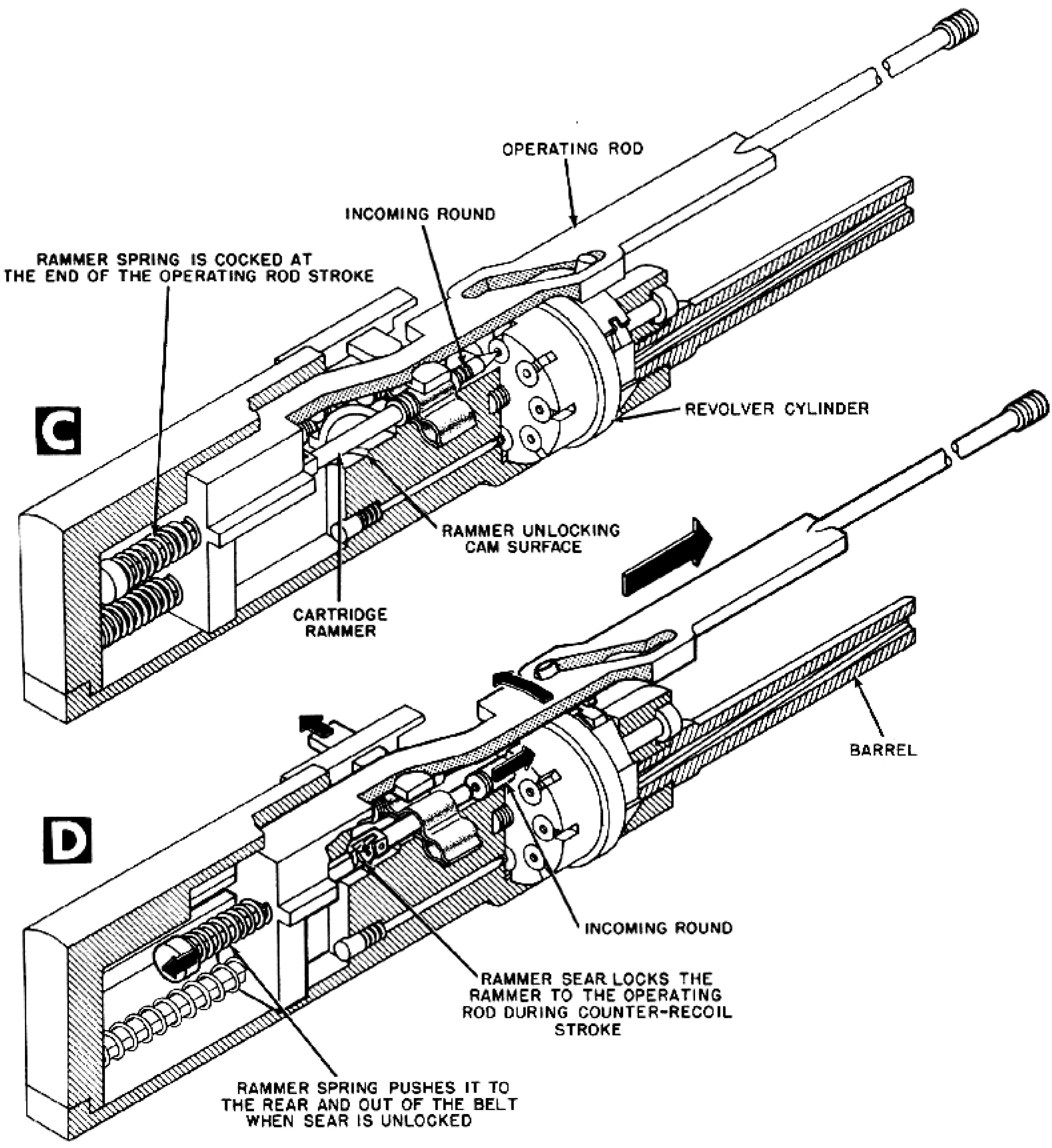


Figure 7–2. Operating Cycle of Gas-Actuated



Single-Barrel Rotary Cannon.

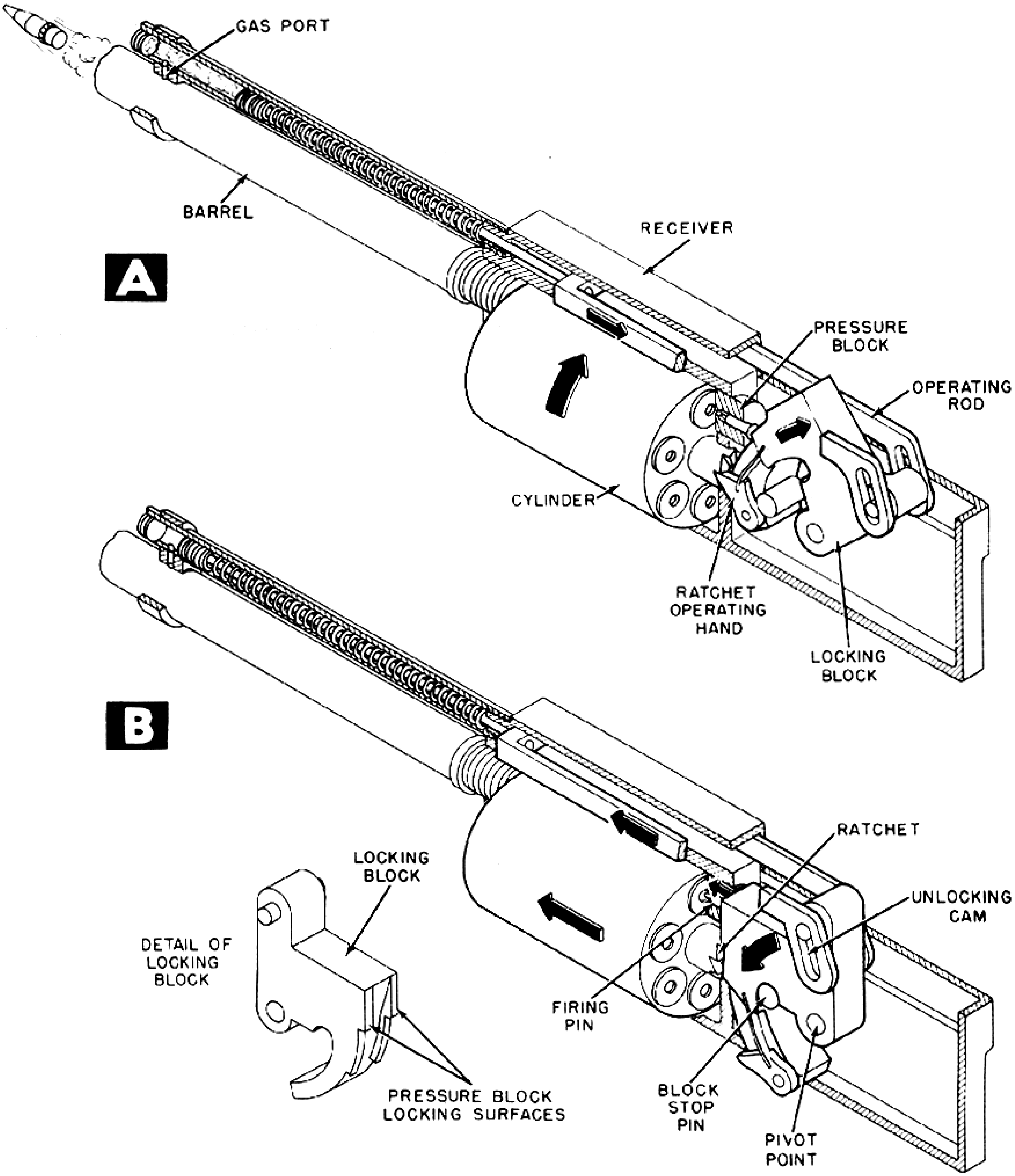


Figure 7–3. Operating Cycle of Gas-Actuated Single-Barrel Rotary Cannon. Action Locks Cylinder to Barrel.

A
B
C

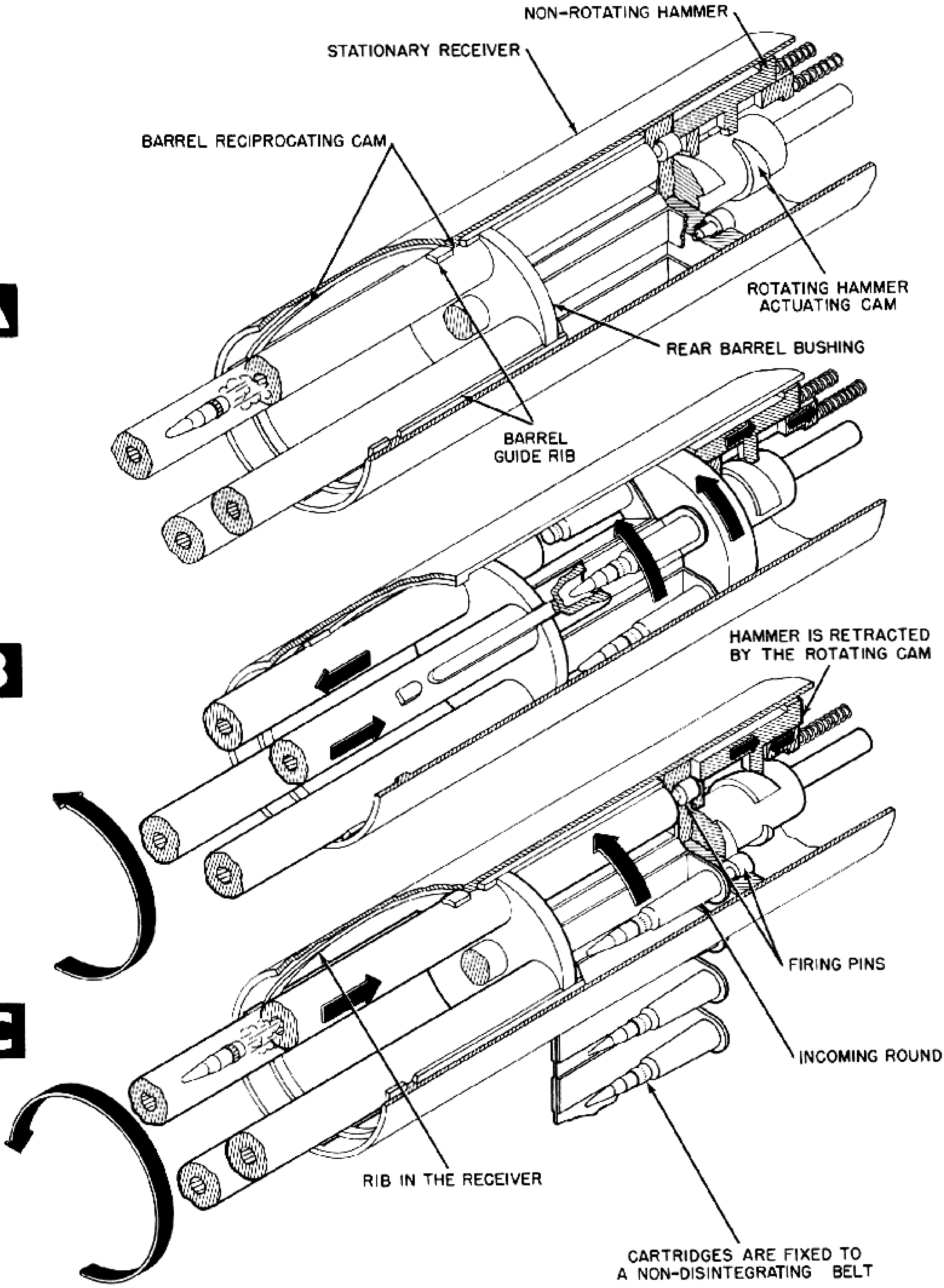


Figure 7–4. Operating Cycle of Multi-Barrel Rotary Cannon.

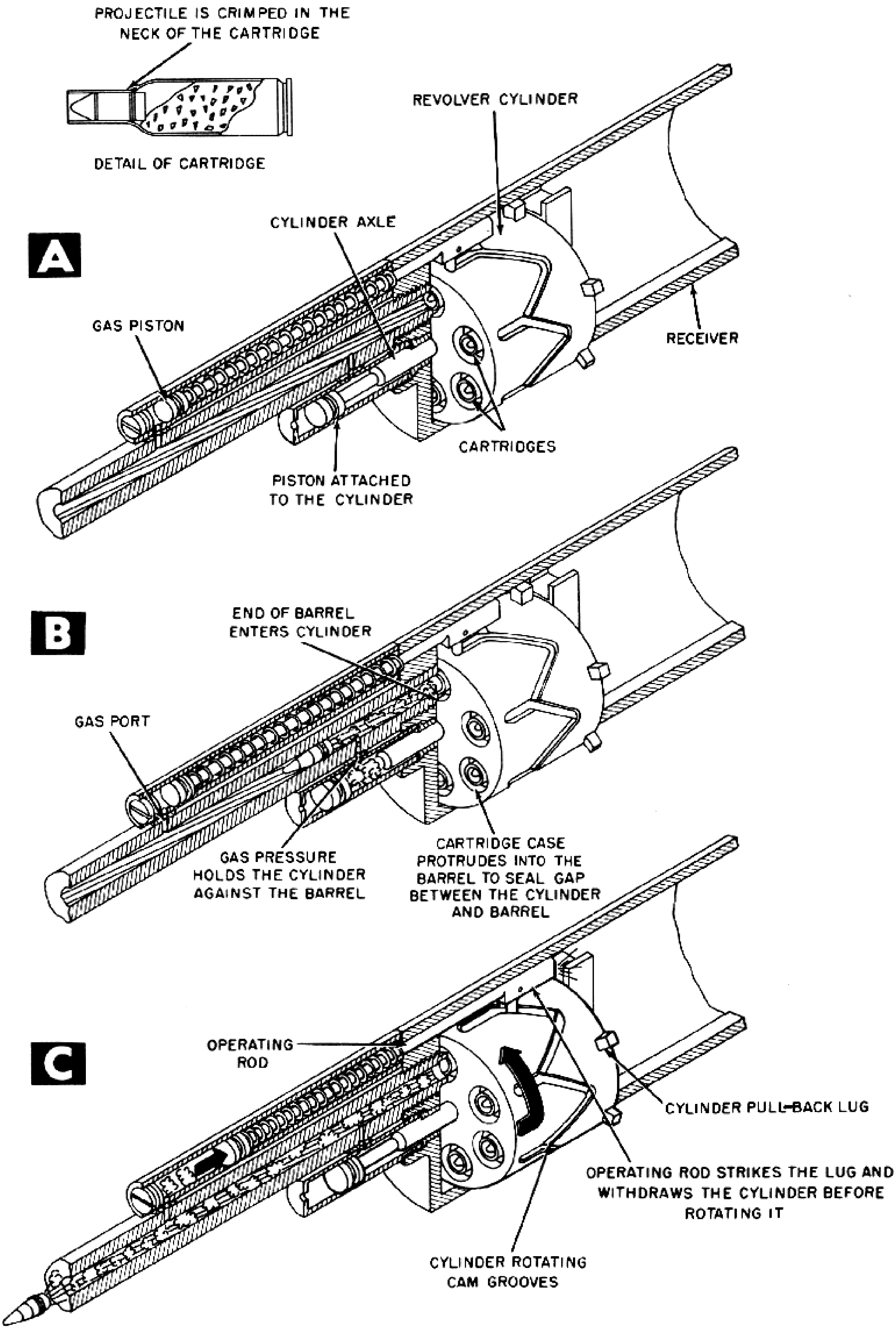


Figure 7–5. Operating Cycle of Gas-Actuated Single-Barrel Rotary Cannon. Gas Pressure and Cartridge Case Seal Bore.

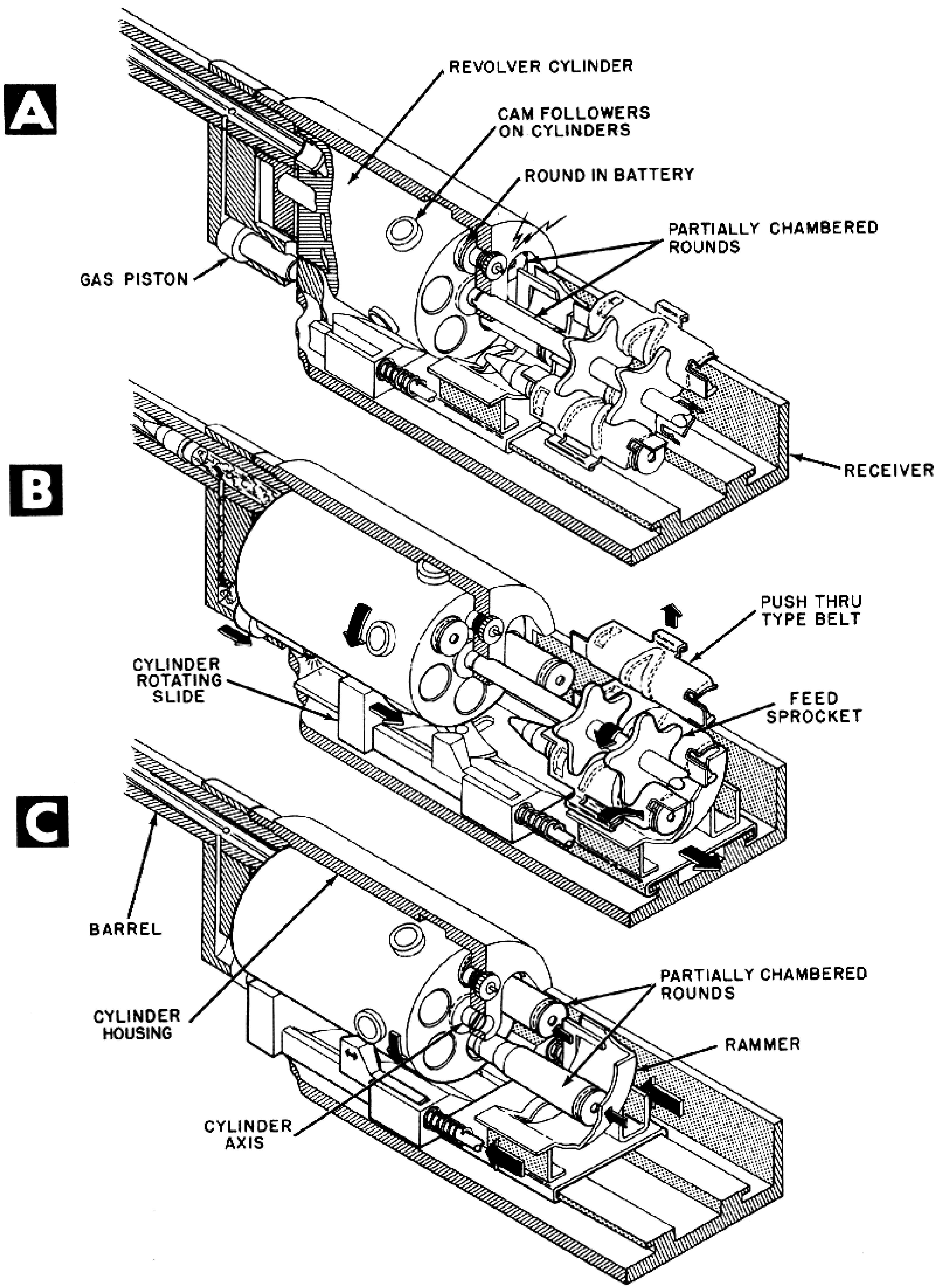


Figure 7–6. Operating Cycle of Gas-Actuated Single-Barrel Rotary Cannon. Bore Sealed by Obturating Ring.

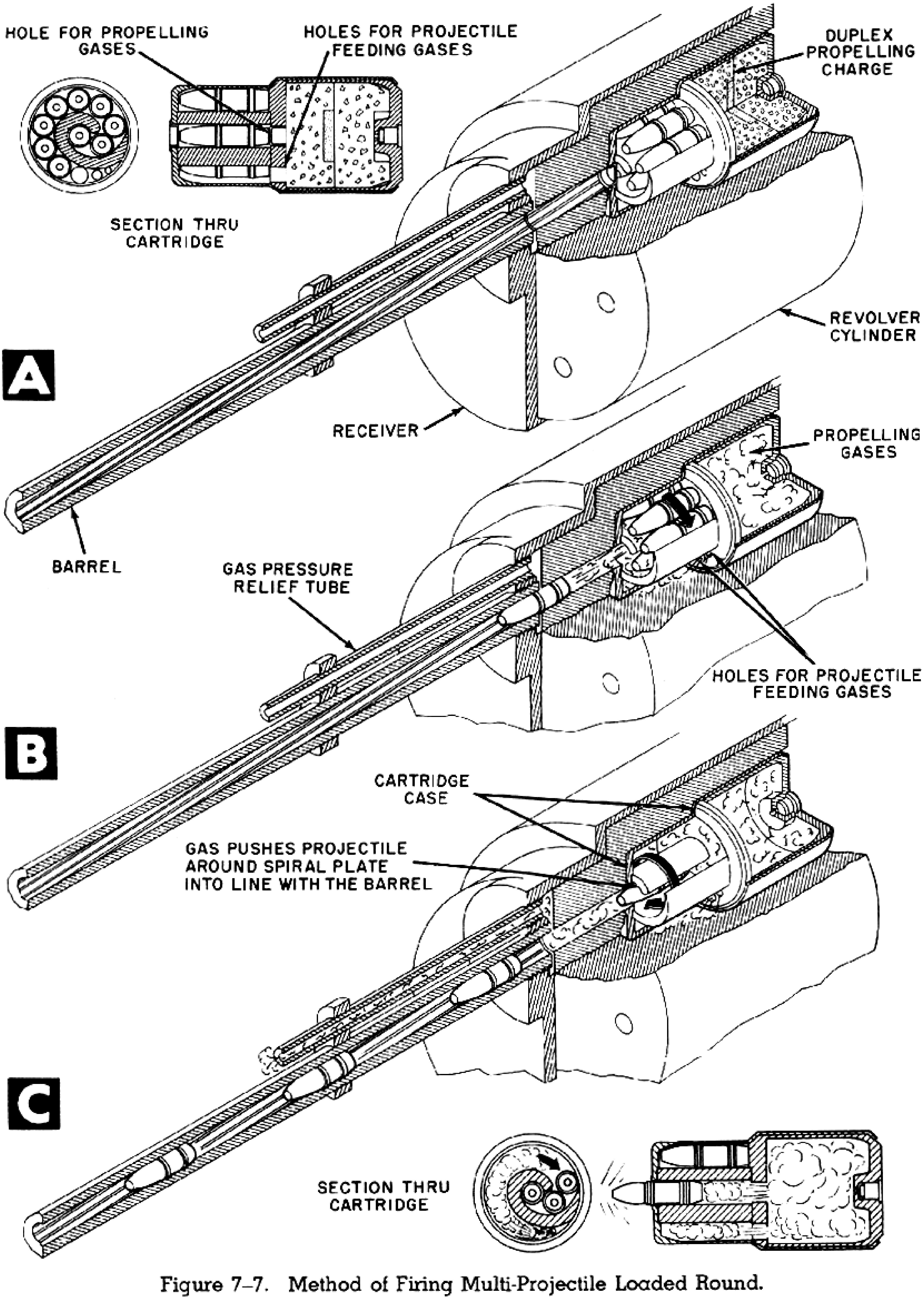


Figure 7–7. Method of Firing Multi-Projectile Loaded Round.

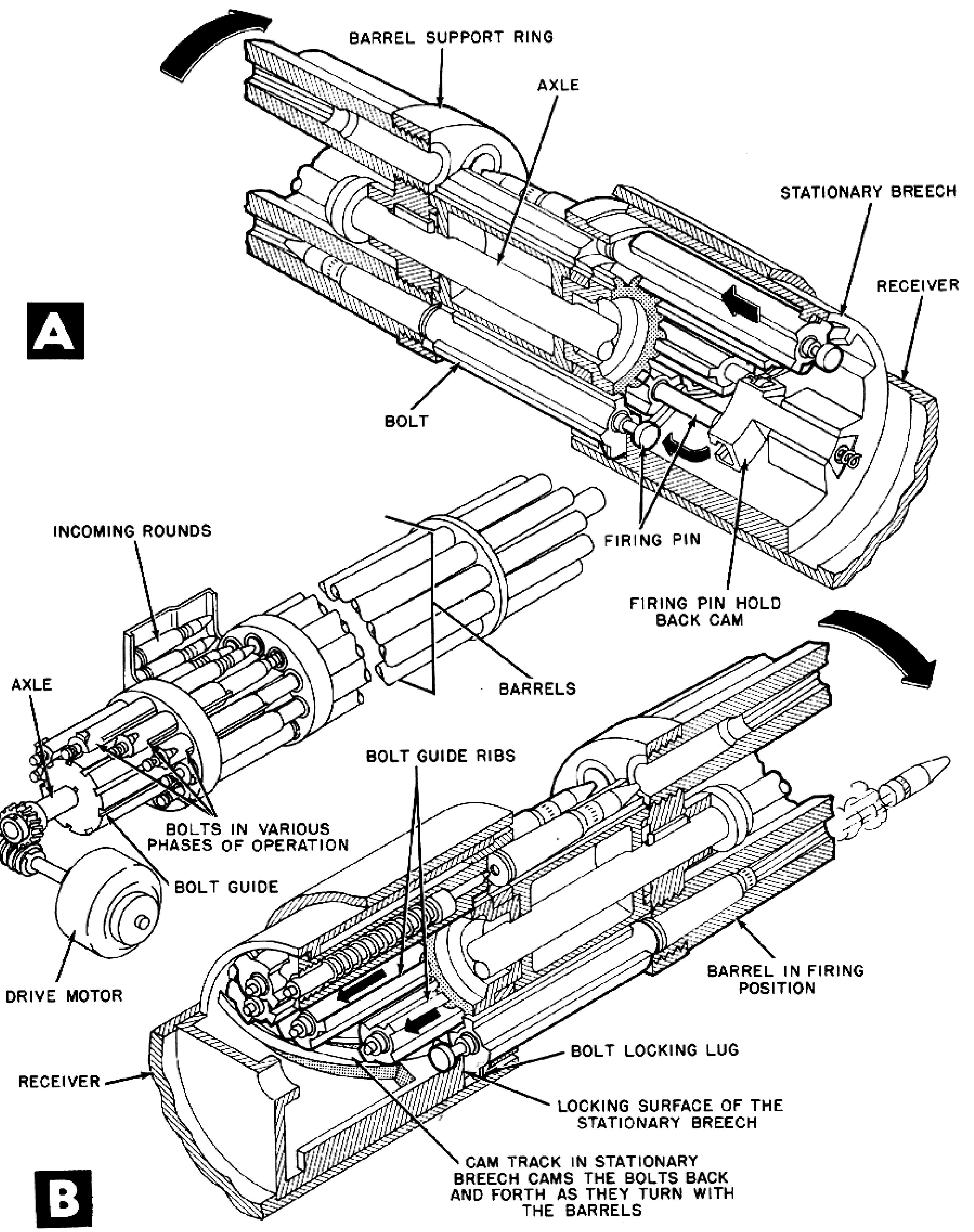


Figure 7–8. Operating Cycle of Multi-Barrel Motorized Rotary Cannon.

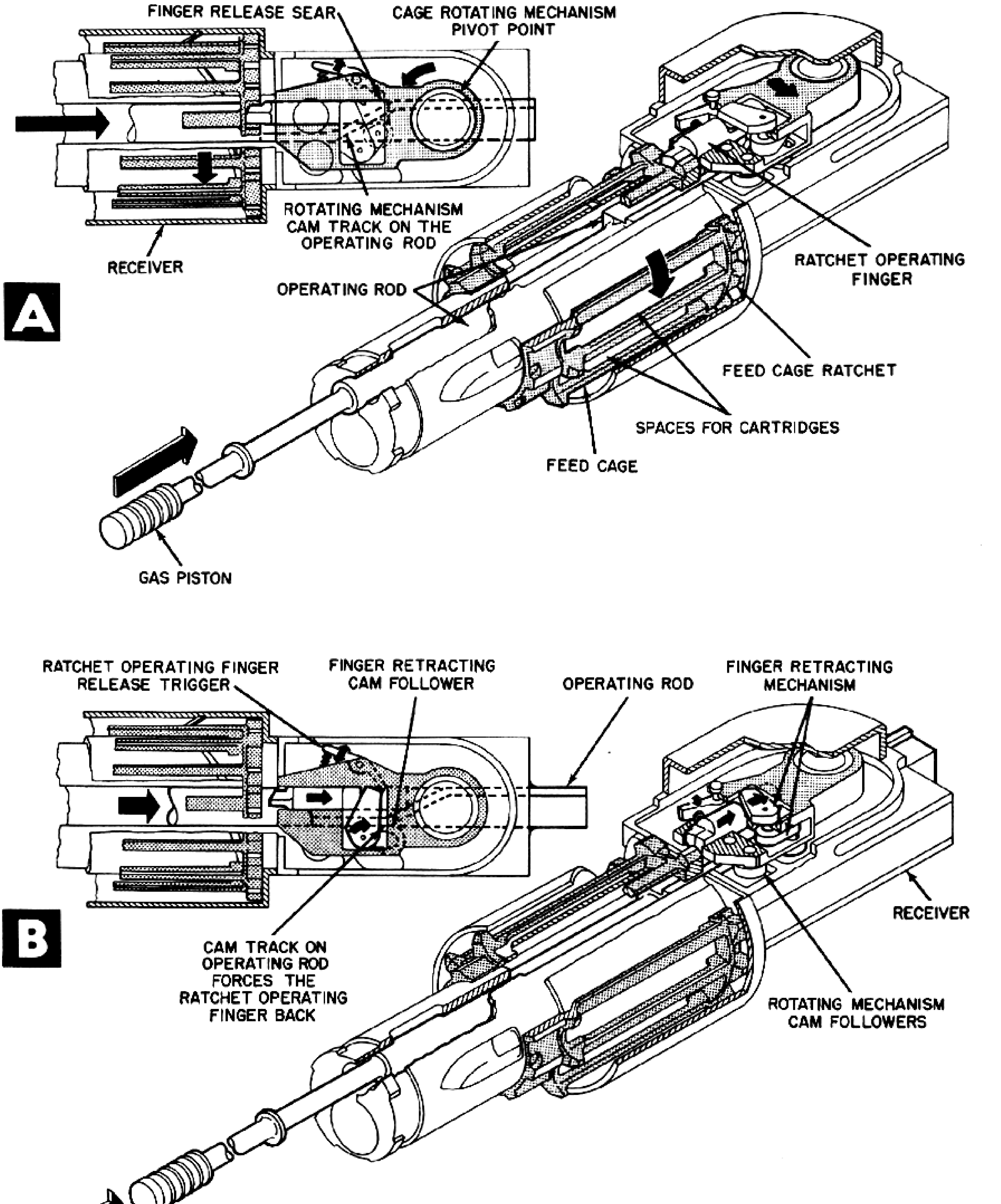
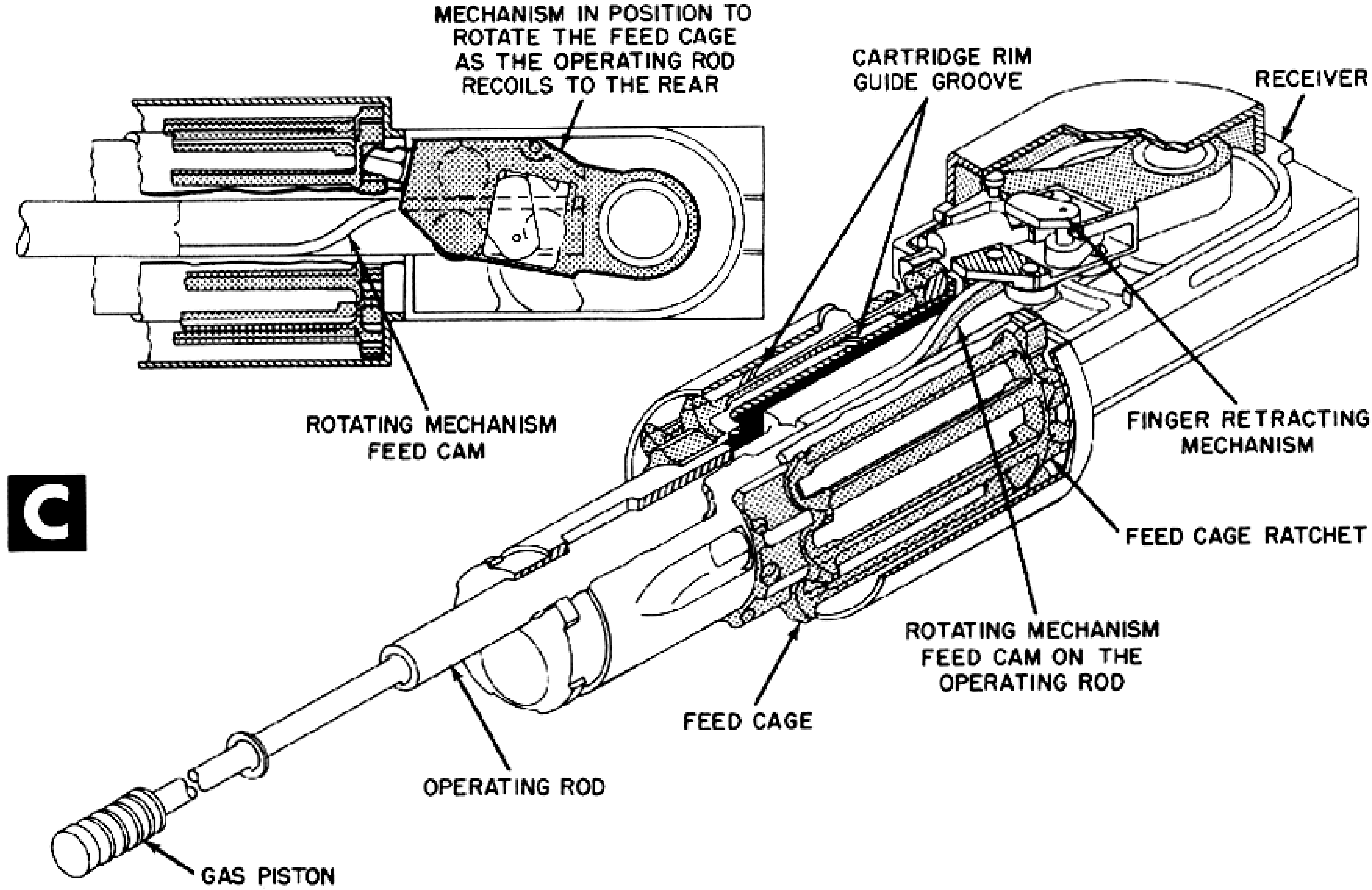


Figure 7–9. Mechanism for Revolving



Rotary-Type Feed.

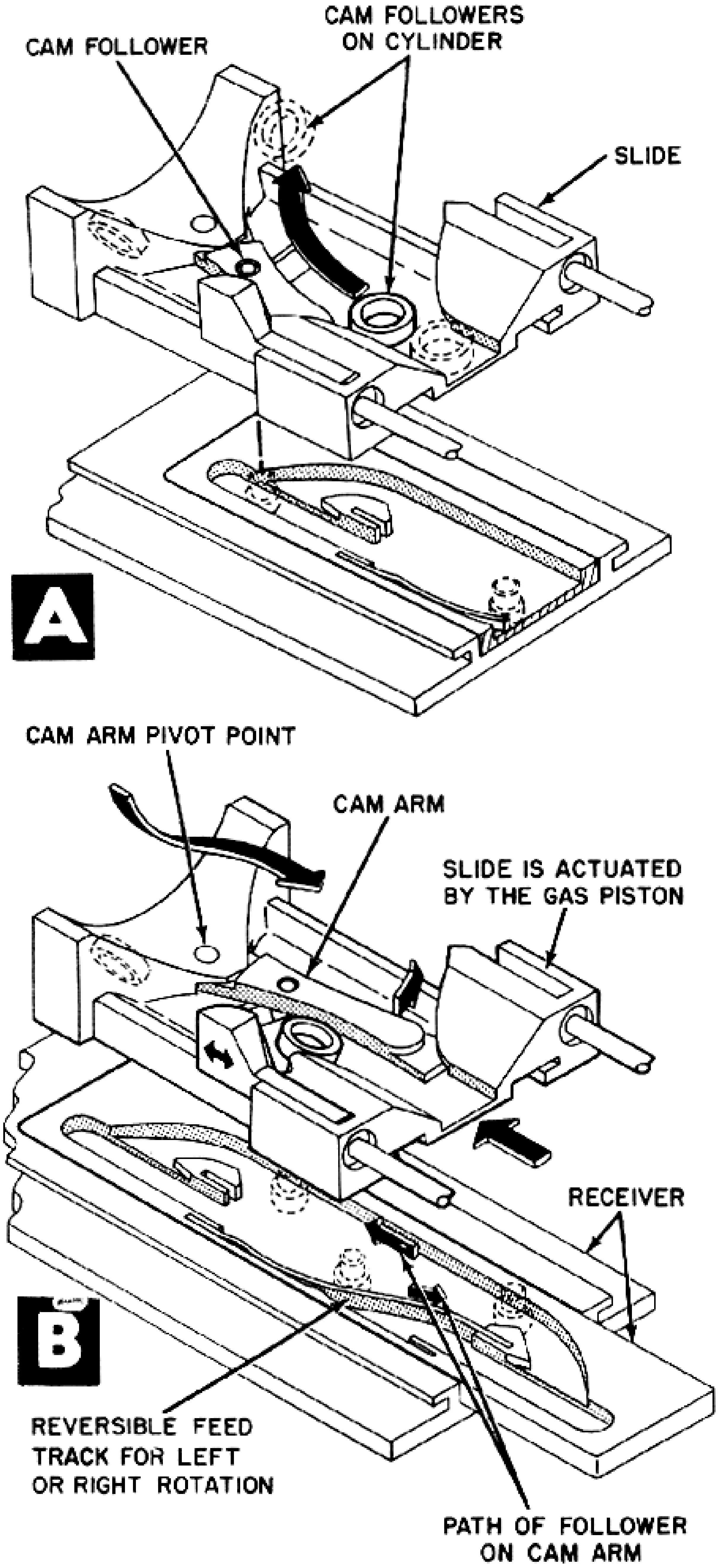


Figure 7–10. Method of Revolving a Rotary Cannon Cylinder.

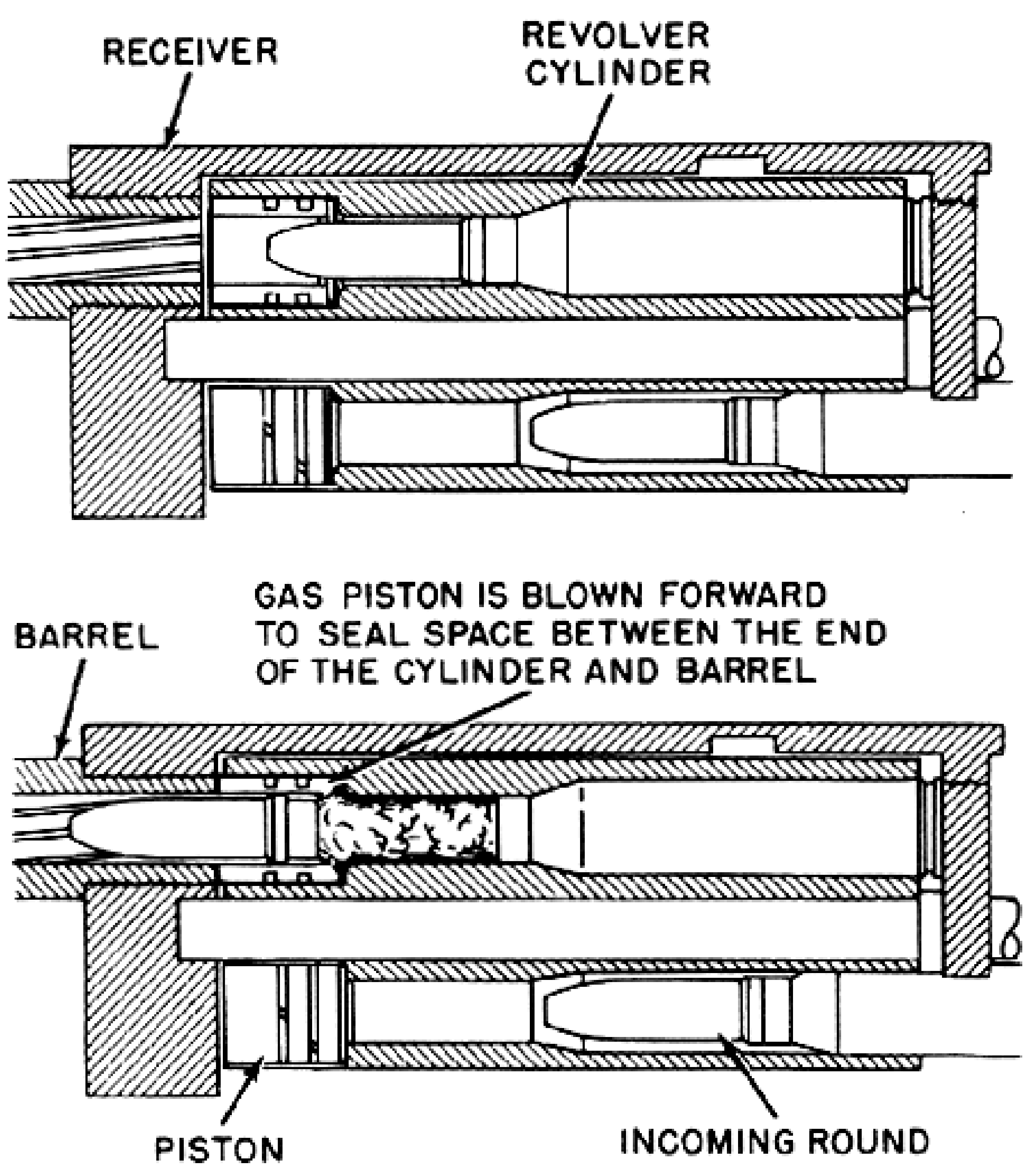


Figure 7–11. Method of Sealing Bore on a Rotary Cannon.

Chapter 8

ACCELERATORS

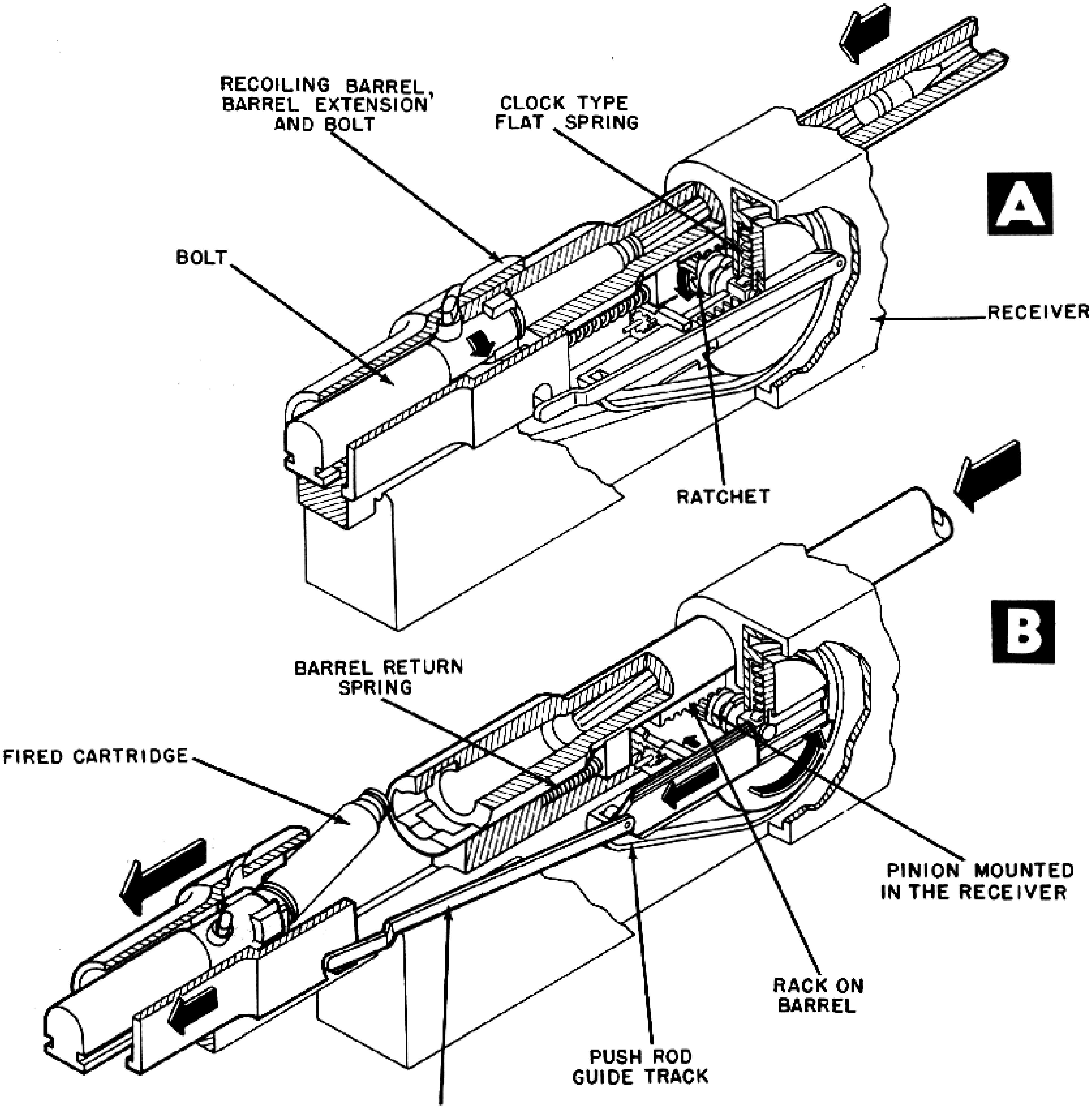


Figure 8–1. Recoil-Loaded Spring Accelerates Bolt to Rear.

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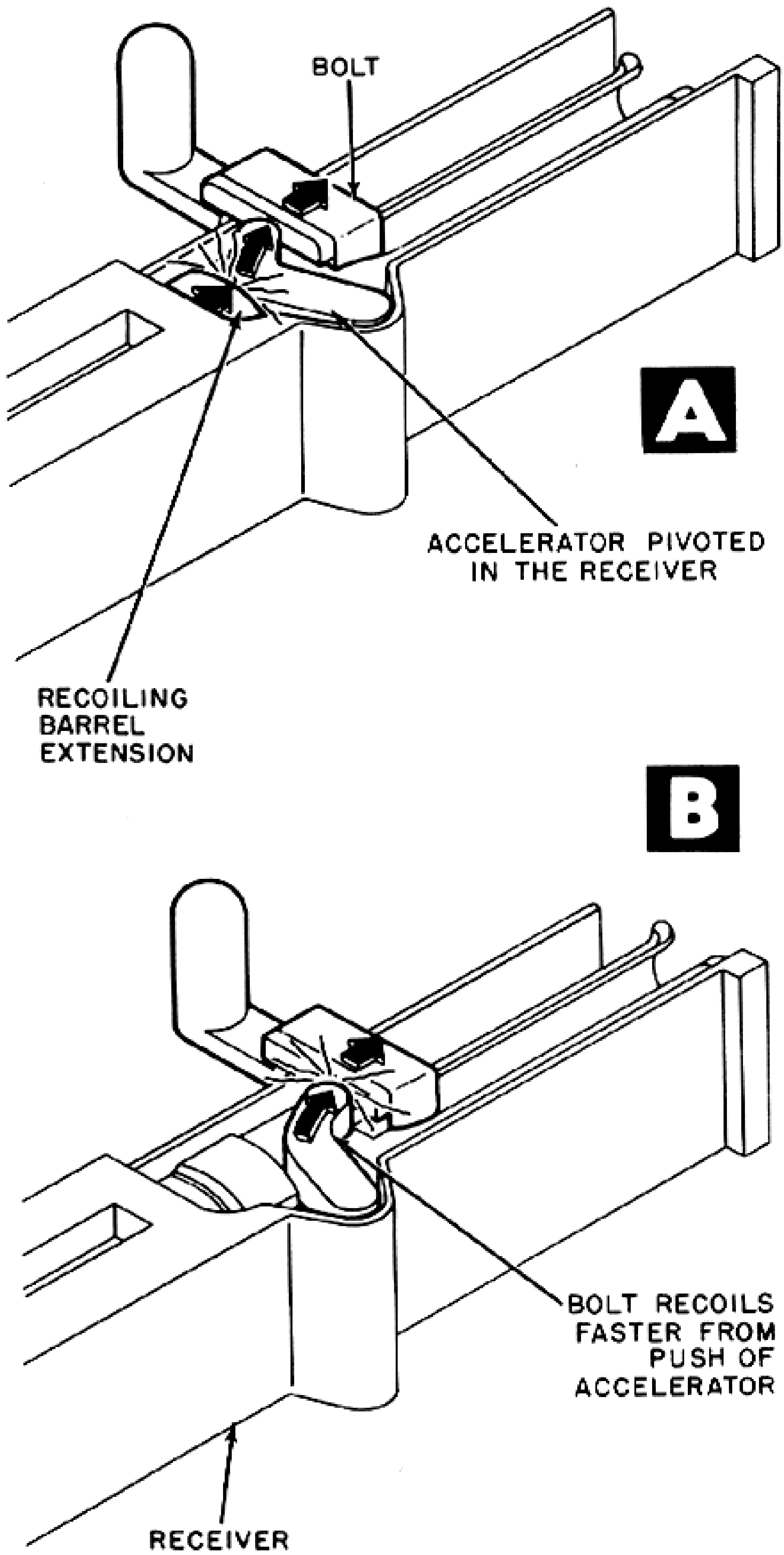

Figure 8–2. Pivoted Lever Accelerates Bolt to Rear.

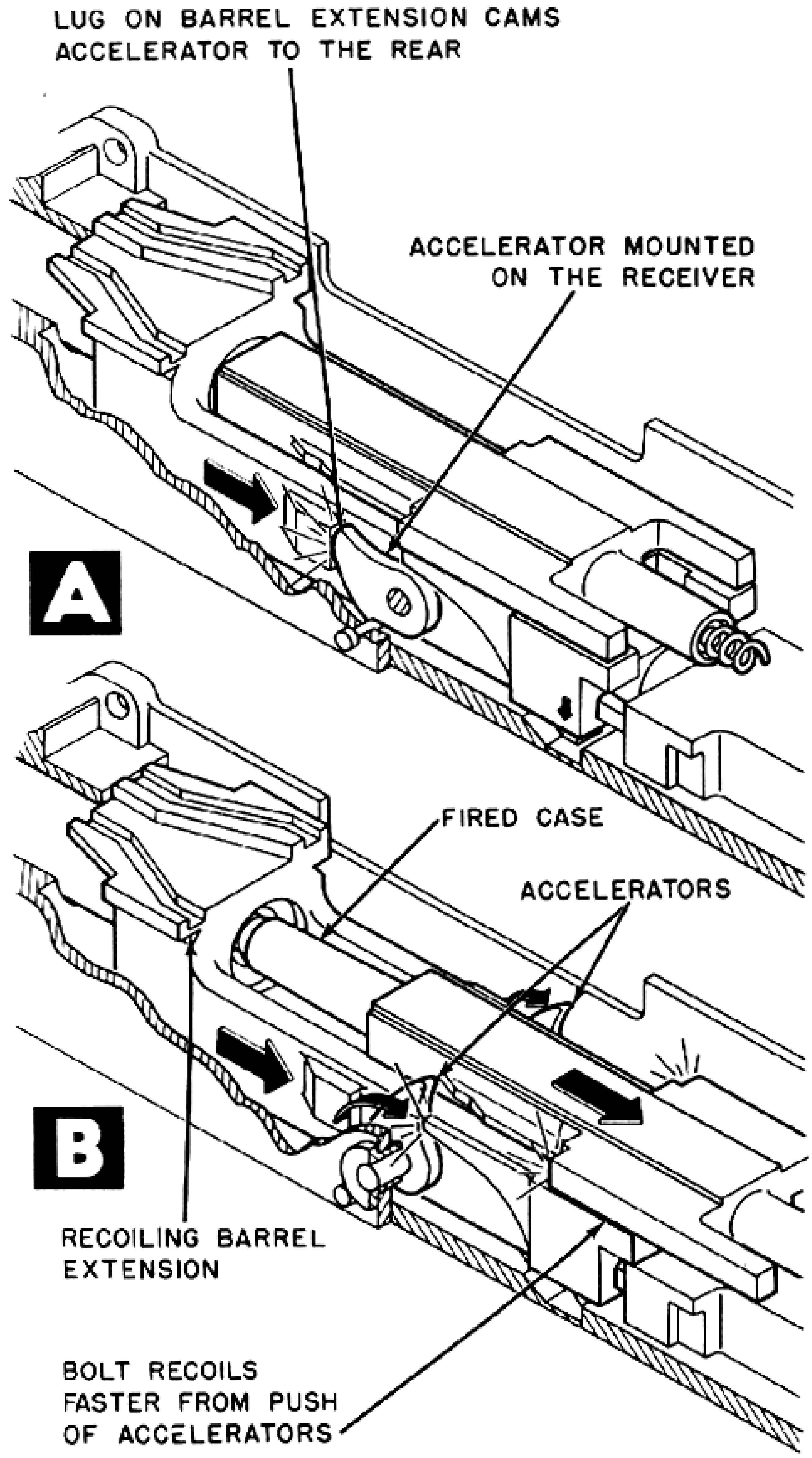

Figure 8–3. Twin Levers Accelerate Bolt to Rear.

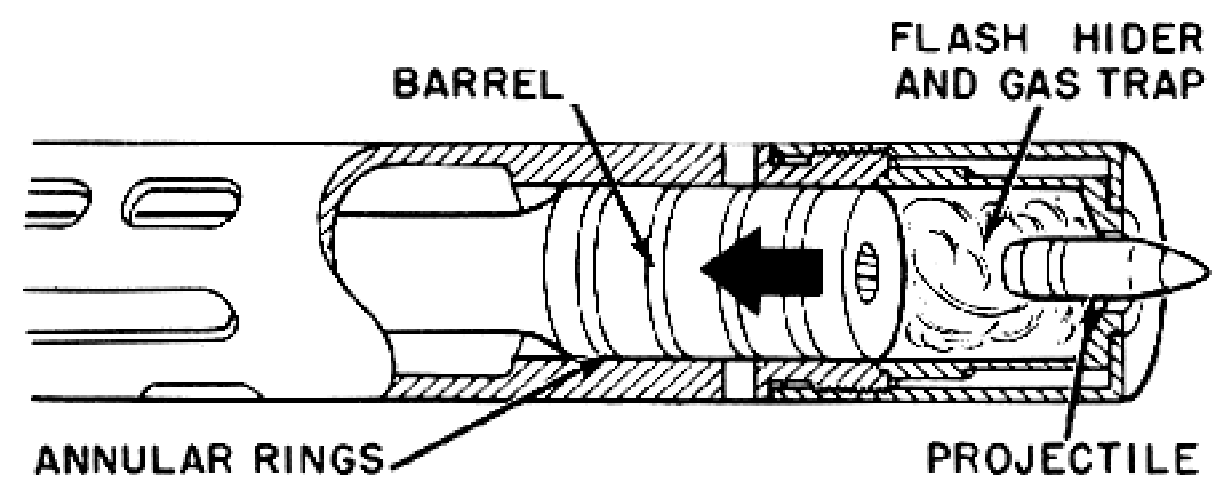

Figure 8–4. Gas Pressure on Muzzle Accelerates Barrel to Rear.

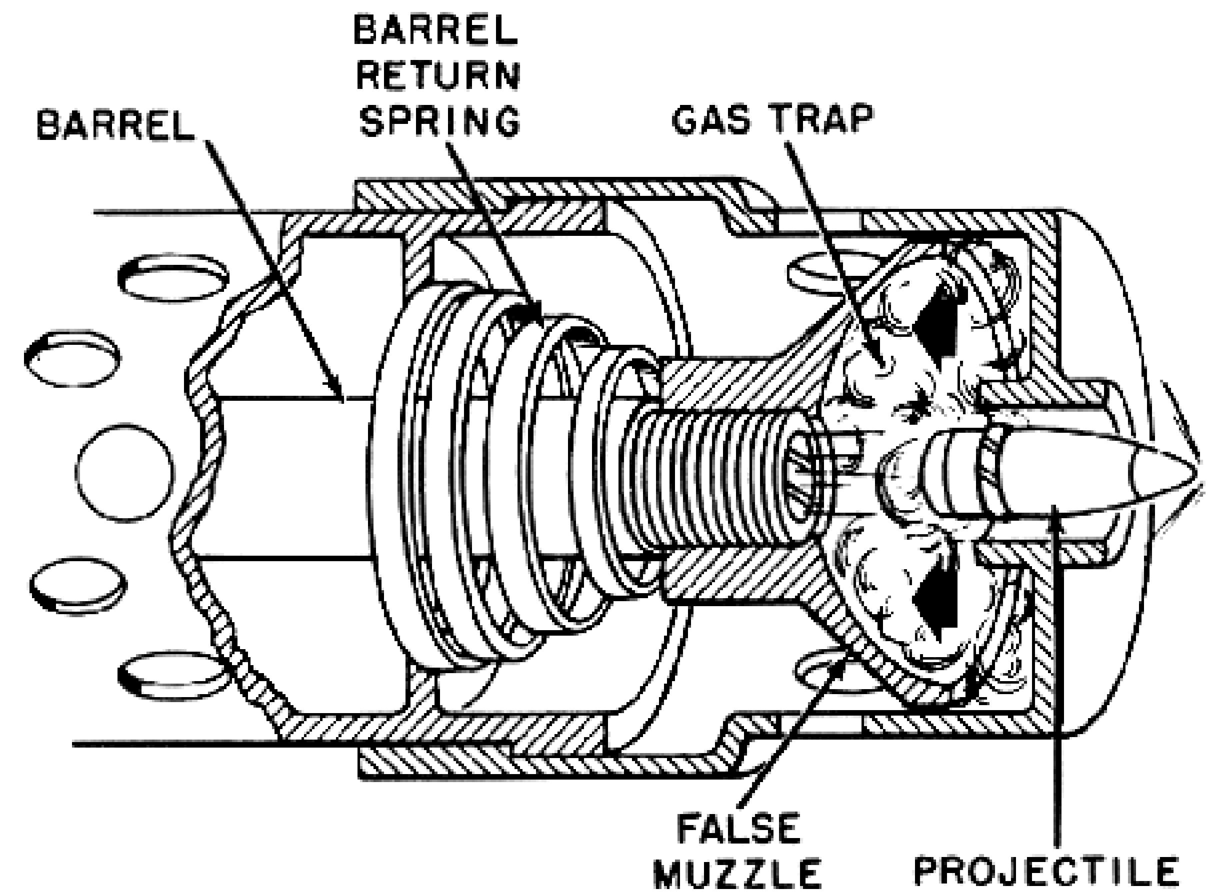

Figure 8–5. Gas Pressure on Muzzle Accelerates Barrel to Rear.

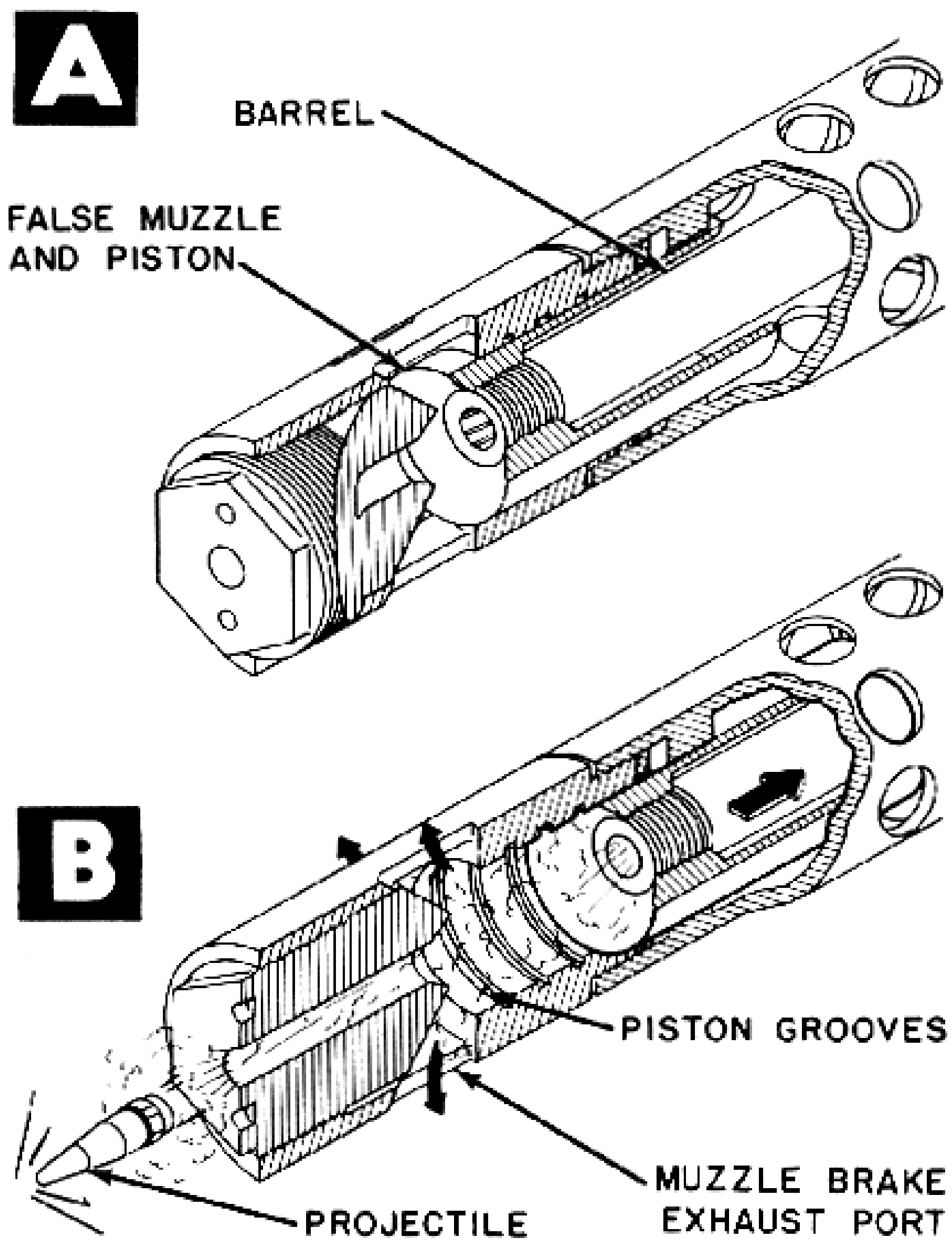

Figure 8–6. Muzzle Insert Allows Pressure on Barrel To Be Varied.

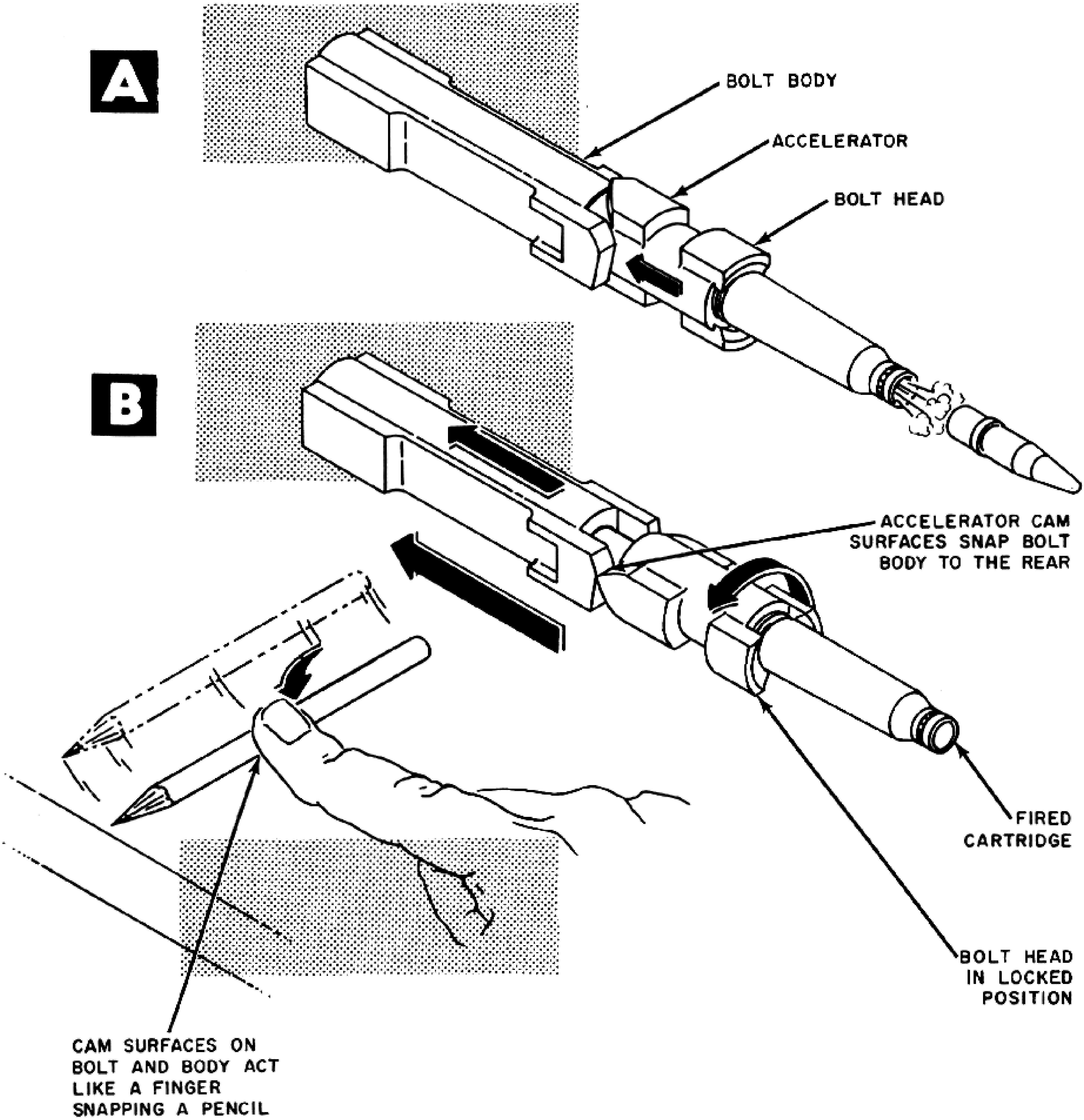

Figure 8–7. Rotation of Unlocking Bolt Head Accelerates the Body of the Bolt to the Rear.

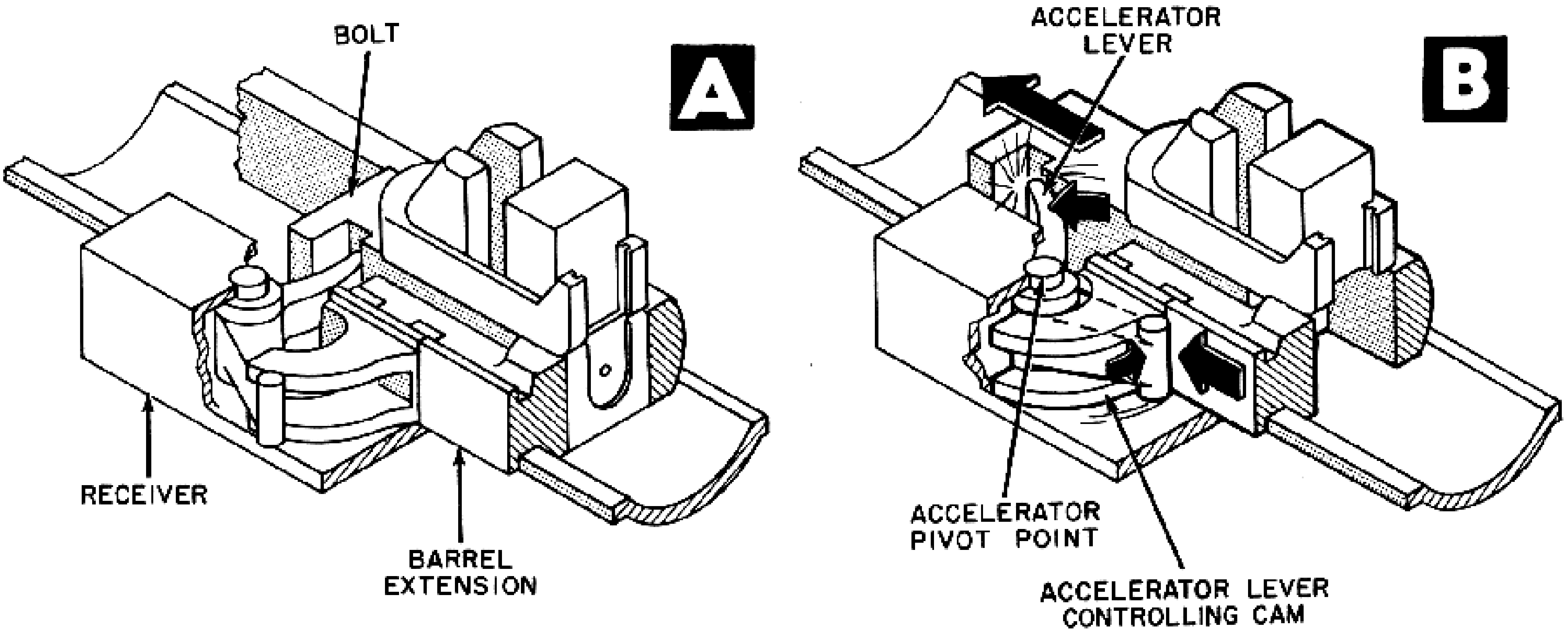

Figure 8–8. Pivoted Lever and Cam Accelerate Bolt to Rear.

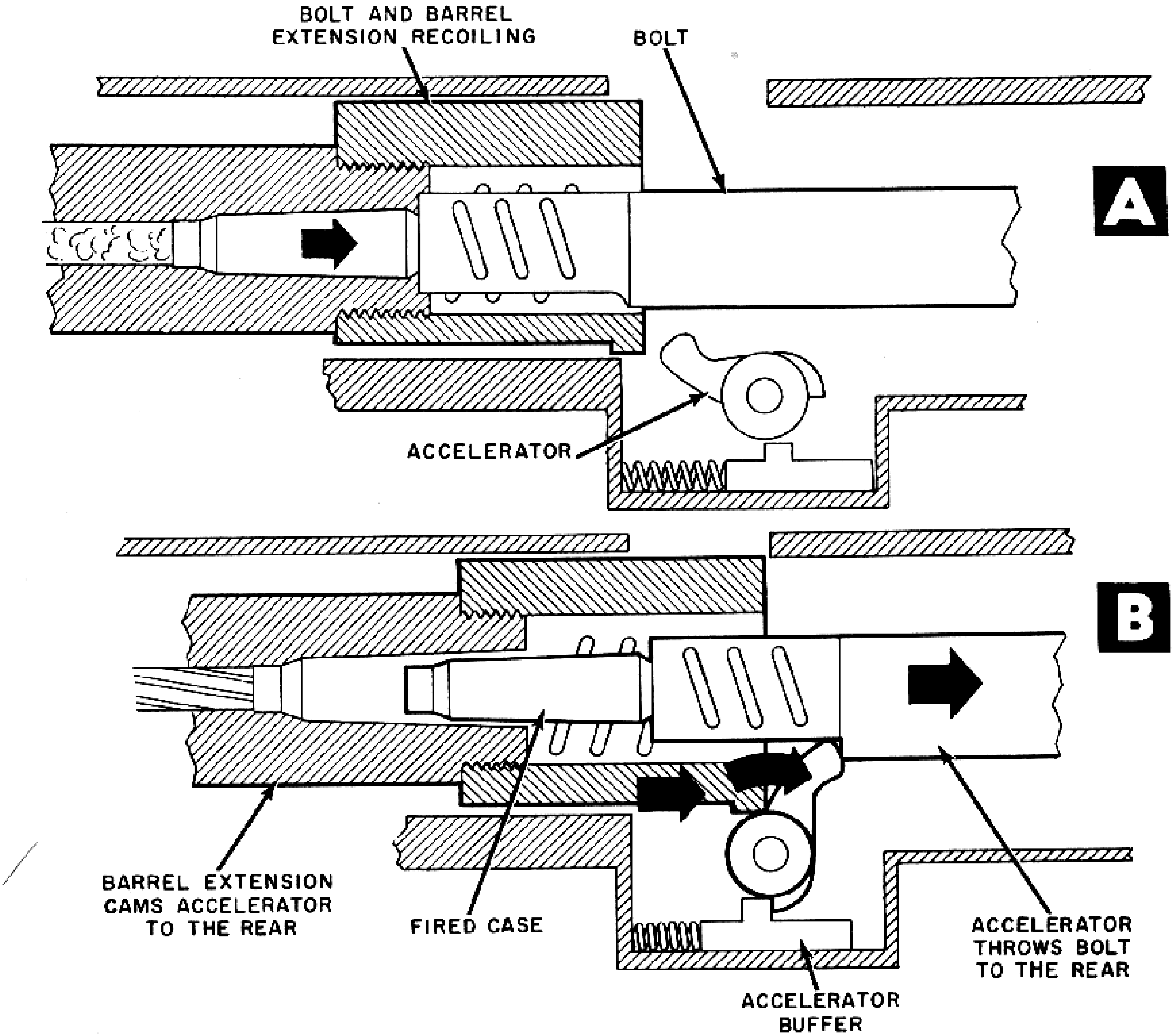

Figure 8–9. Pivoted Lever Accelerates Bolt to Rear.

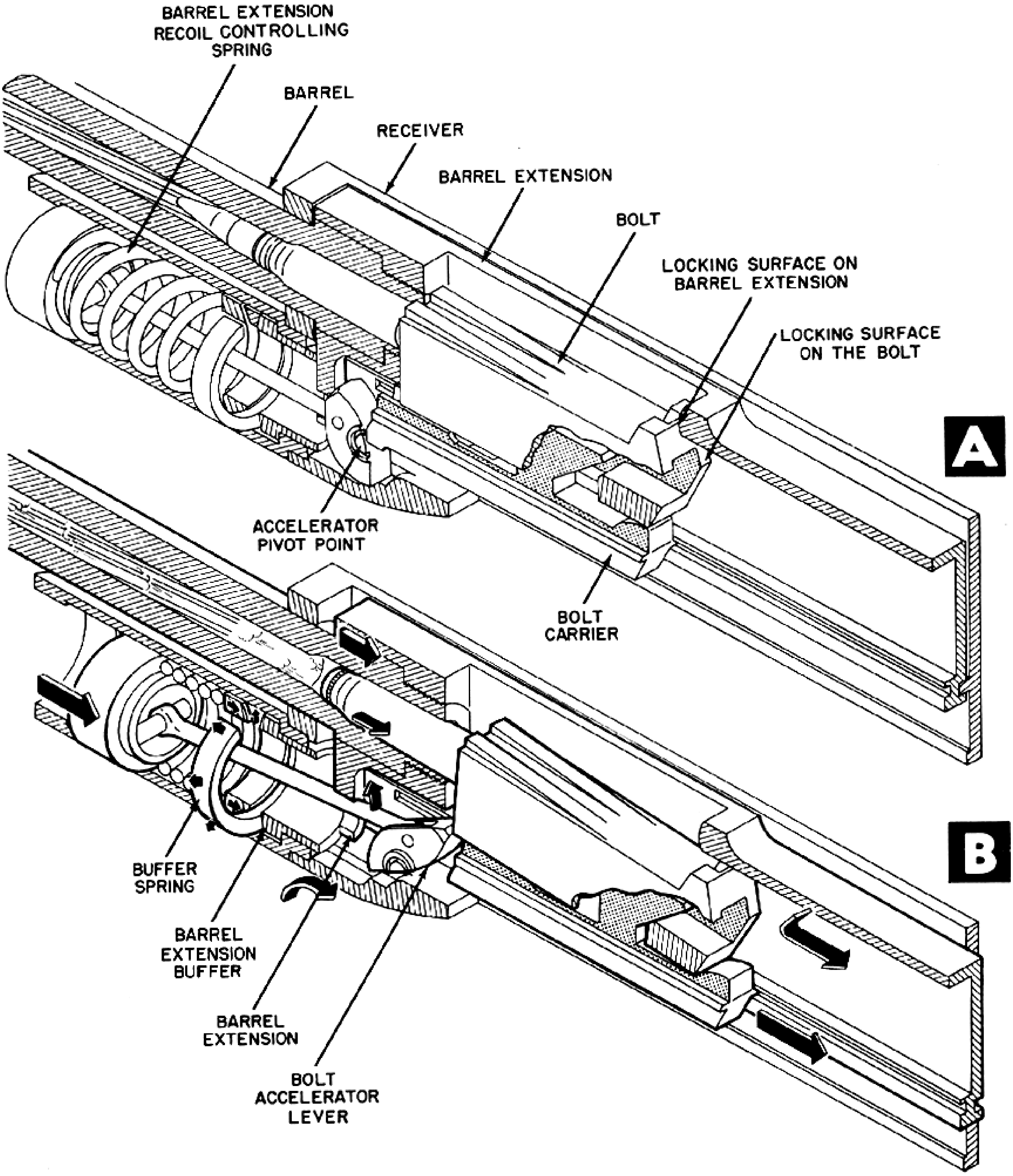

Figure 8–10. Recoil Operated Accelerator Forces Bolt to Rear and Also Acts as Barrel Extension Buffer.

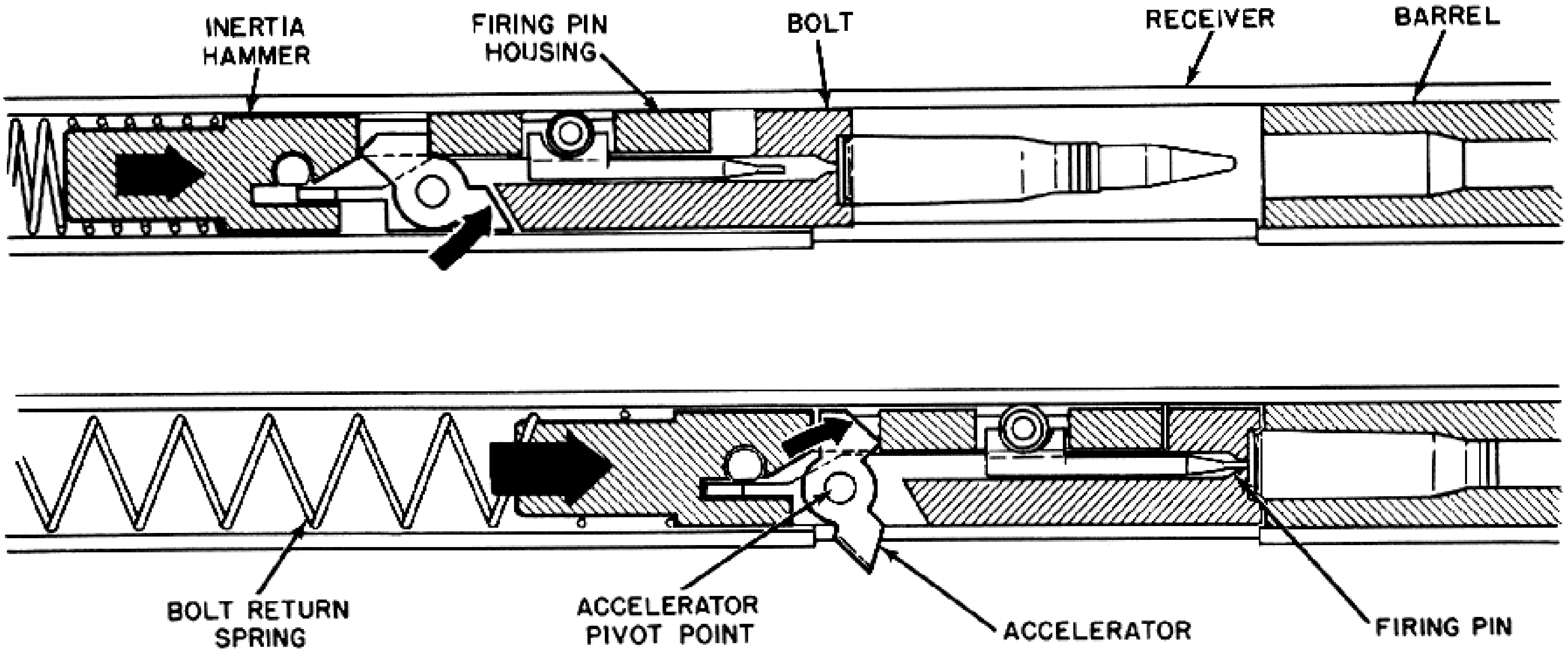

Figure 8–11. Cam-Operated Inertia Block Accelerates Bolt to Rear.

Chapter 9

GAS PORT ADJUSTMENT

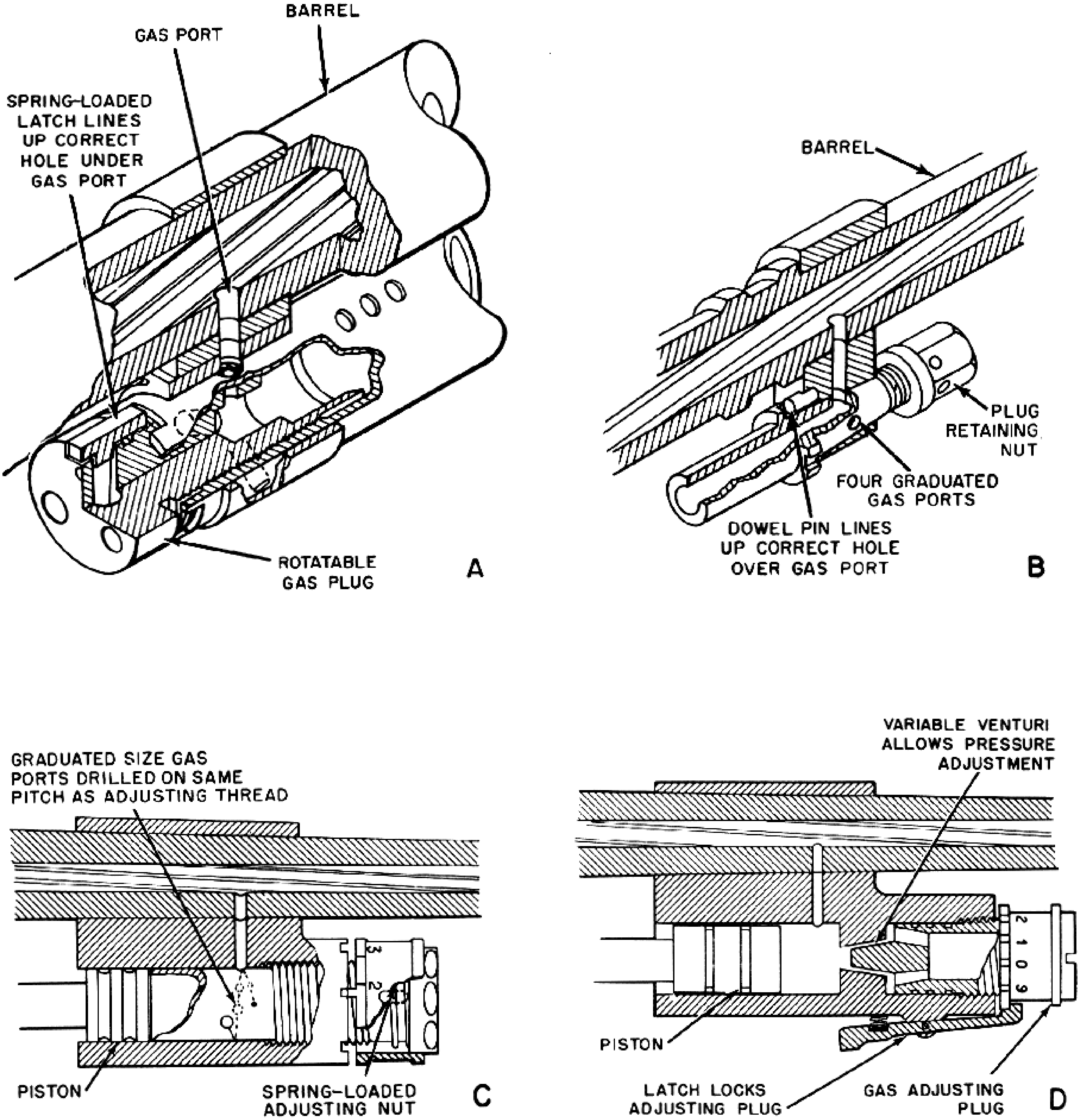

Figure 9–1. Various Methods of Gas Port Adjustment.

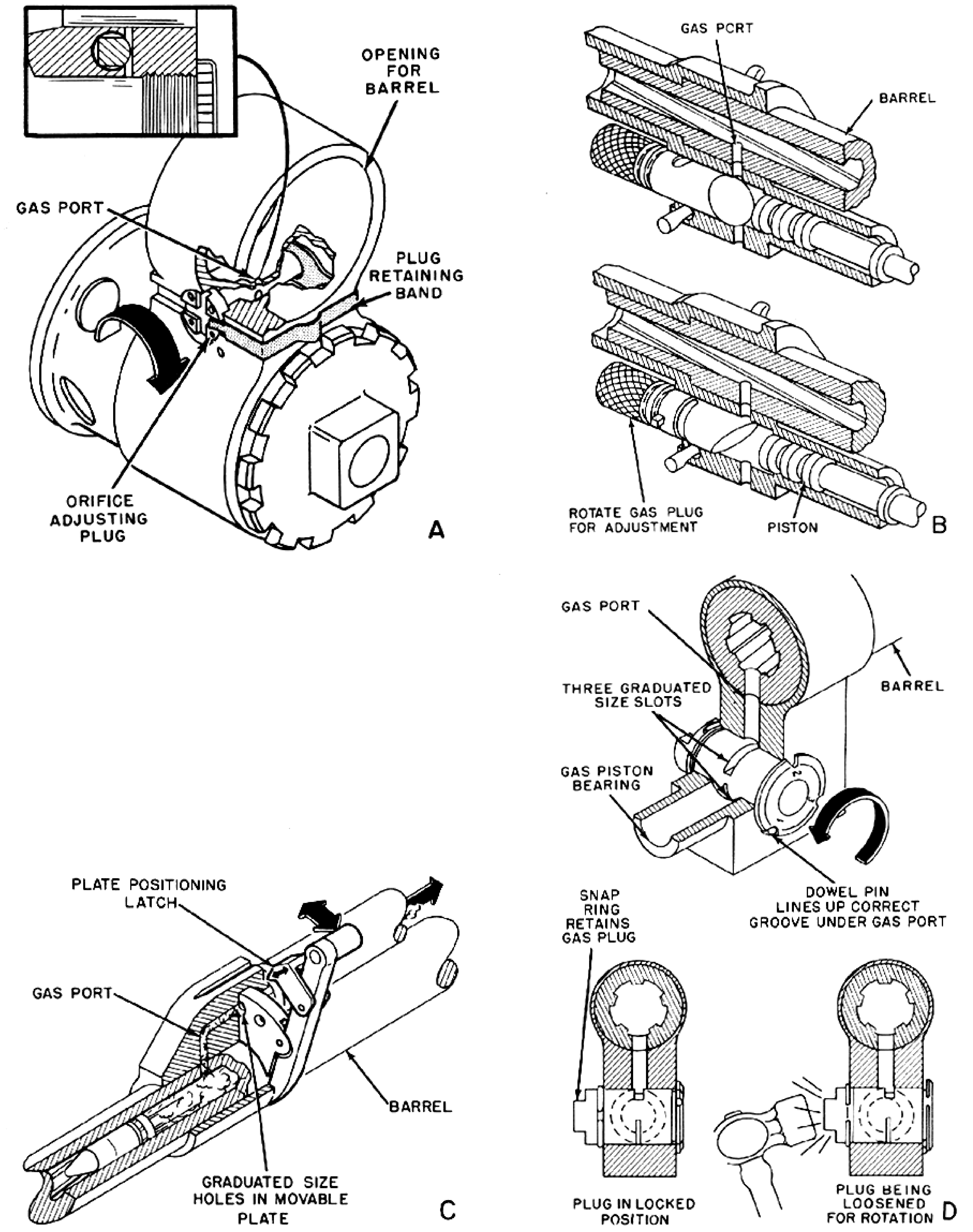

Figure 9–2. Various Methods of Gas Port Adjustment.

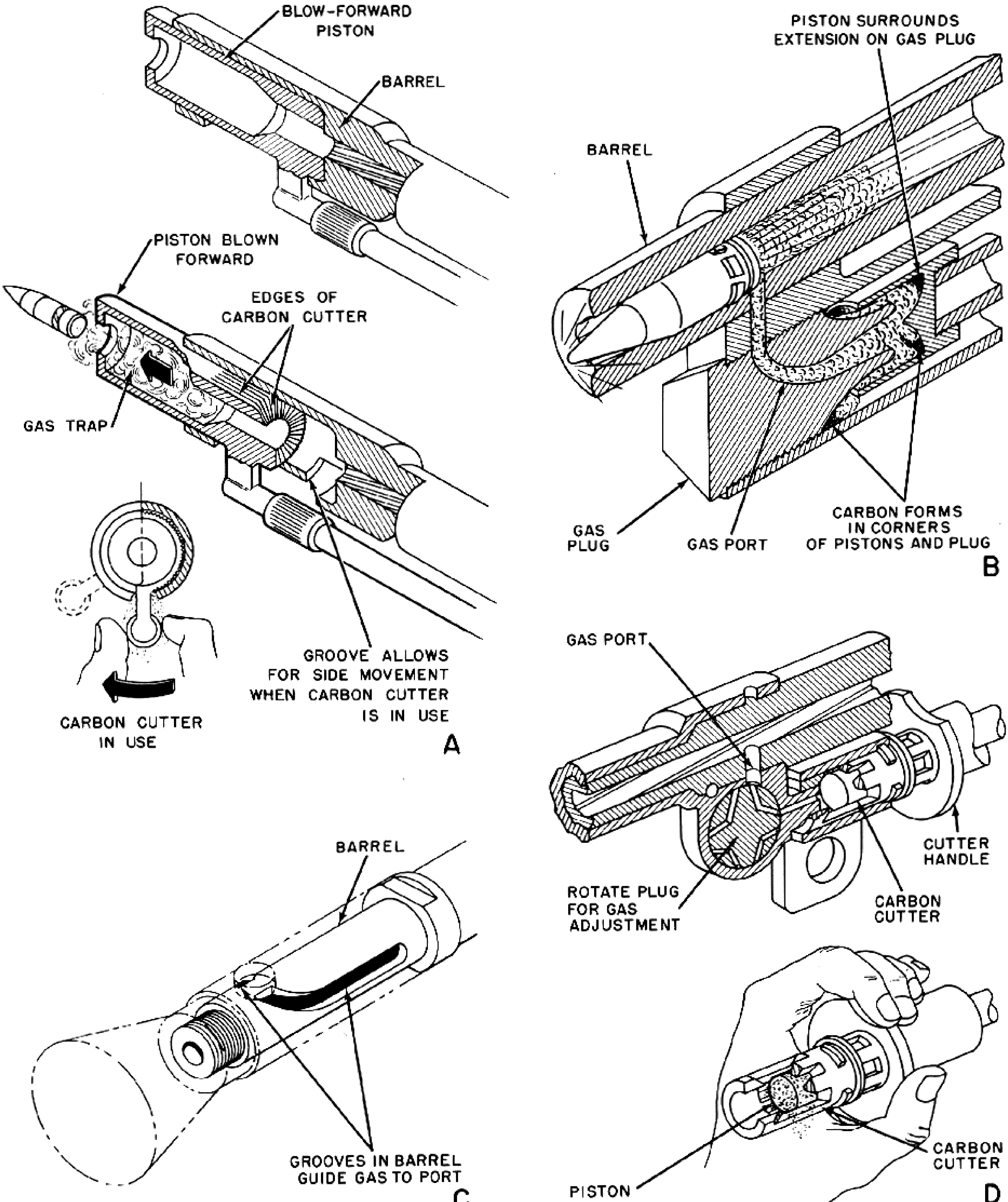

Figure 9–3. Methods of Carbon Removal and Preventing Carbon Build Up.

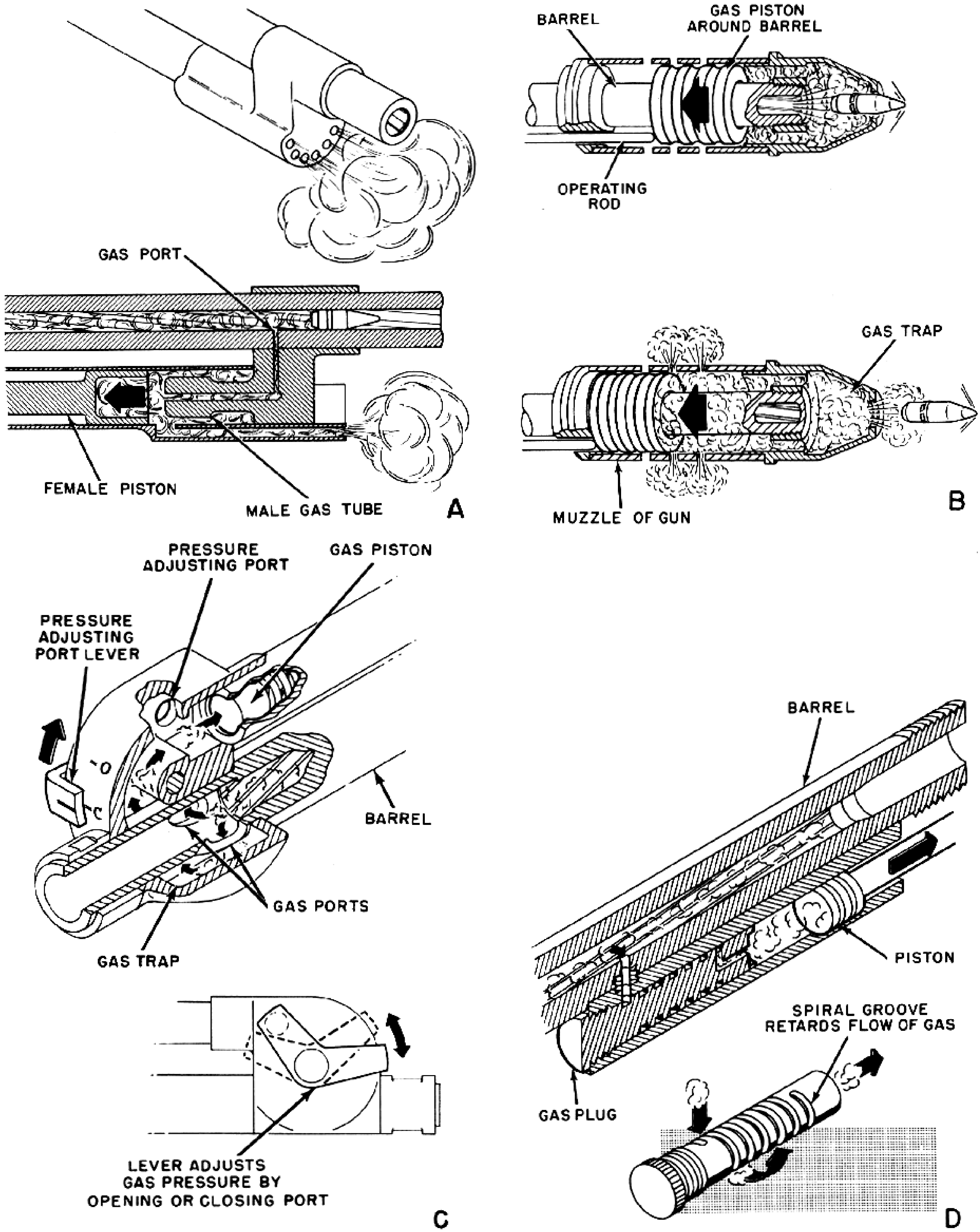

Figure 9–4. Various Methods of Adjusting, Utilizing and Retarding Gas Pressure.

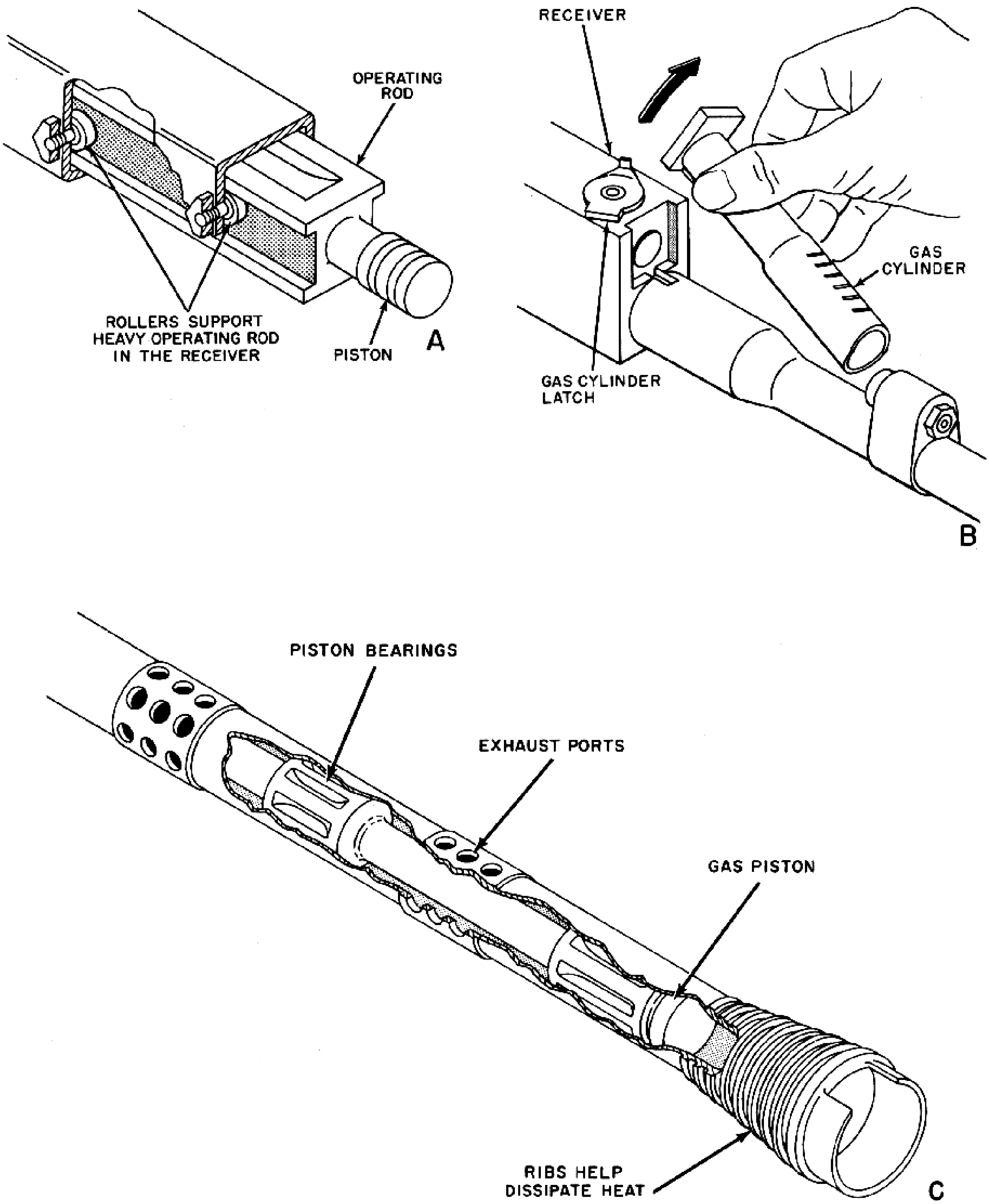

Figure 9–5. Various Methods of Supporting and Removing Gas Pistons.

Chapter 10

BARREL LOCKING DEVICES

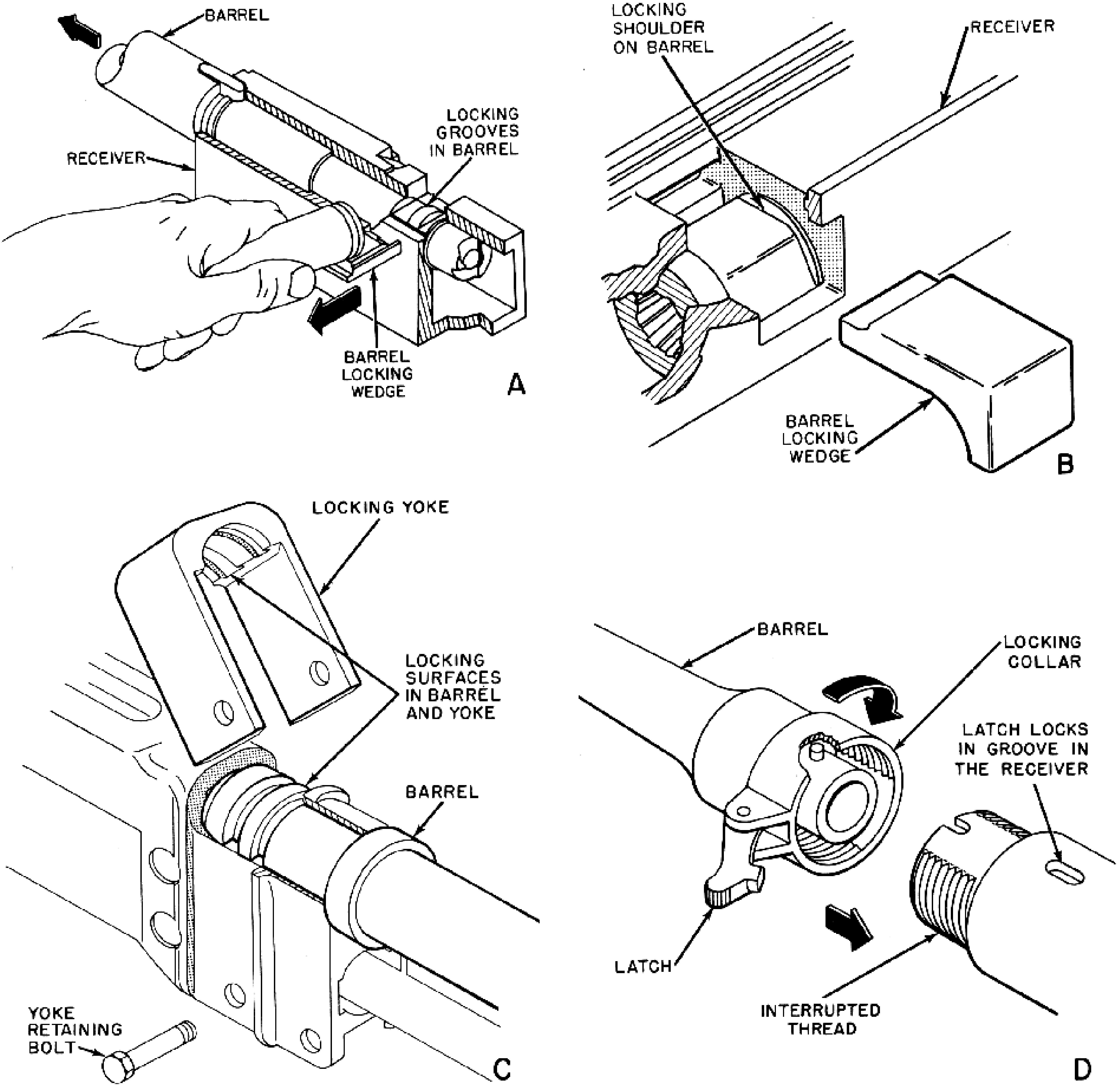

Figure 10–1. Various Methods of Retaining Barrels.

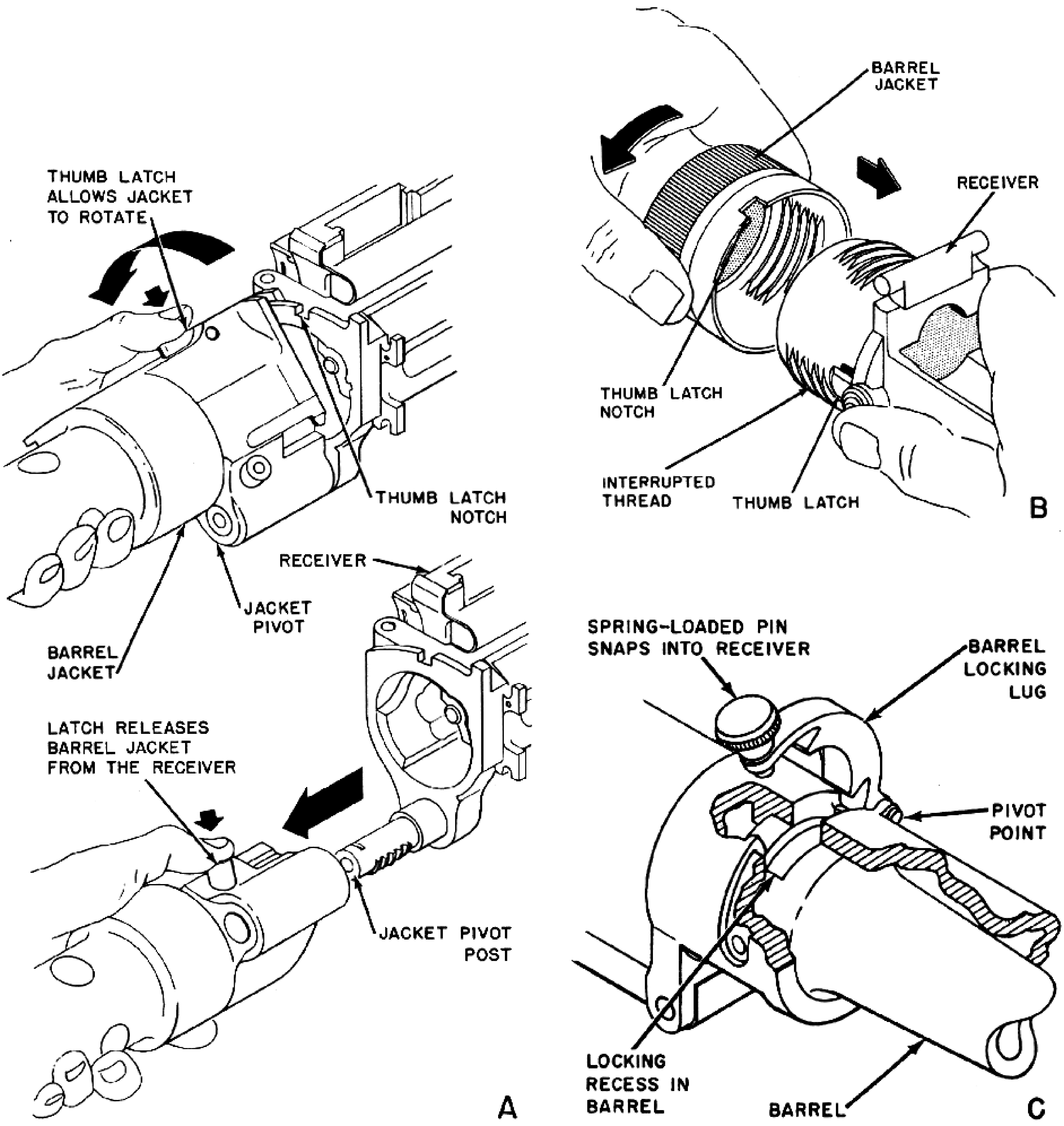

Figure 10-2. Various Methods of Retaining Barrels and Barrel Jackets.

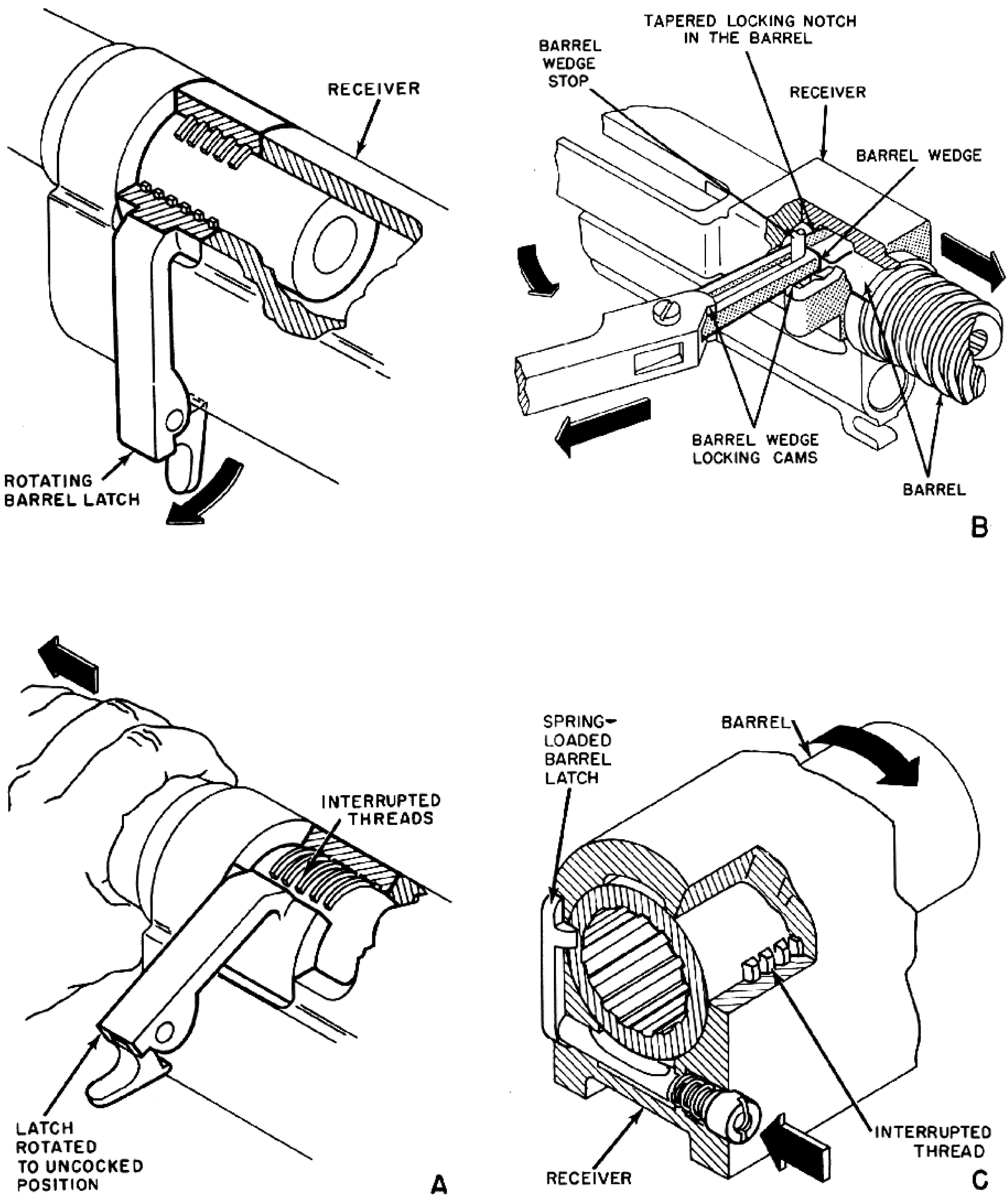

Figure 10–3. Various Methods of Retaining Barrels.

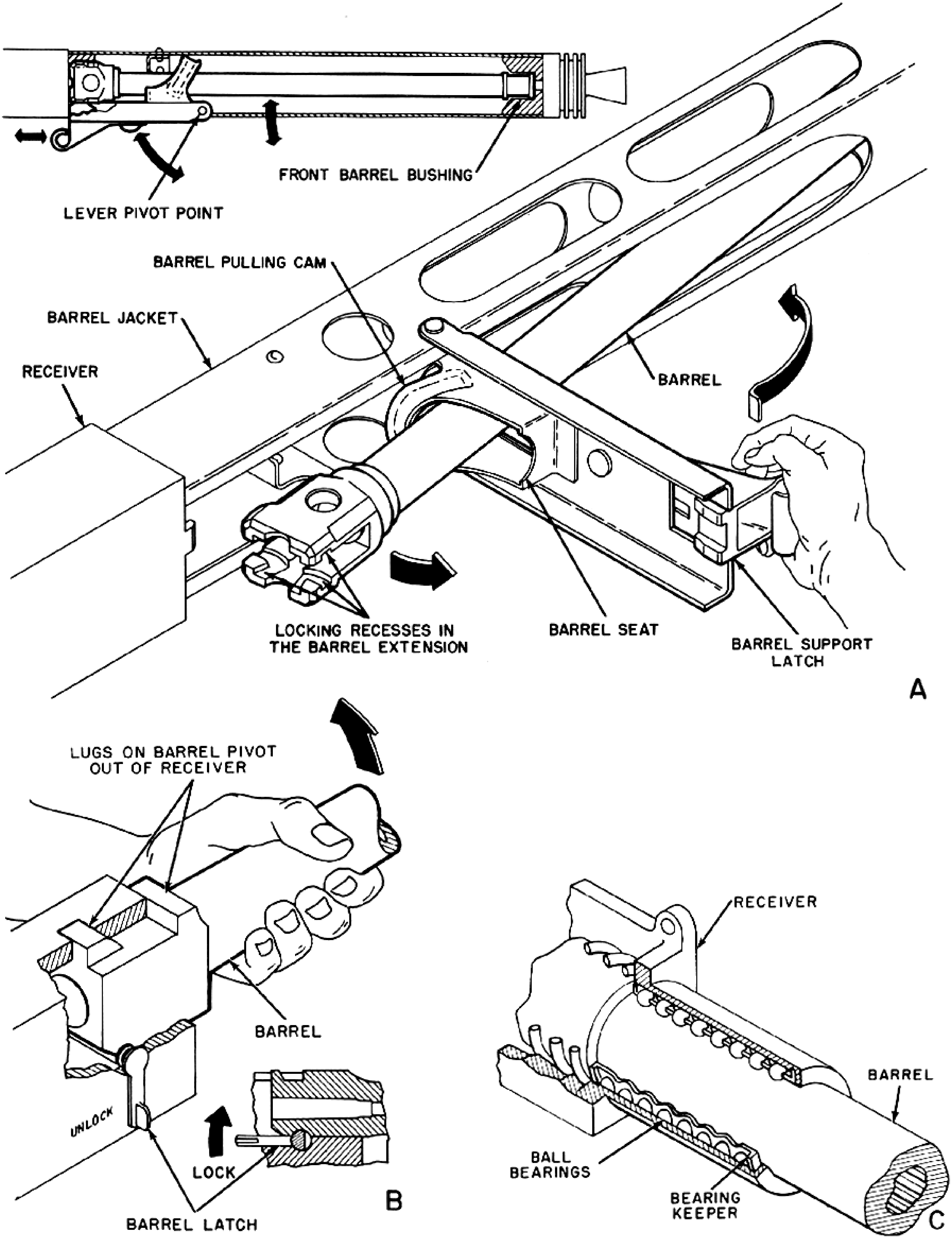

Figure 10–4. Various Methods of Supporting and Unlocking Barrels.

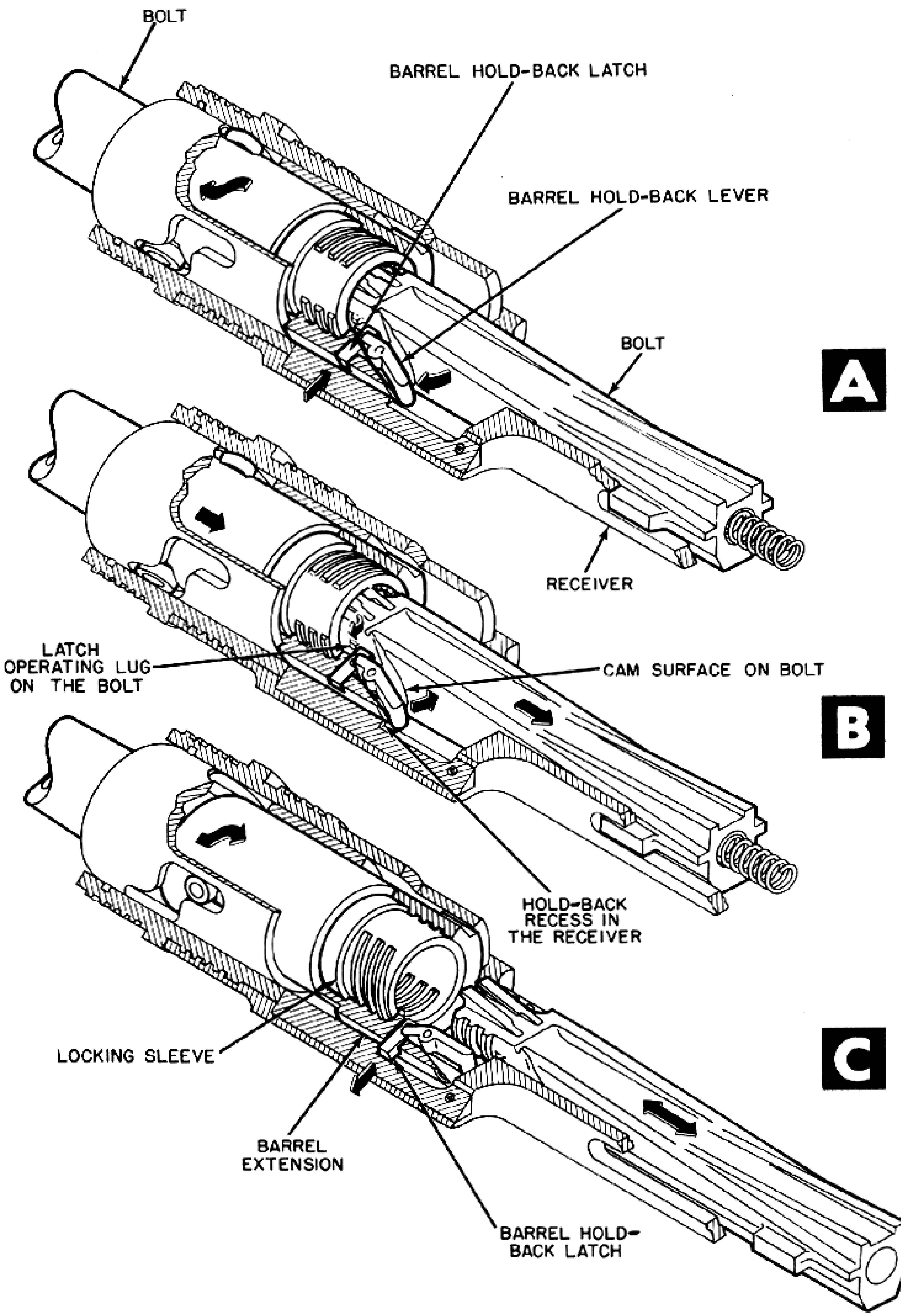

Figure 10–5. Barrel Hold-Back Device.

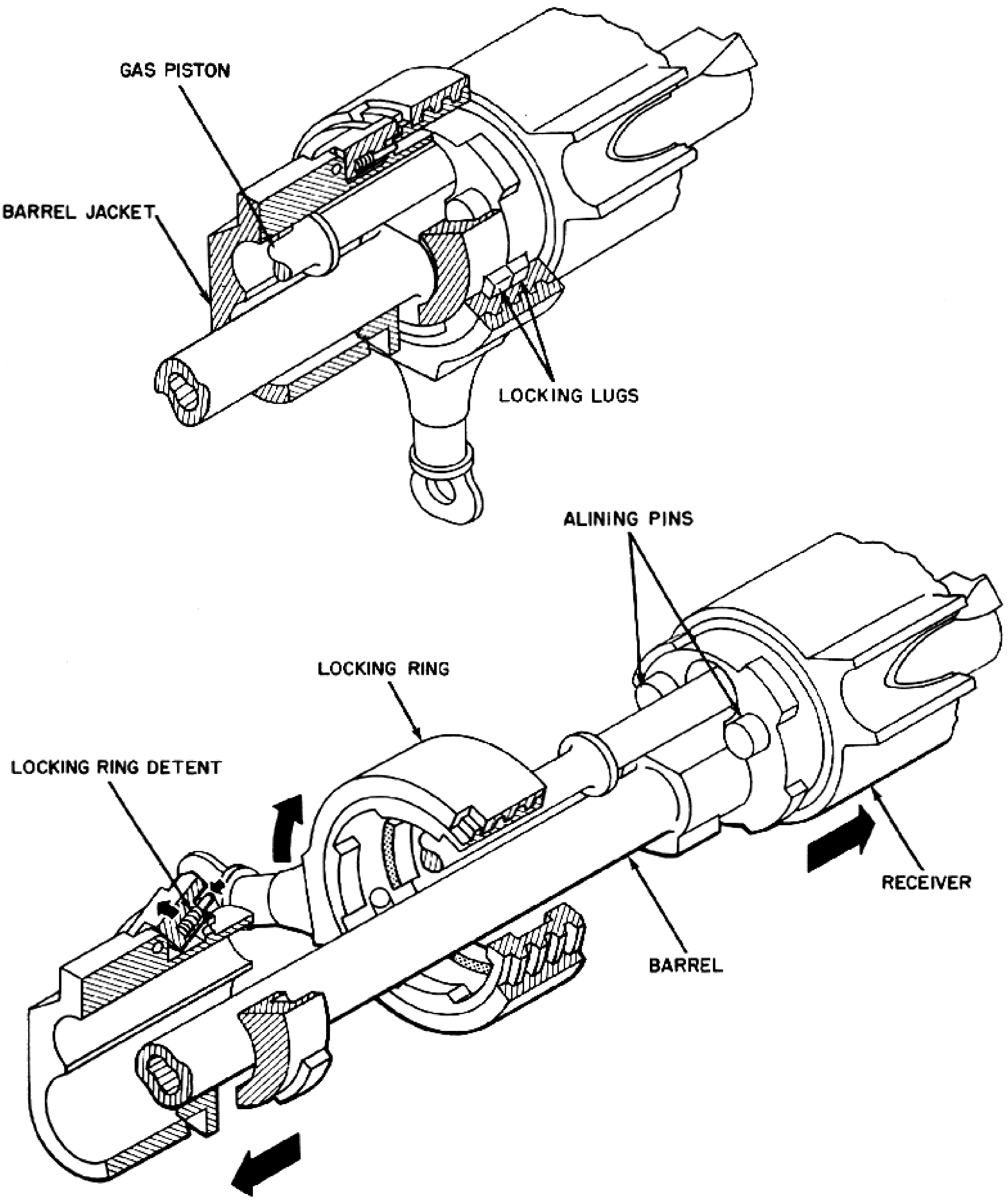

Figure 10-6. Method of Retaining Barrel.

Chapter 11

EXTRACTORS

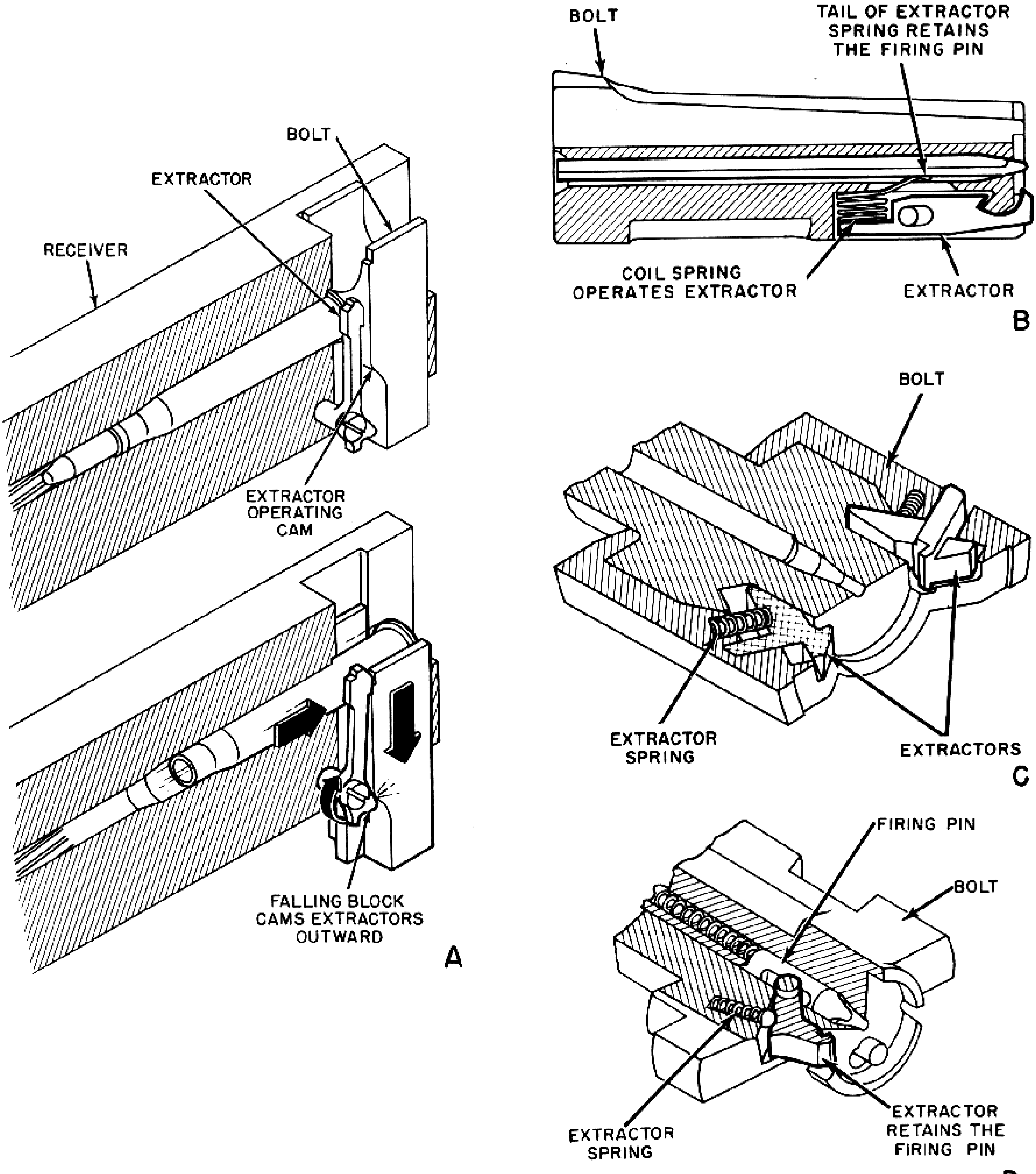

Figure 11–1. Various Methods of Retaining and Powering Extractors.

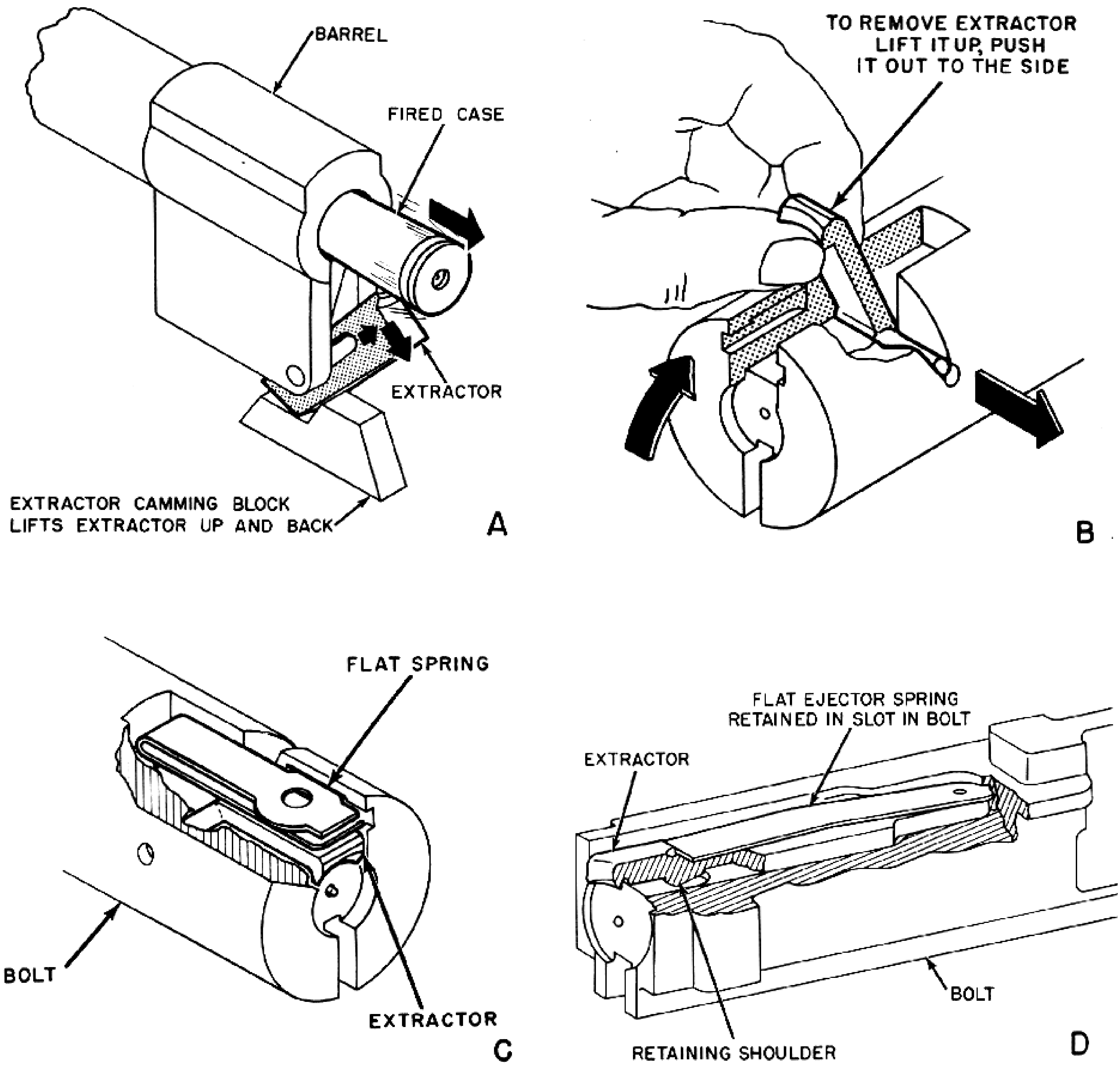

Figure 11–2. Various Methods of Retaining and Powering Extractors.

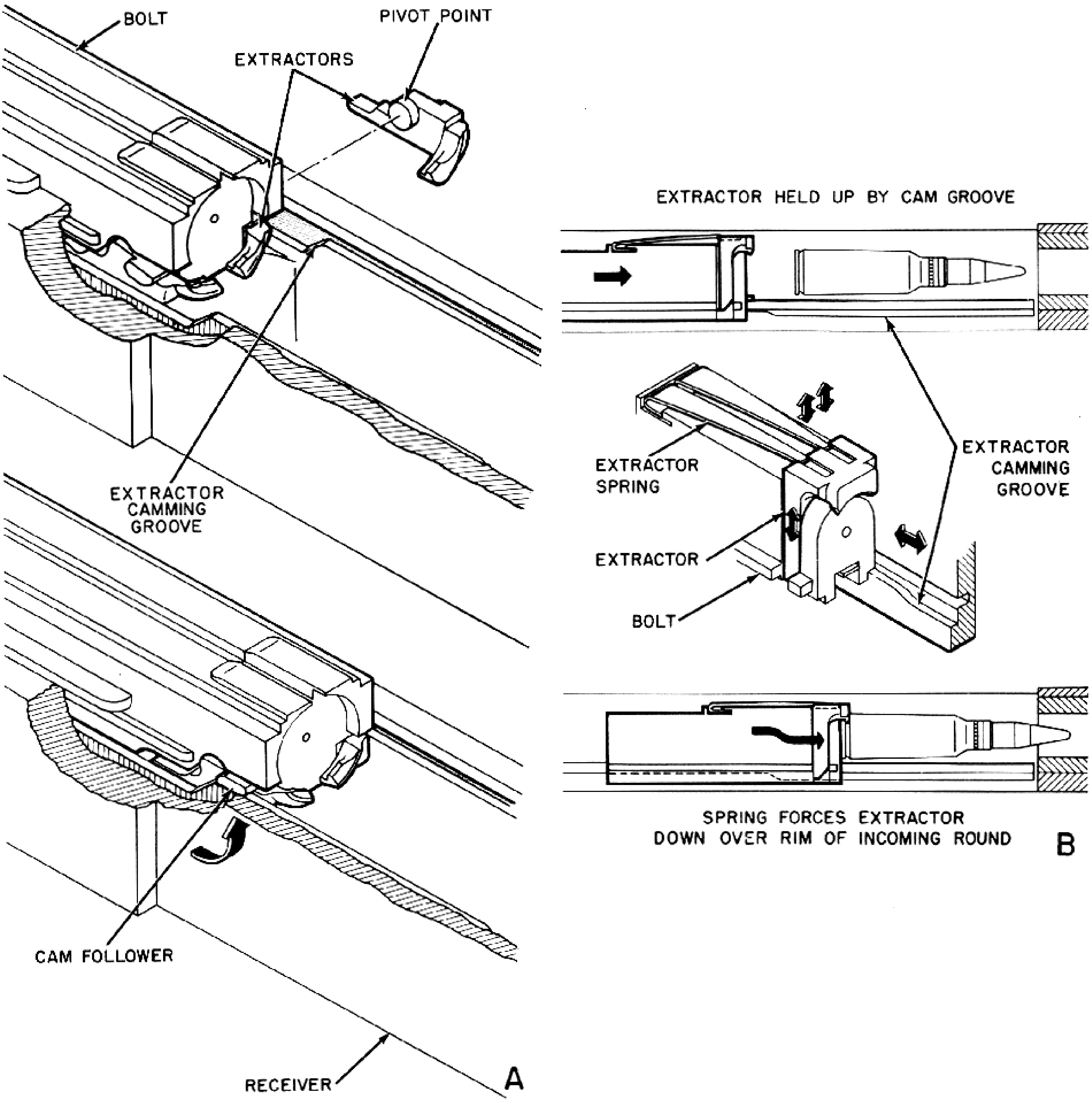

Figure 11–3. Methods of Retaining and Powering Extractors.

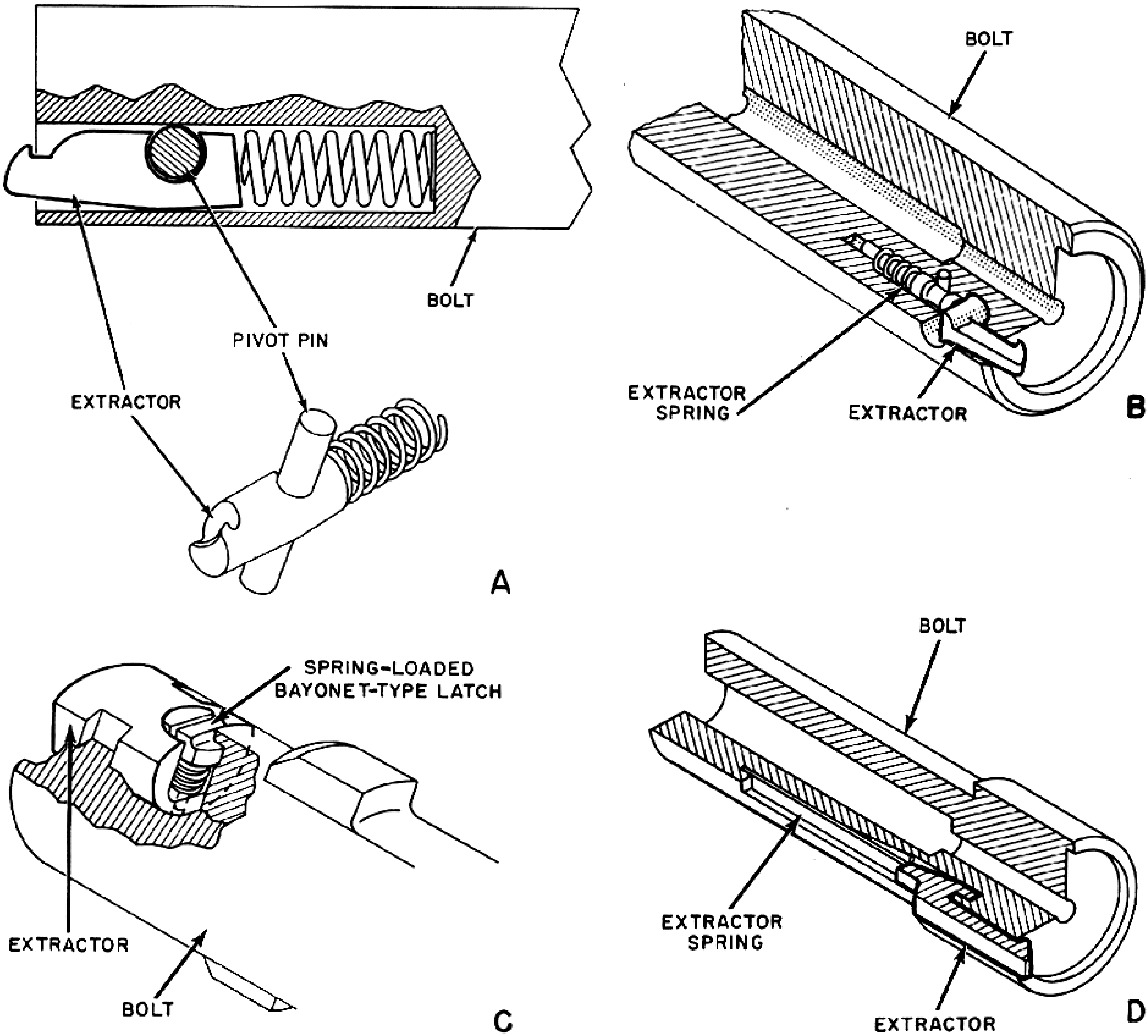

Figure 11–4. Methods of Retaining and Powering Extractors.

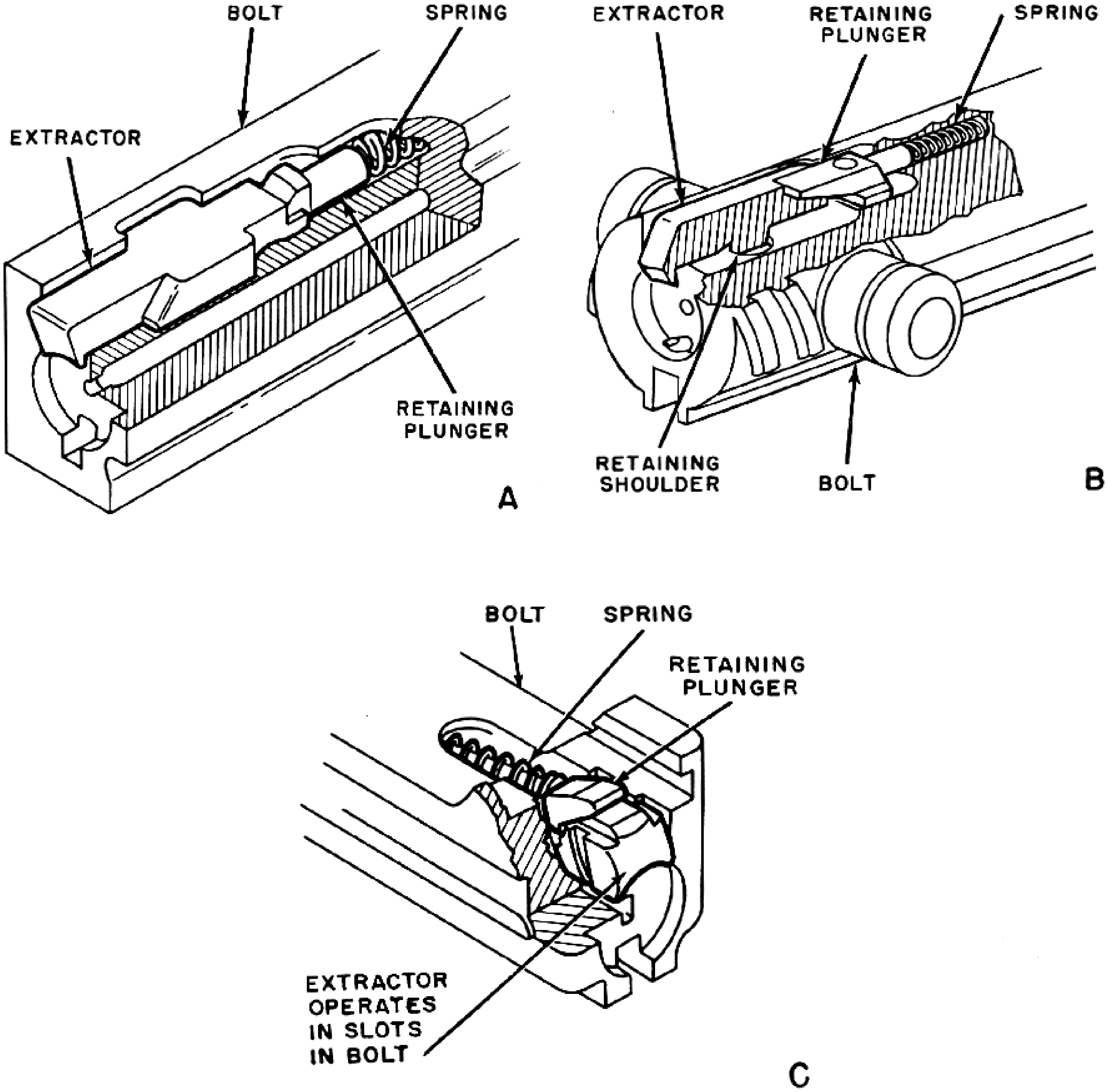

Figure 11–5. Methods of Retaining and Powering Extractors.

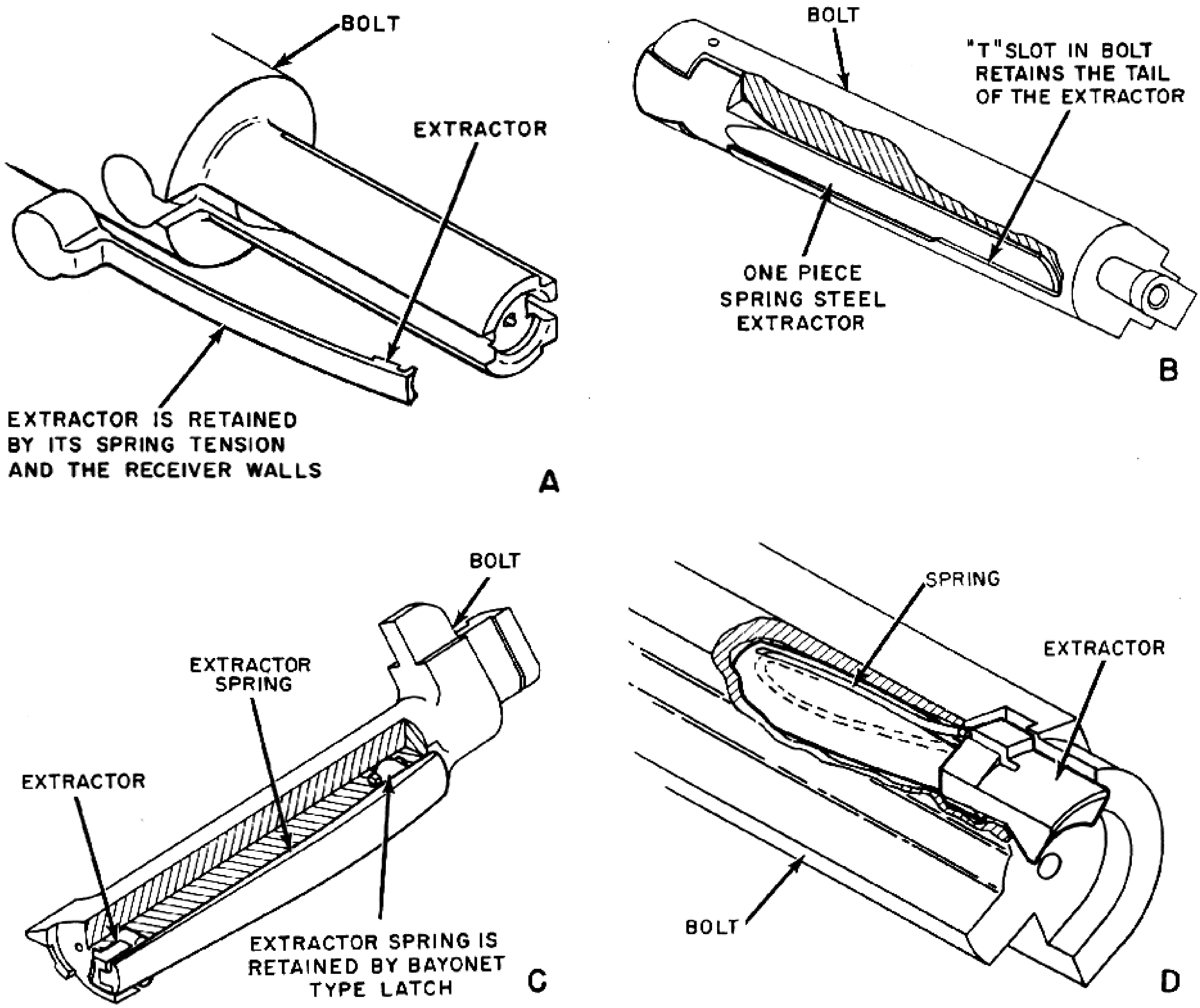

Figure 11–6. Methods of Retaining and Powering Extractors.

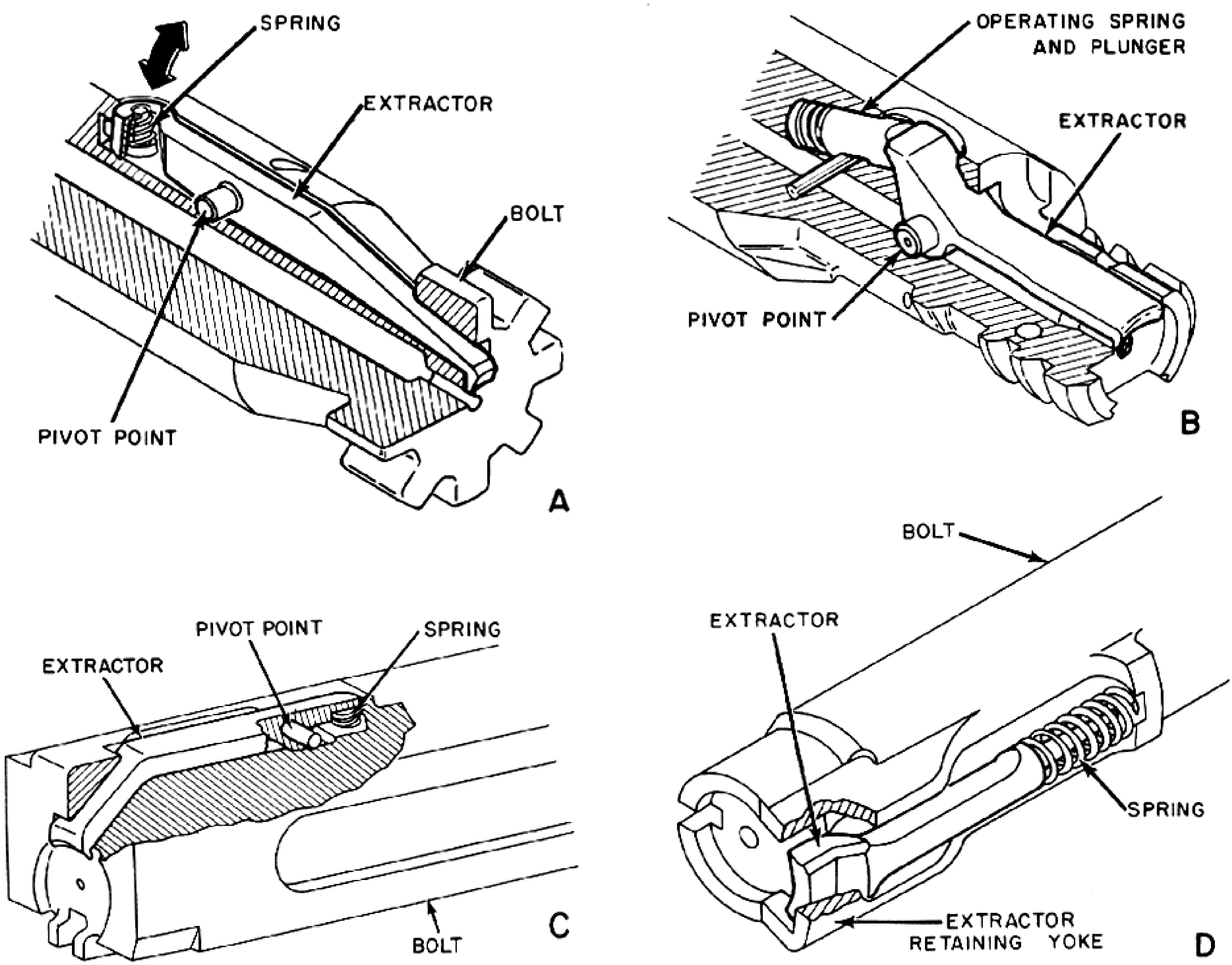

Figure 11–7. Methods of Retaining and Powering Extractors.

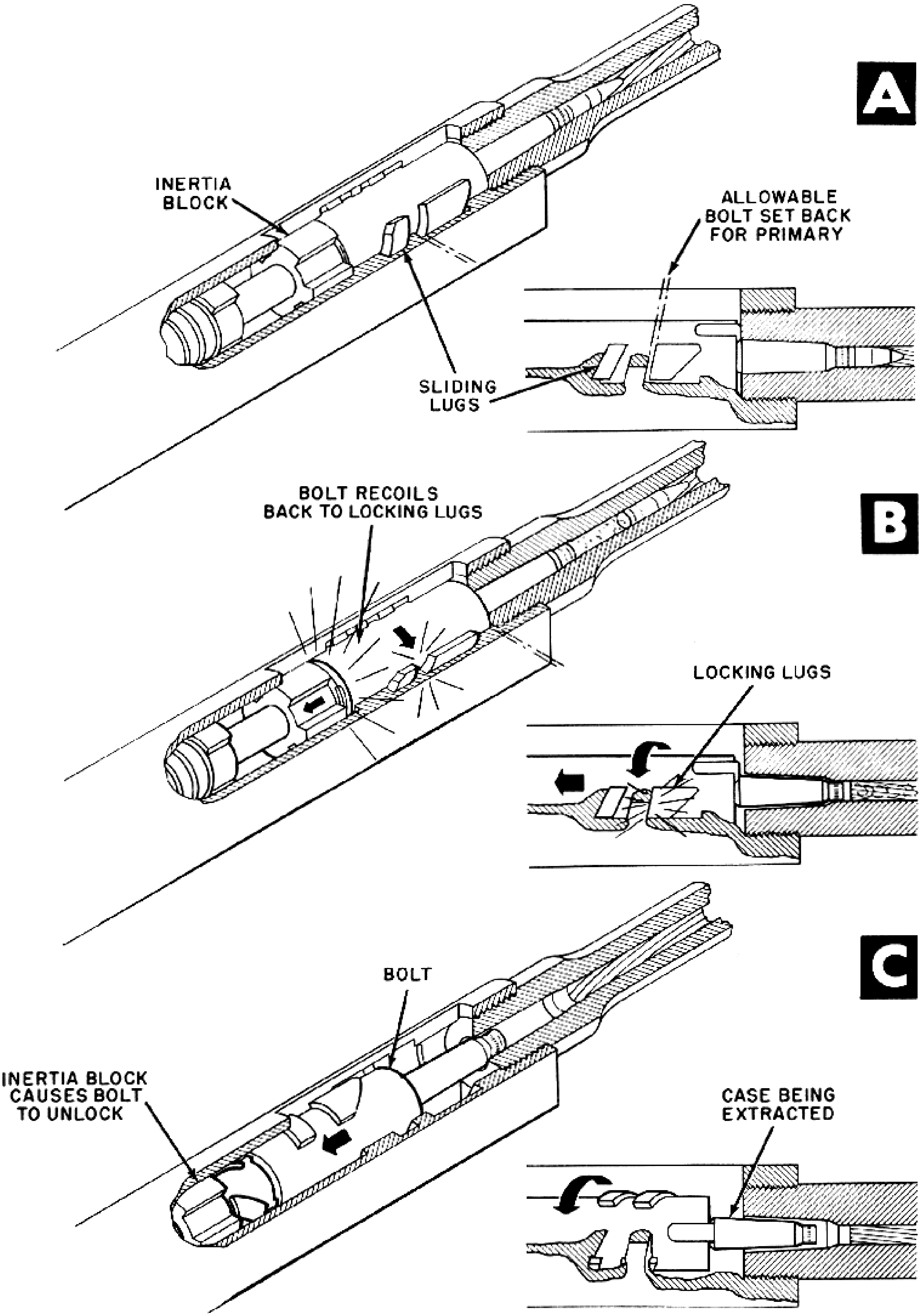

Figure 11–8. Impact of Initial Extraction Actuates Bolt Unlocking.

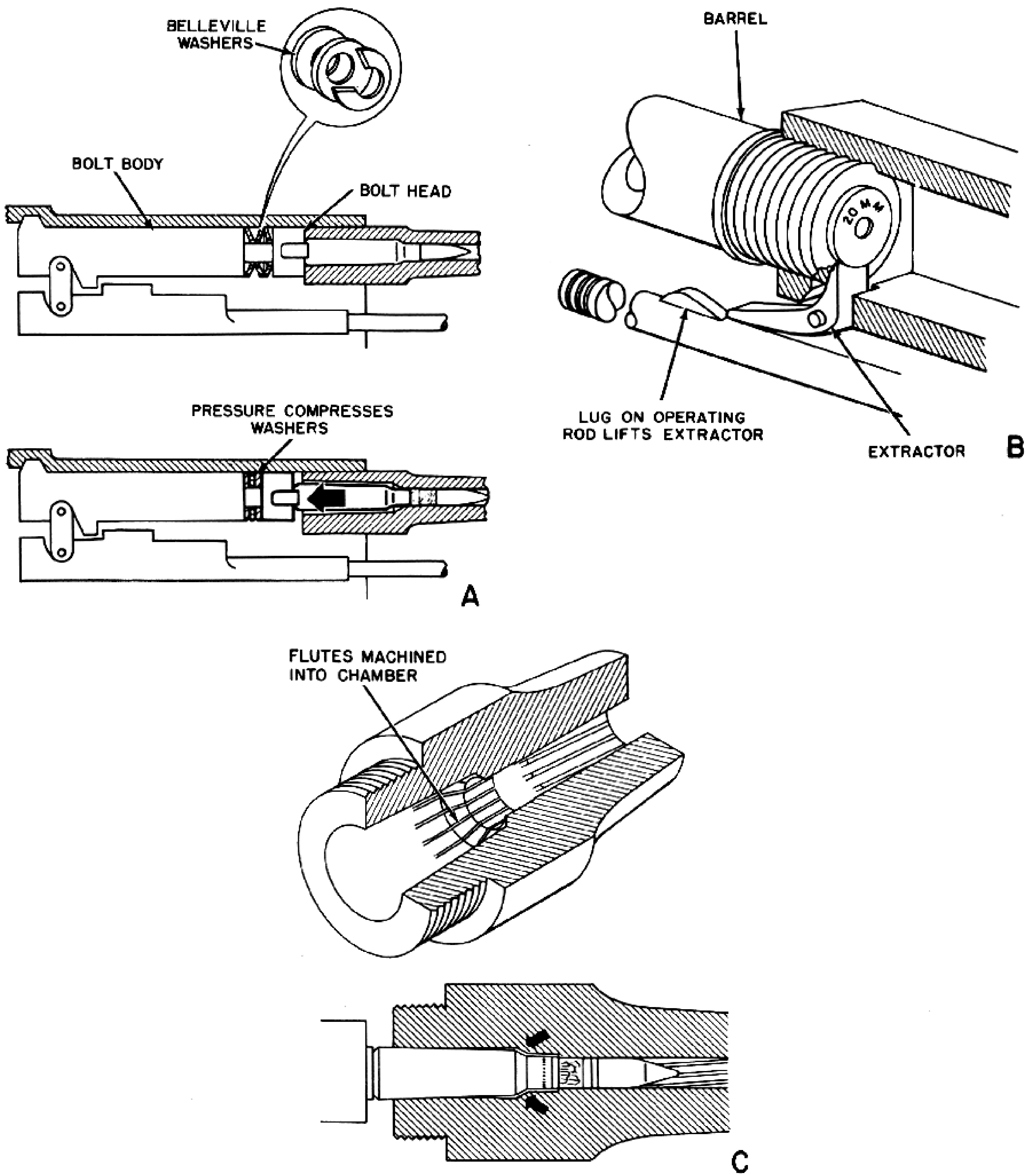

Figure 11–9. Methods of Assisting and Obtaining Initial Extraction.

Chapter 12

EJECTORS

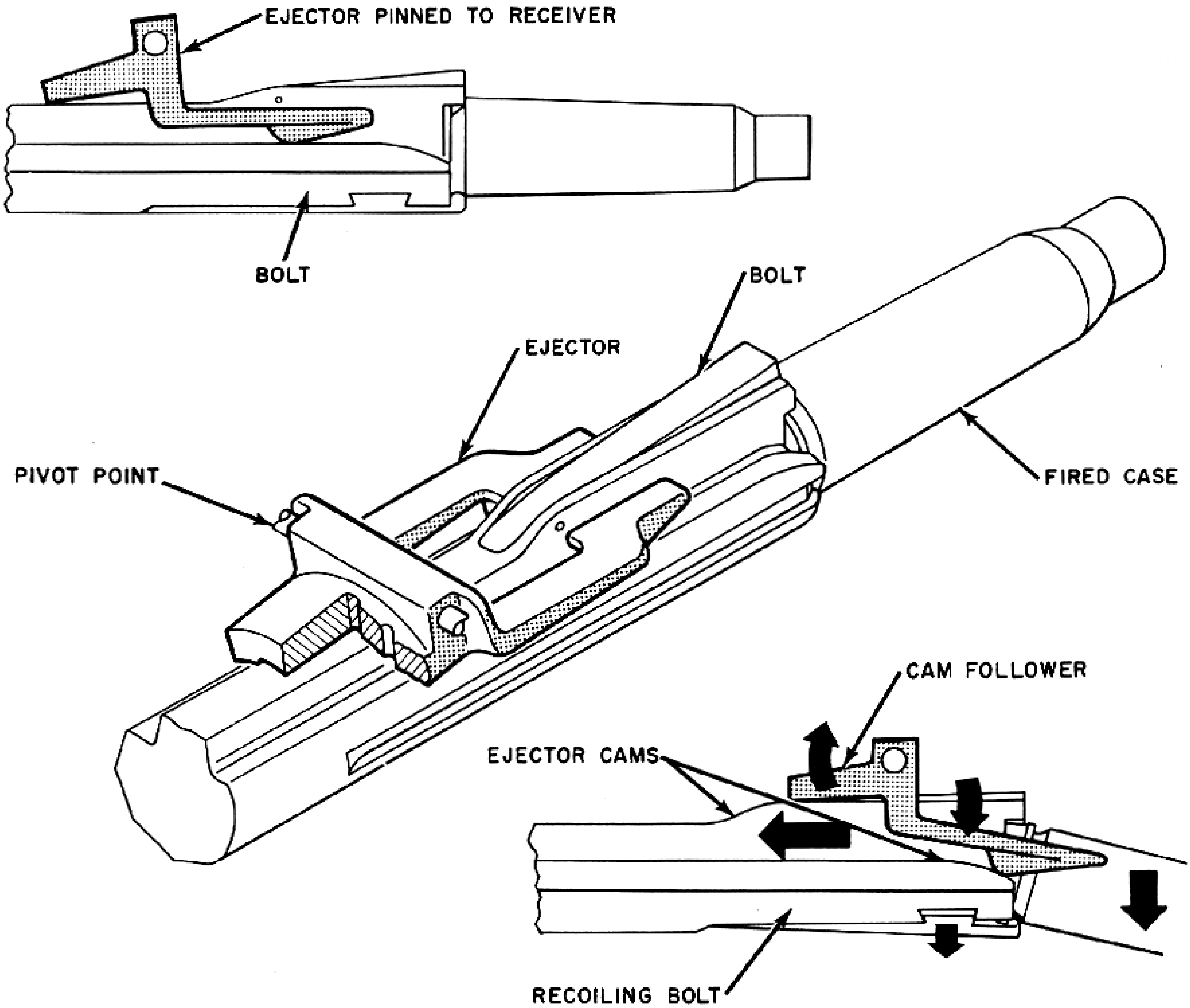

Figure 12–1. Operation of Cam-Actuated Ejector.

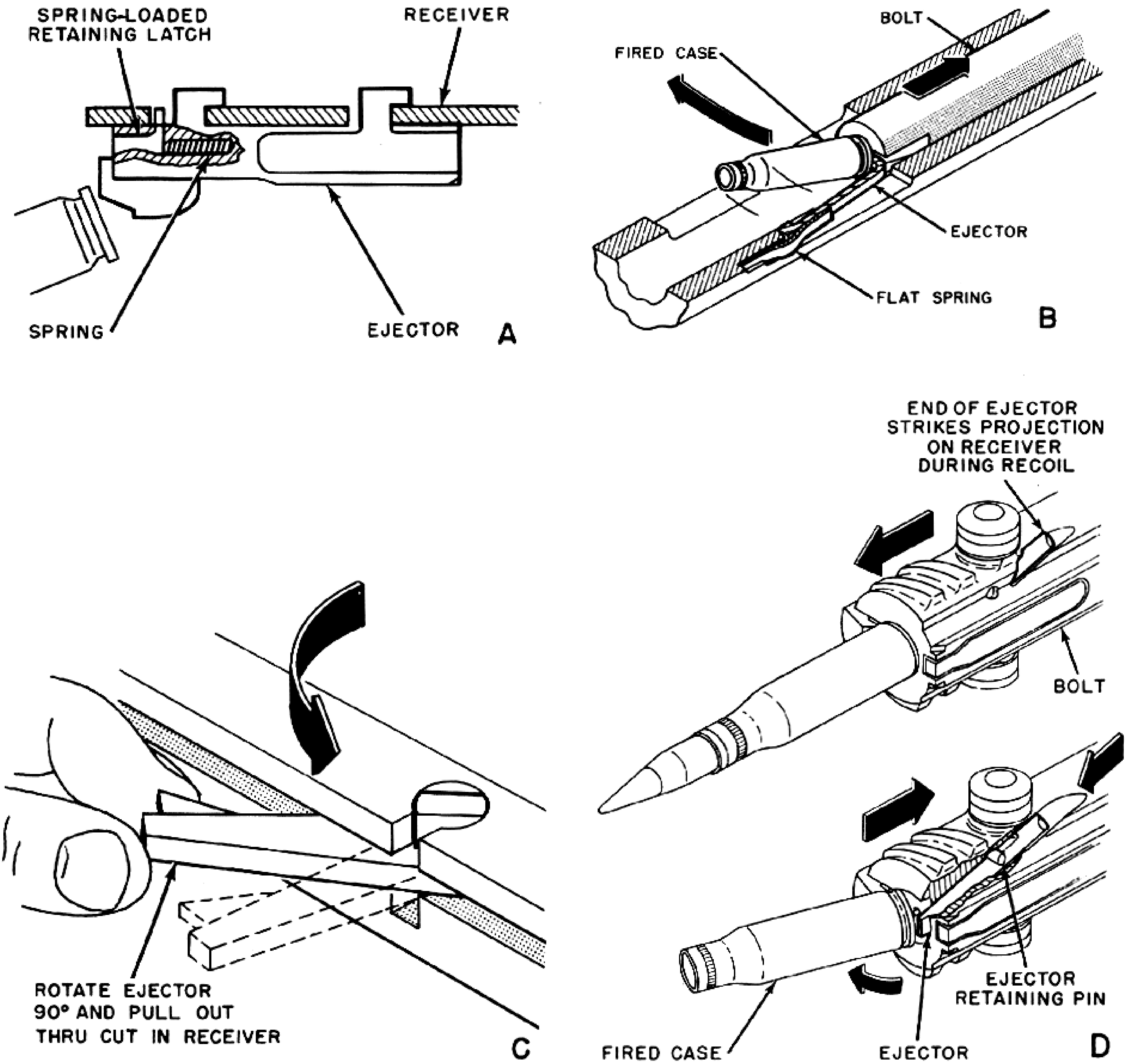

Figure 12–2. Methods of Retaining and Operating Ejectors.

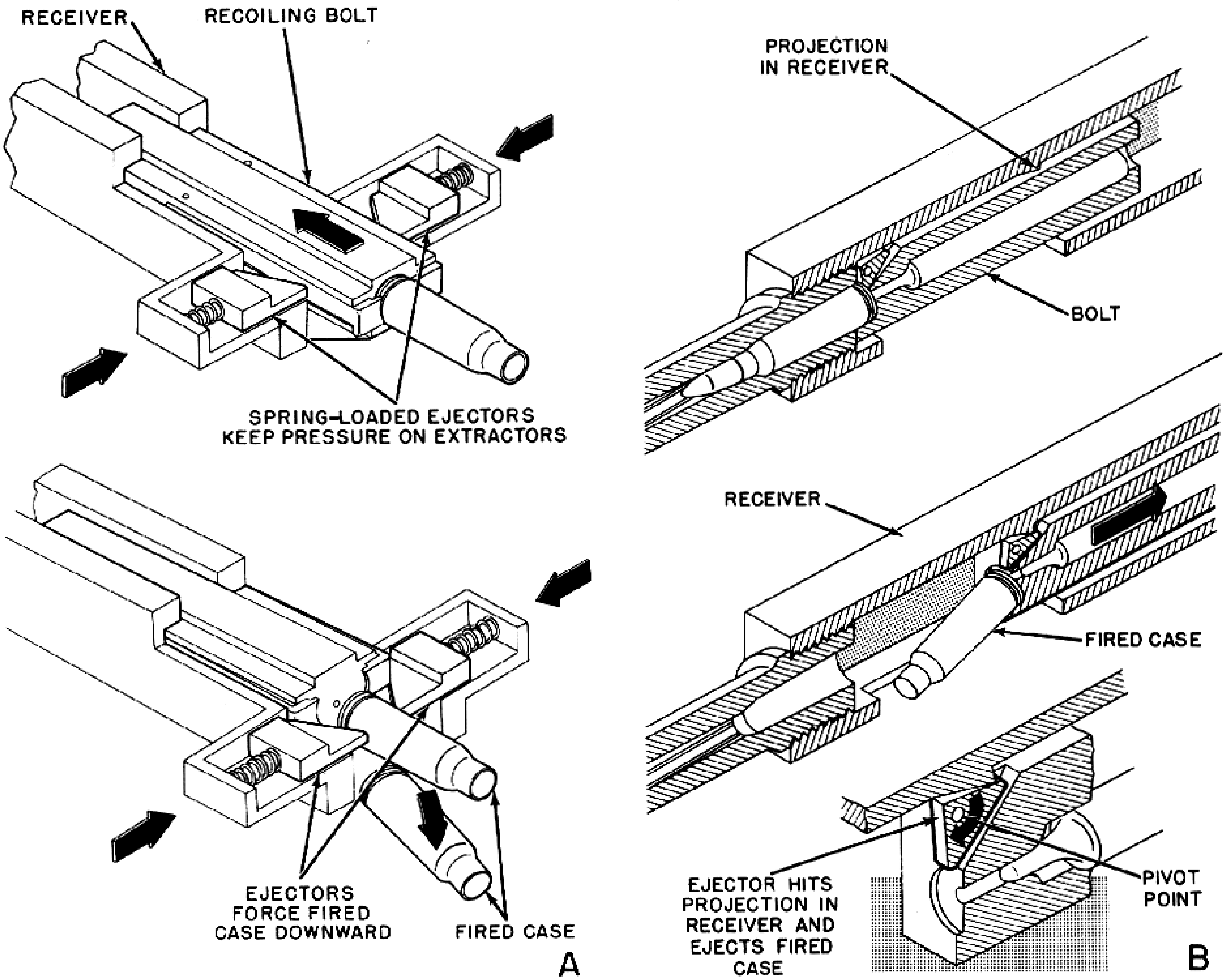

Figure 12–3. Methods of Retaining and Operating Ejectors.

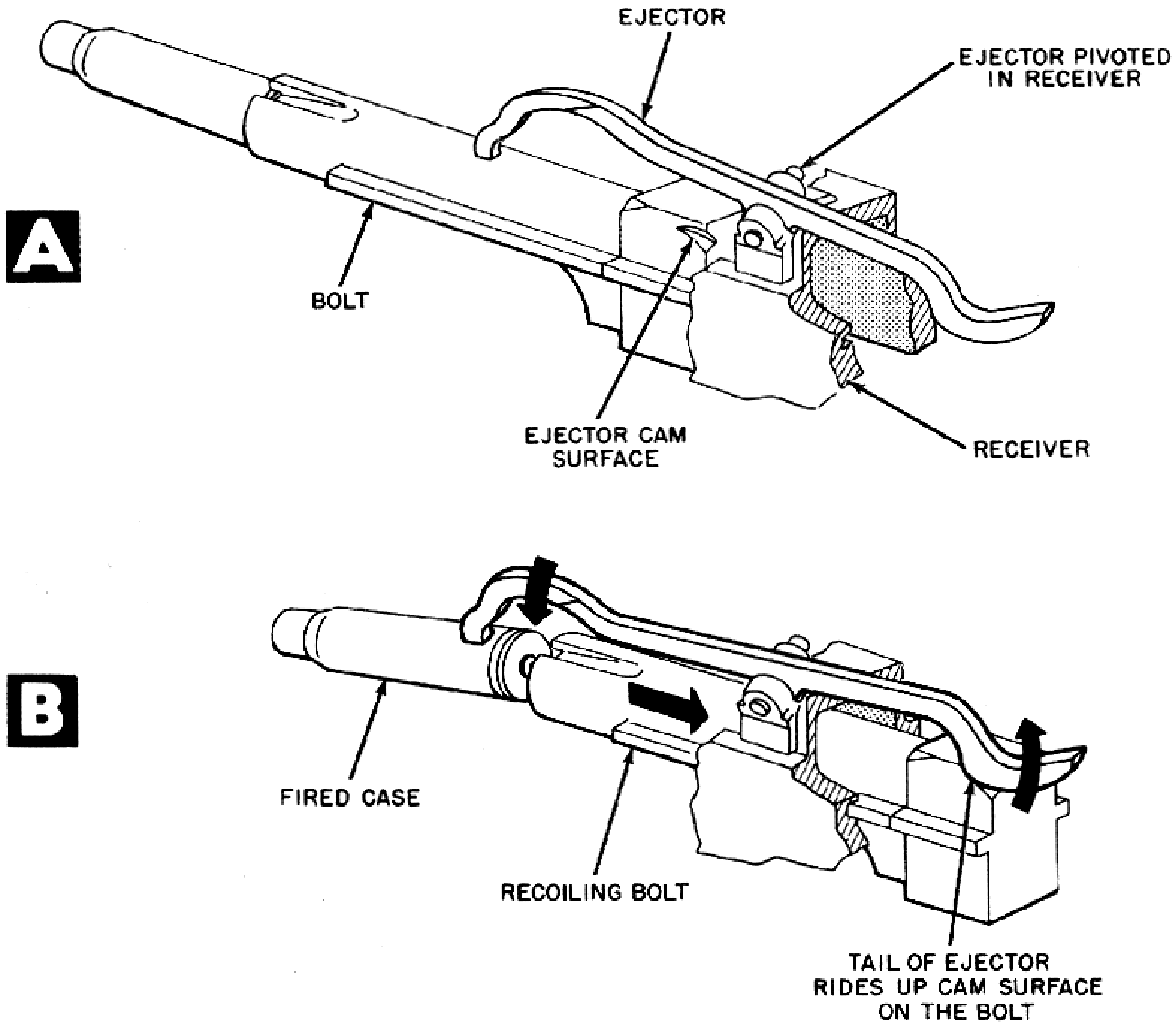

Figure 12–4. Operation of Cam-Actuated Ejector

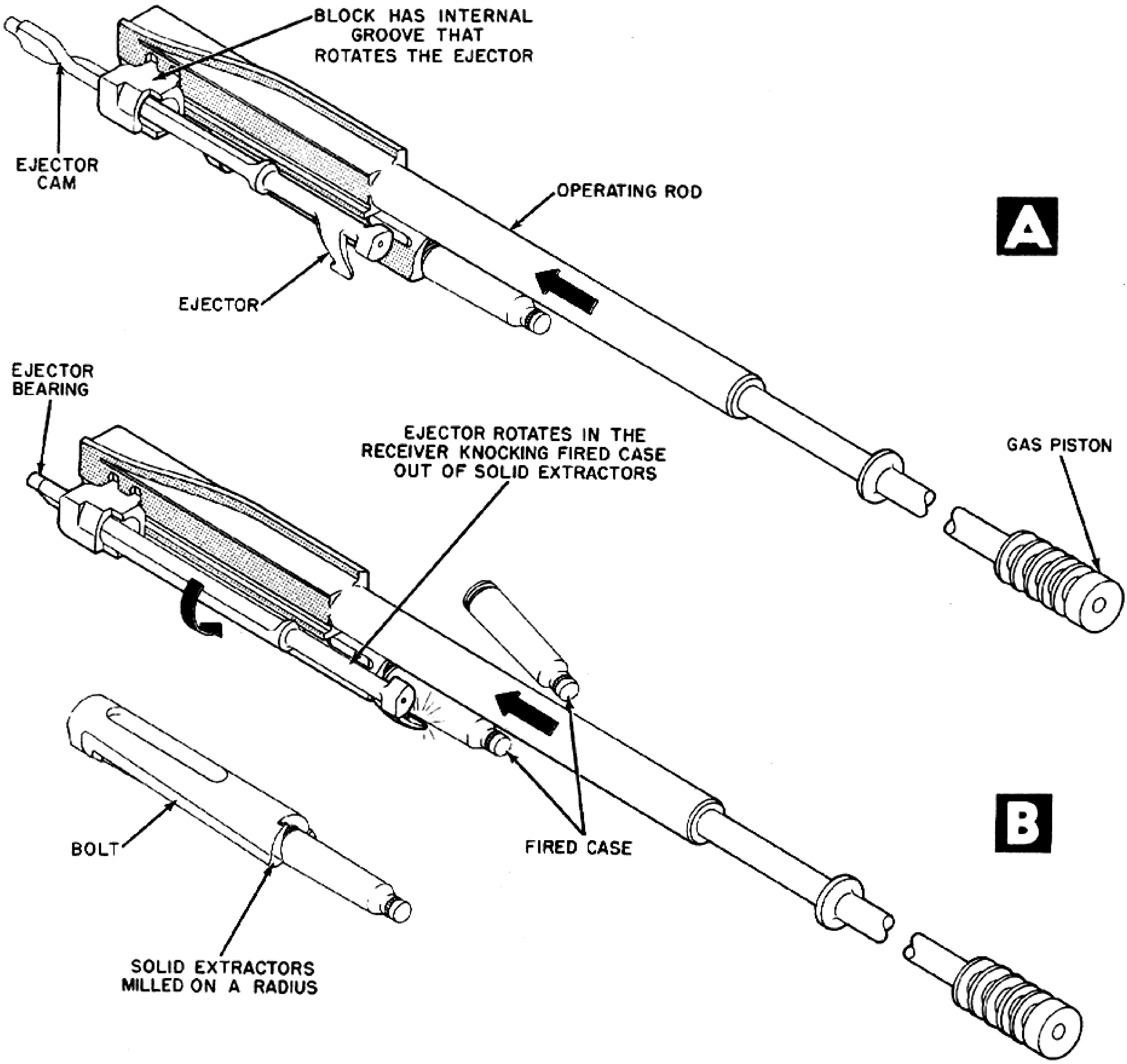

Figure 12-5. Method of Operating Cam-Actuated Ejector.

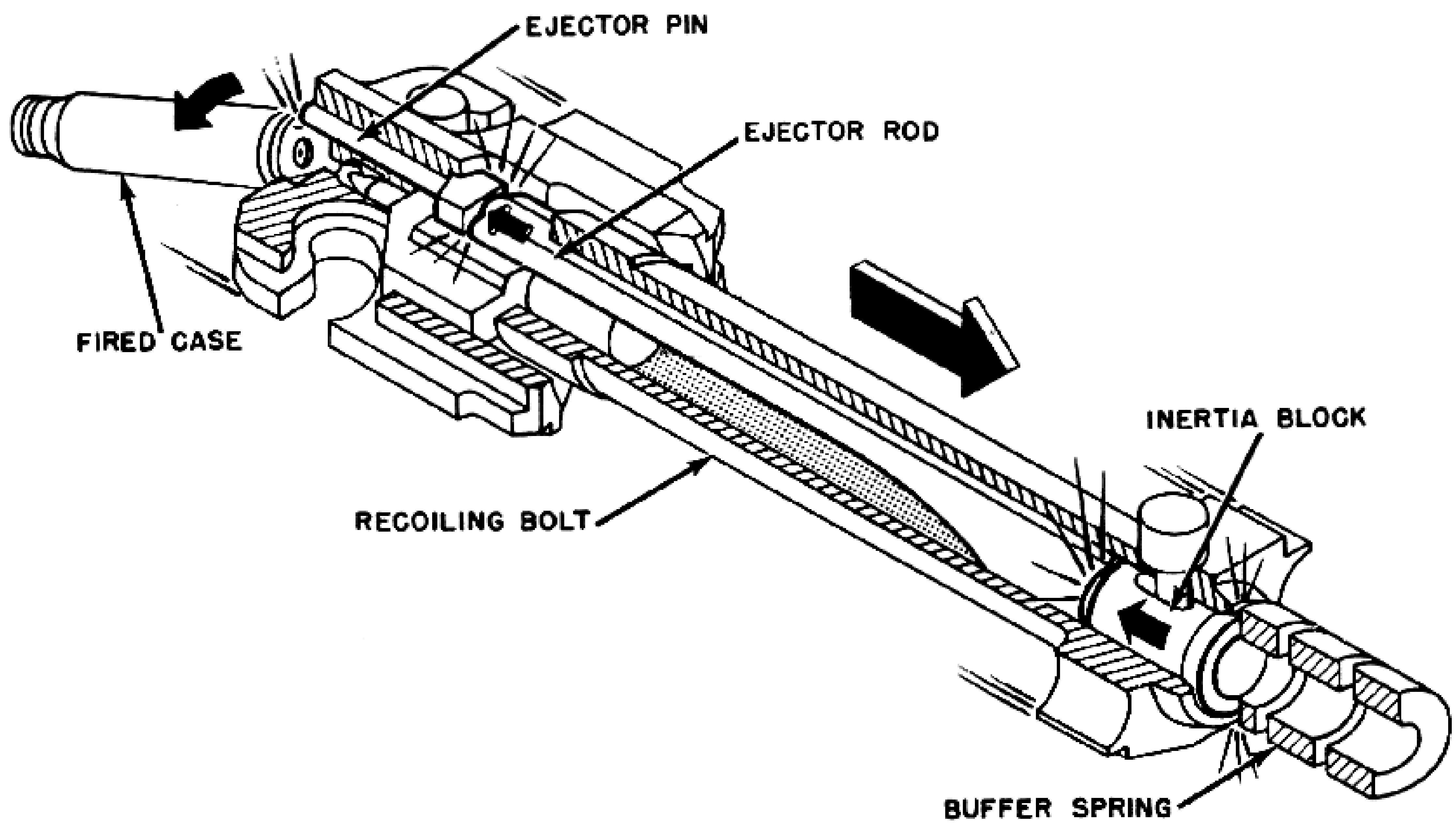

Figure 12–6. Buffer Operated Ejector.

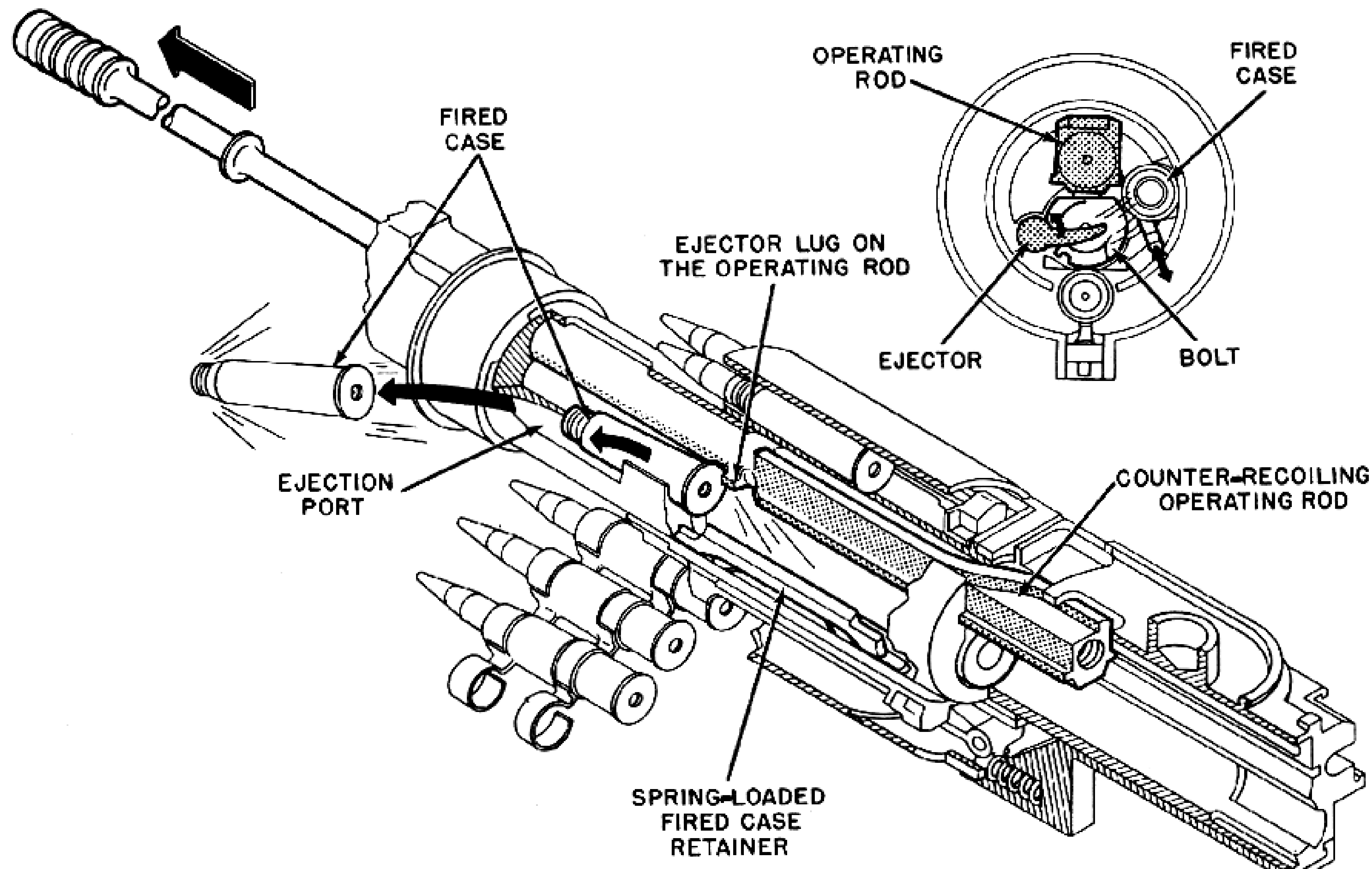

Figure 12–7. Method of Obtaining Forward Ejection.

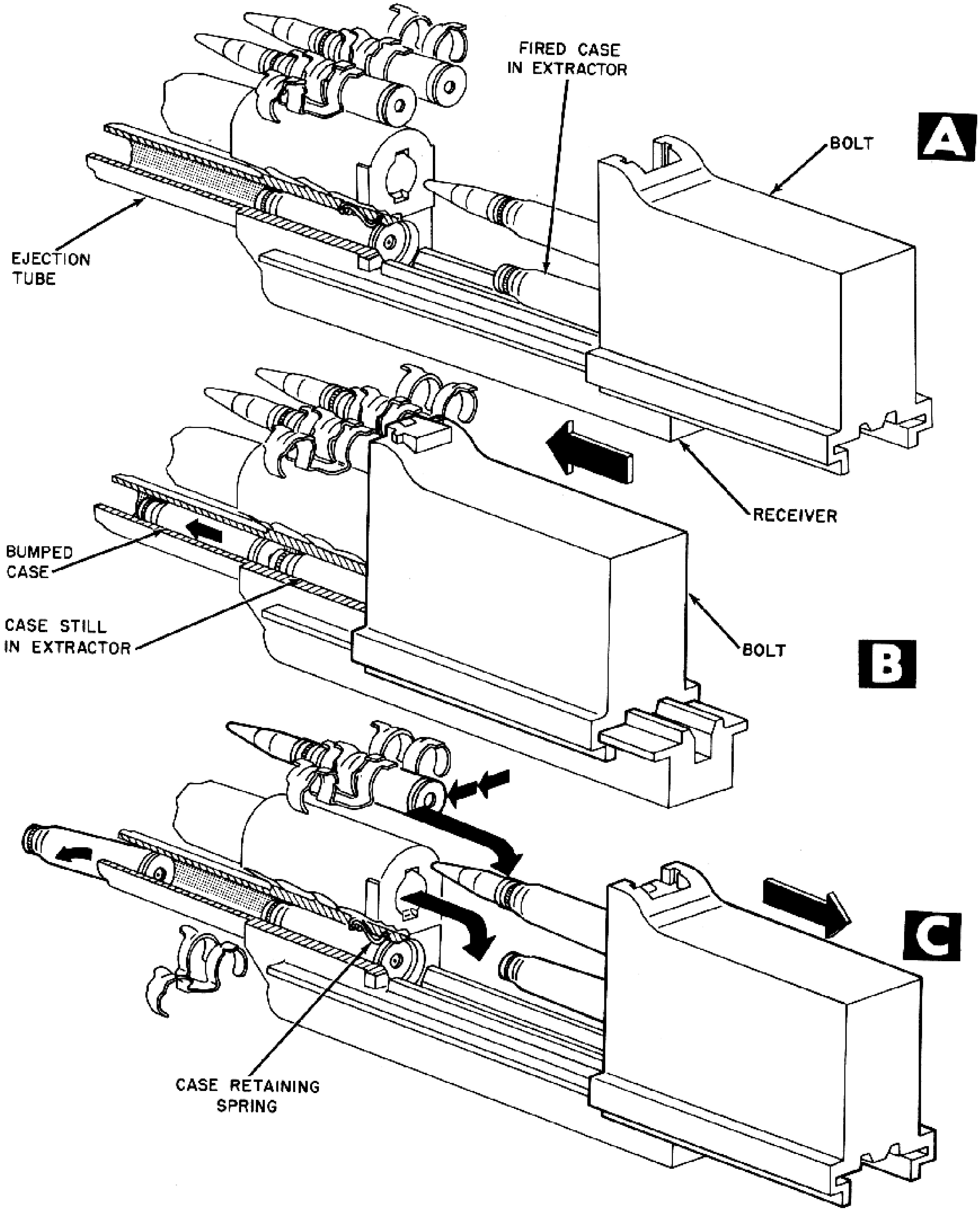

Figure 12–8. Method of Obtaining Forward Ejection.

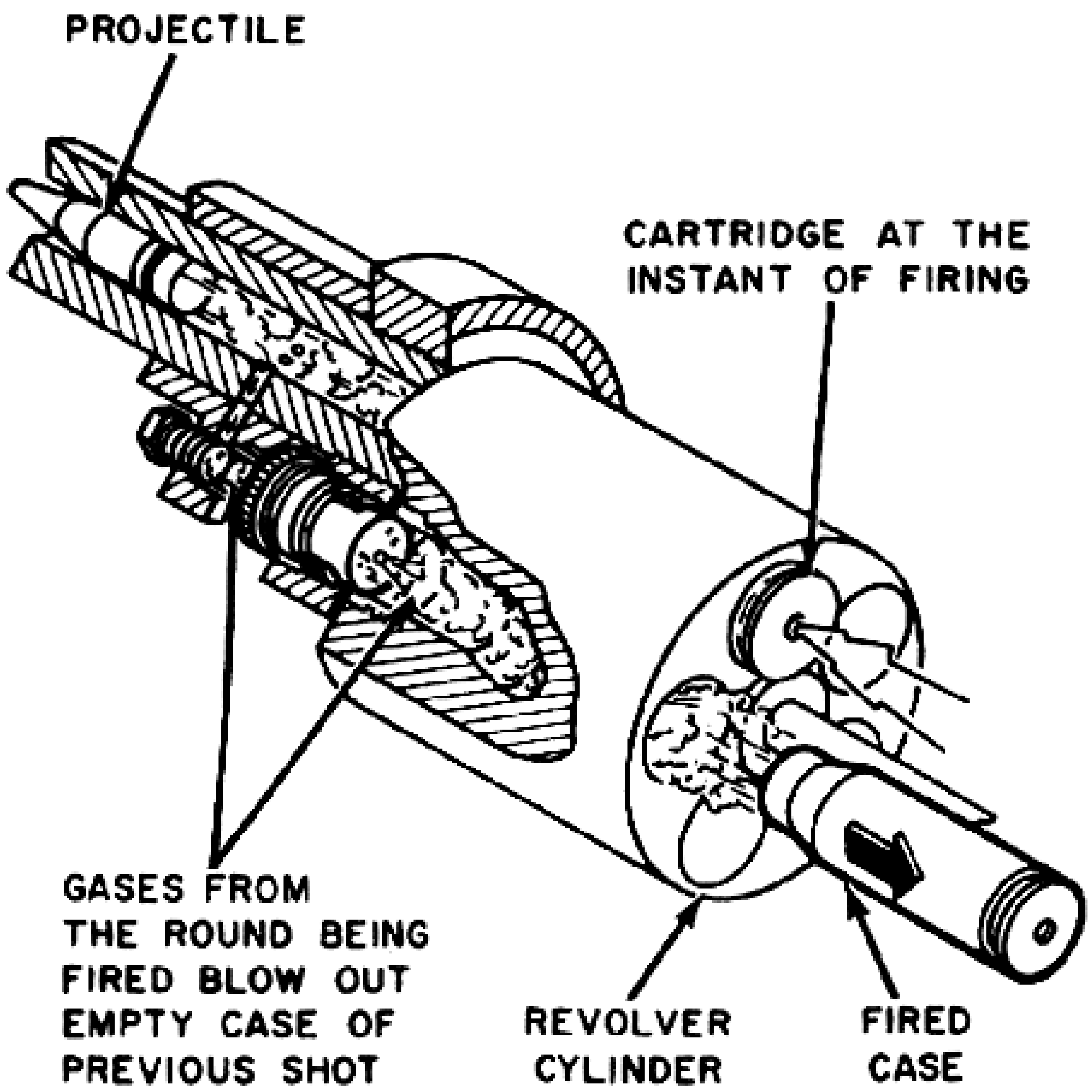

Figure 12–9. Operation of Gas Ejector.

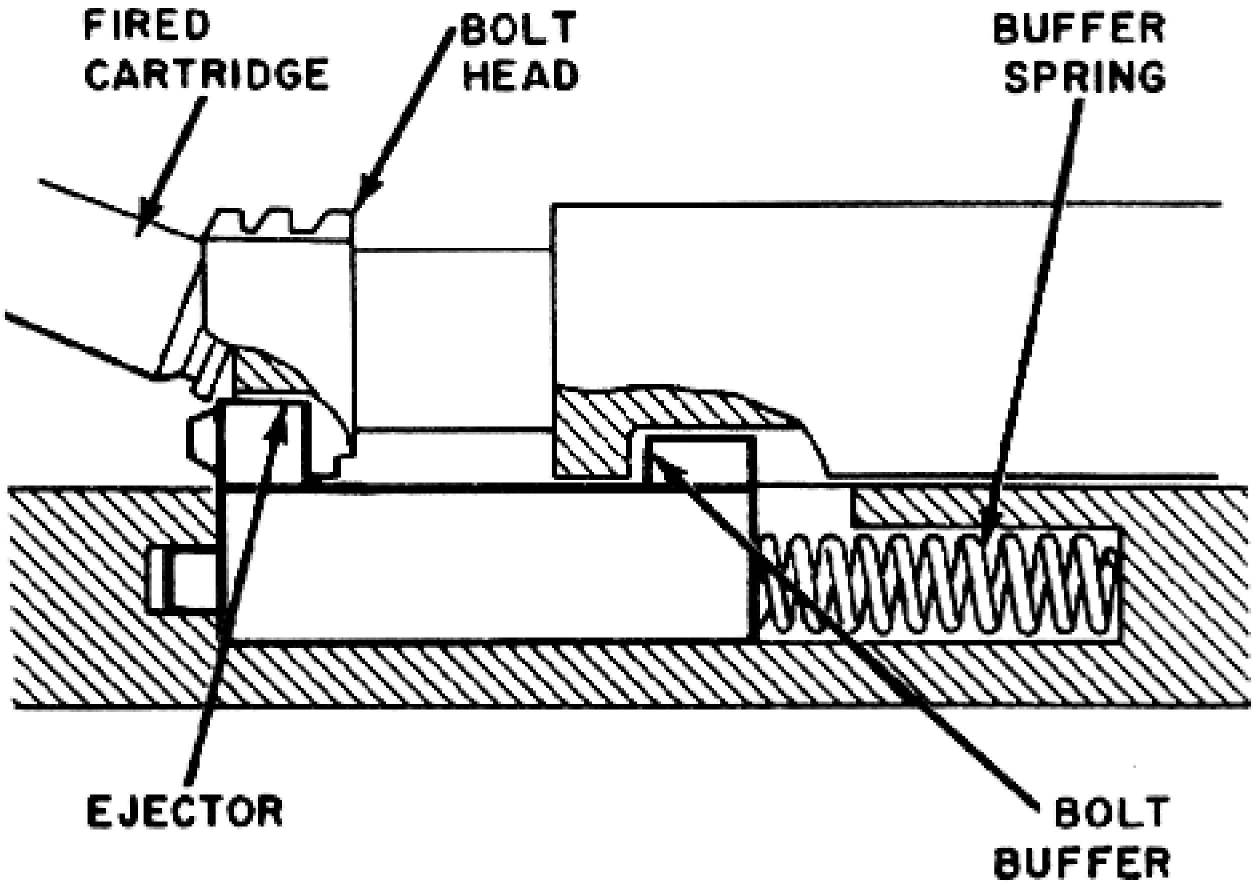

Figure 12–10. Combination Buffer and Ejector.

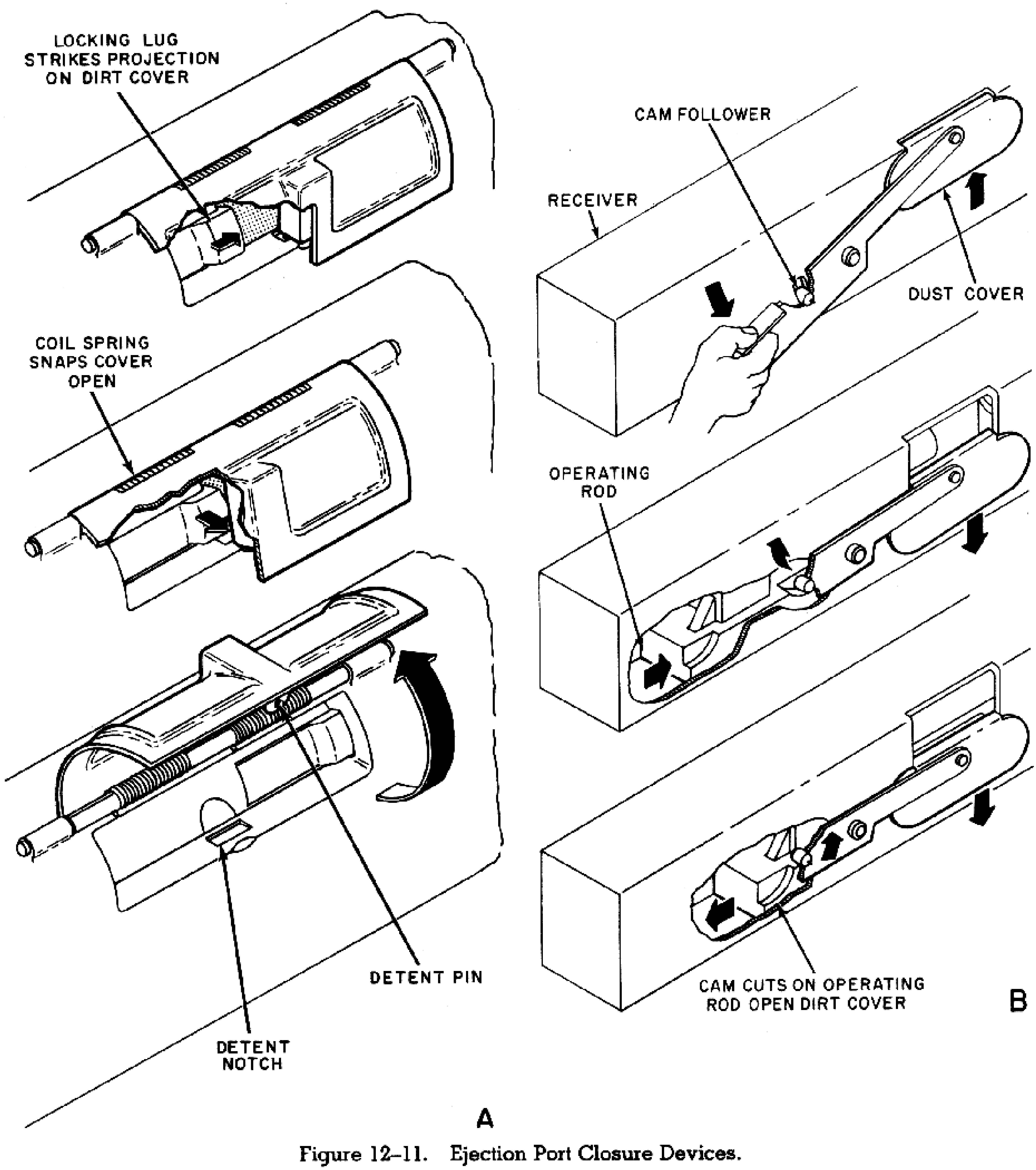

Figure 12-11. Ejection Port Closure Devices.

SEAR MECHANISMS

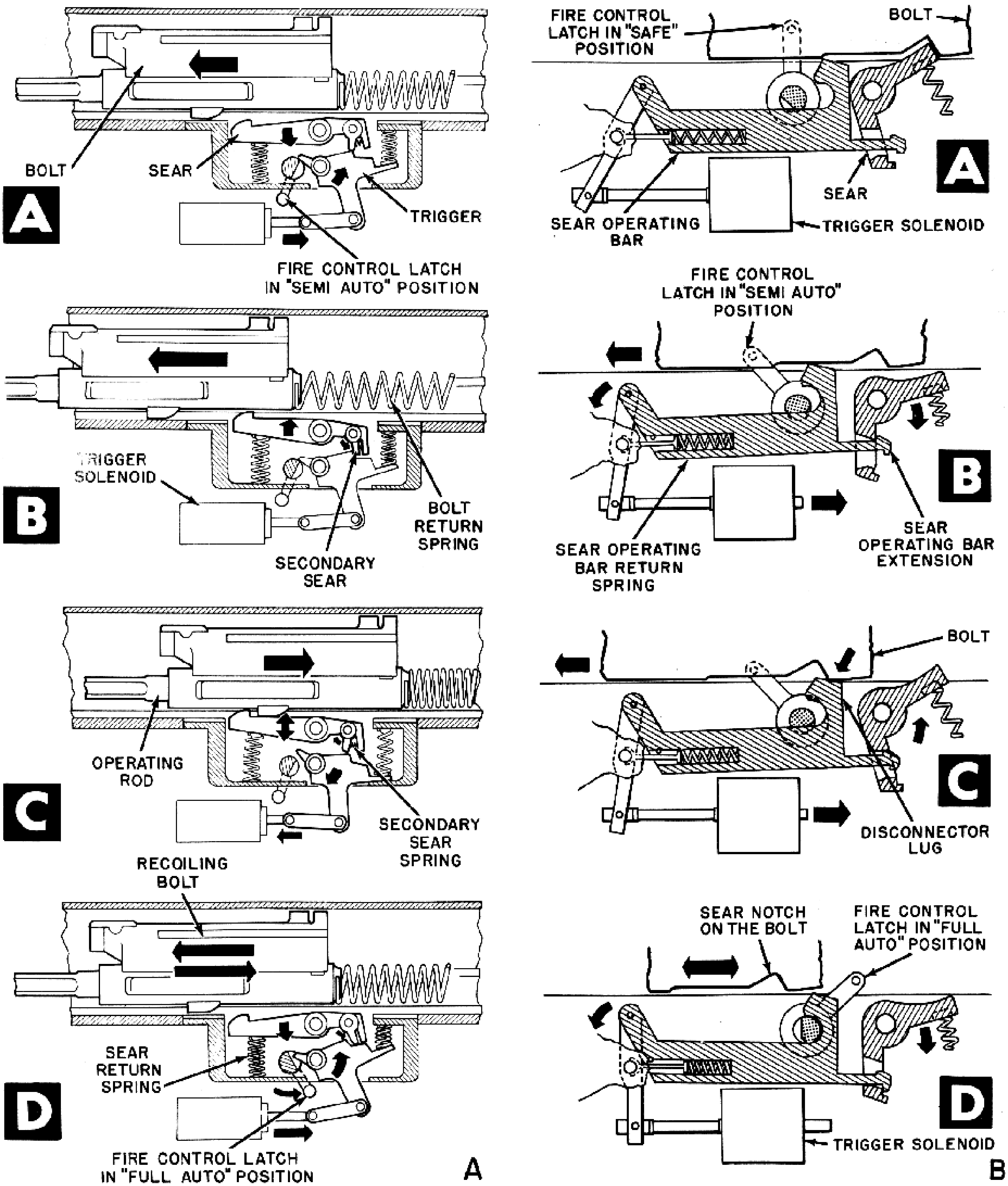

Figure 13–1. Operation of Sear Mechanisms.

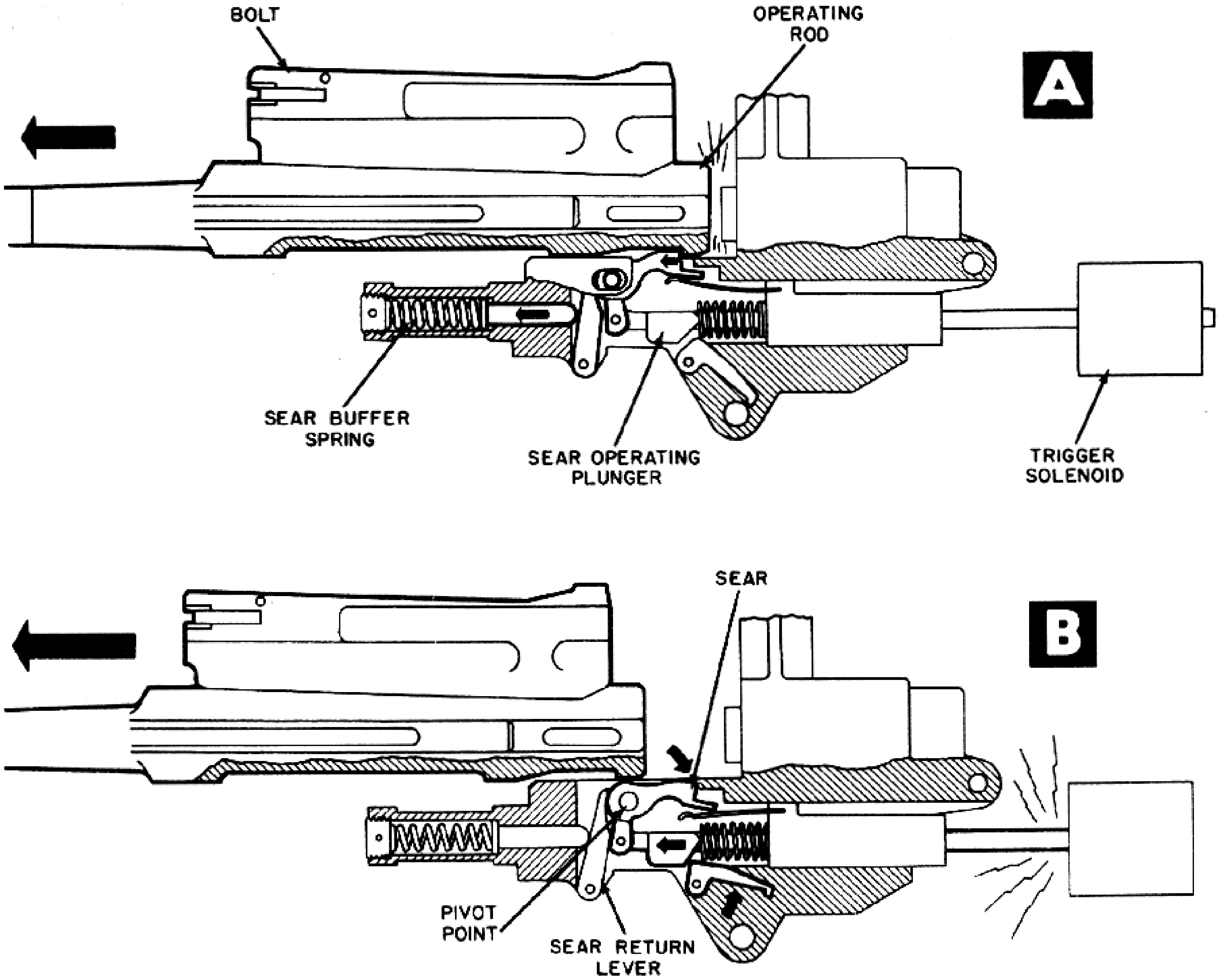

Figure 13–2. Operation of Sear Mechanism and Sear Buffer.

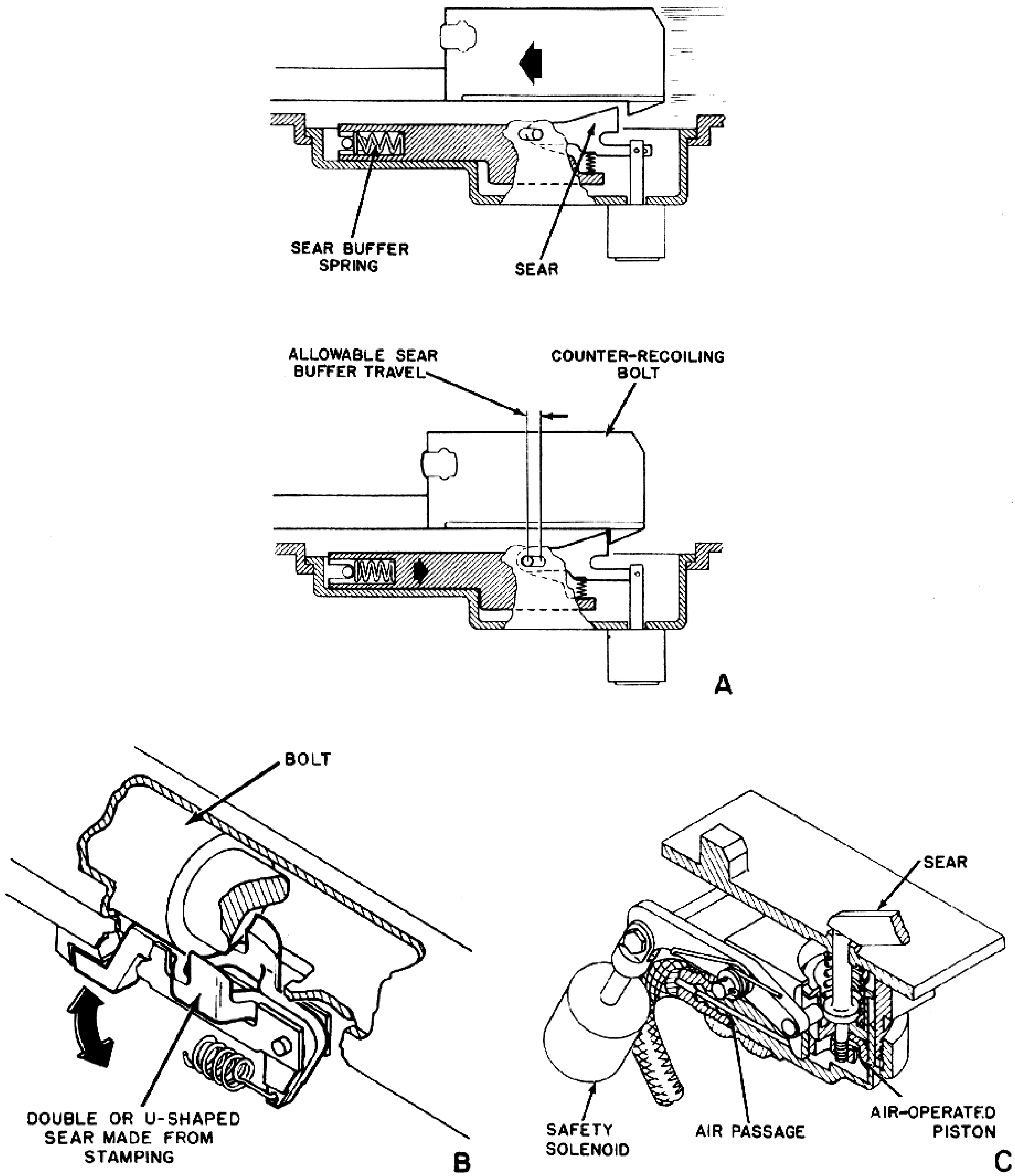

Figure 13–3. Operation of Sear Mechanisms.

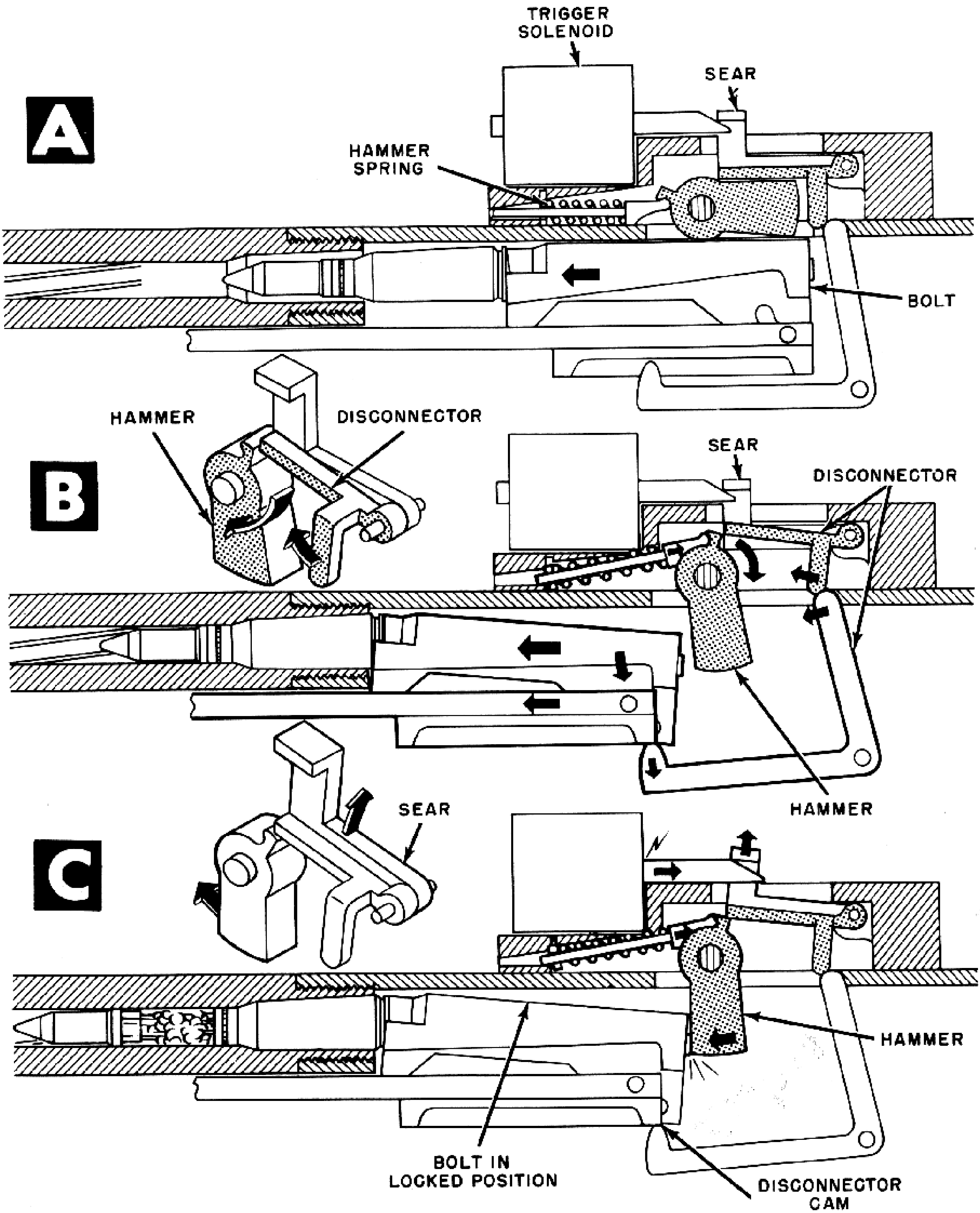

Figure 13–4. Operating Cycle of Sear Mechanism.

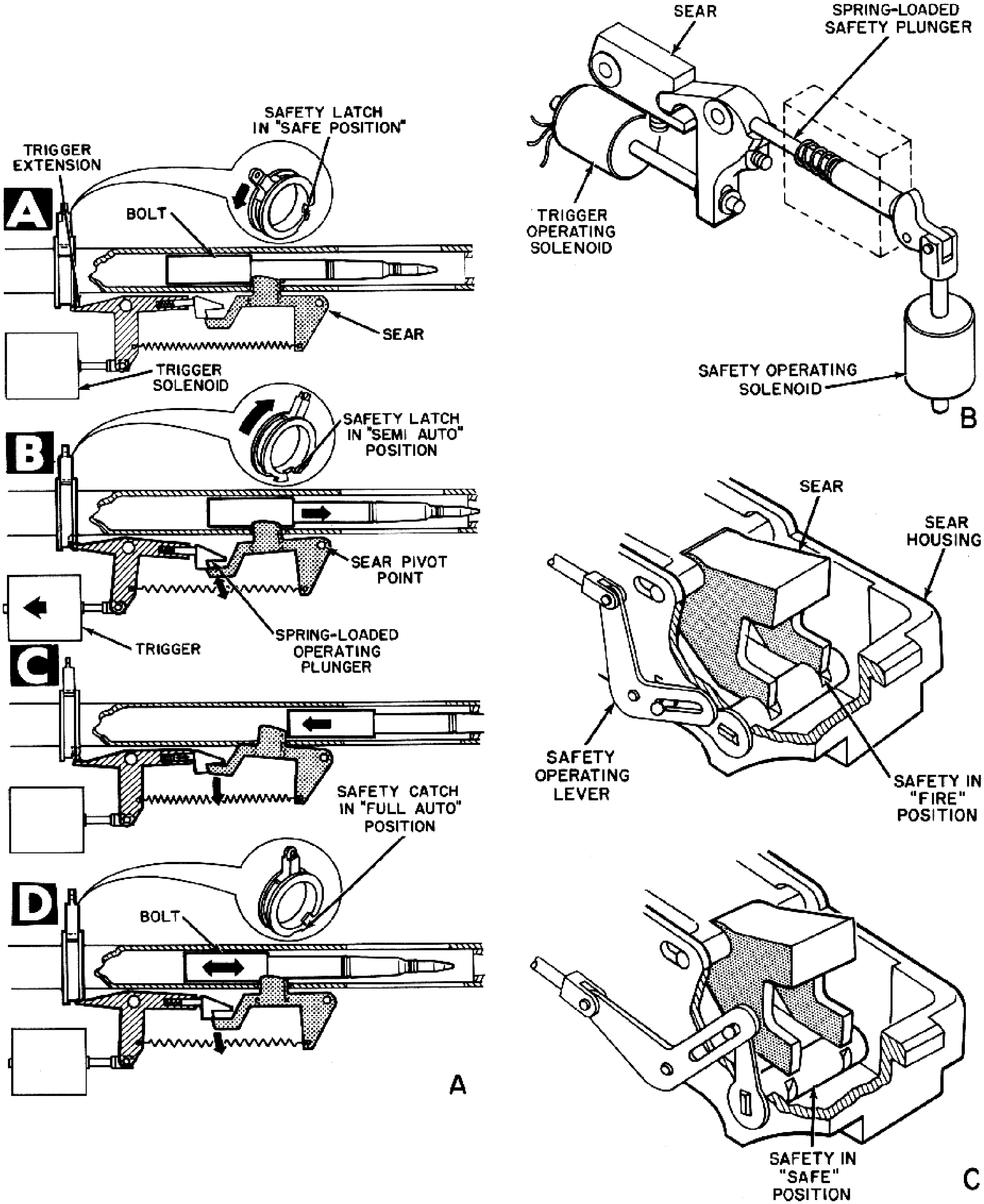

Figure 13–5. Operating Cycle of Sear Mechanism and Safety Latches.

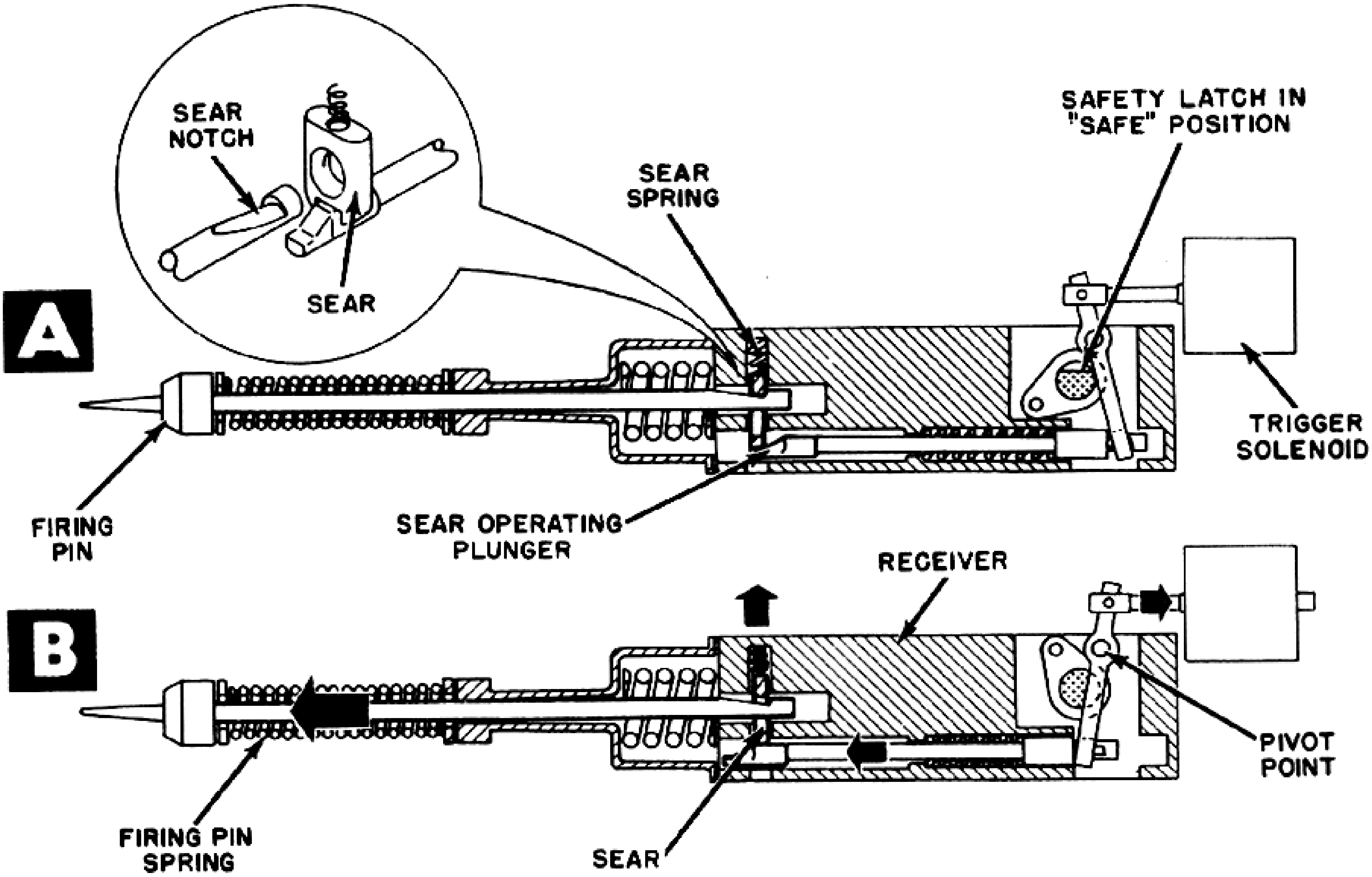

Figure 13–6. Operating Cycle of Sear Mechanism.

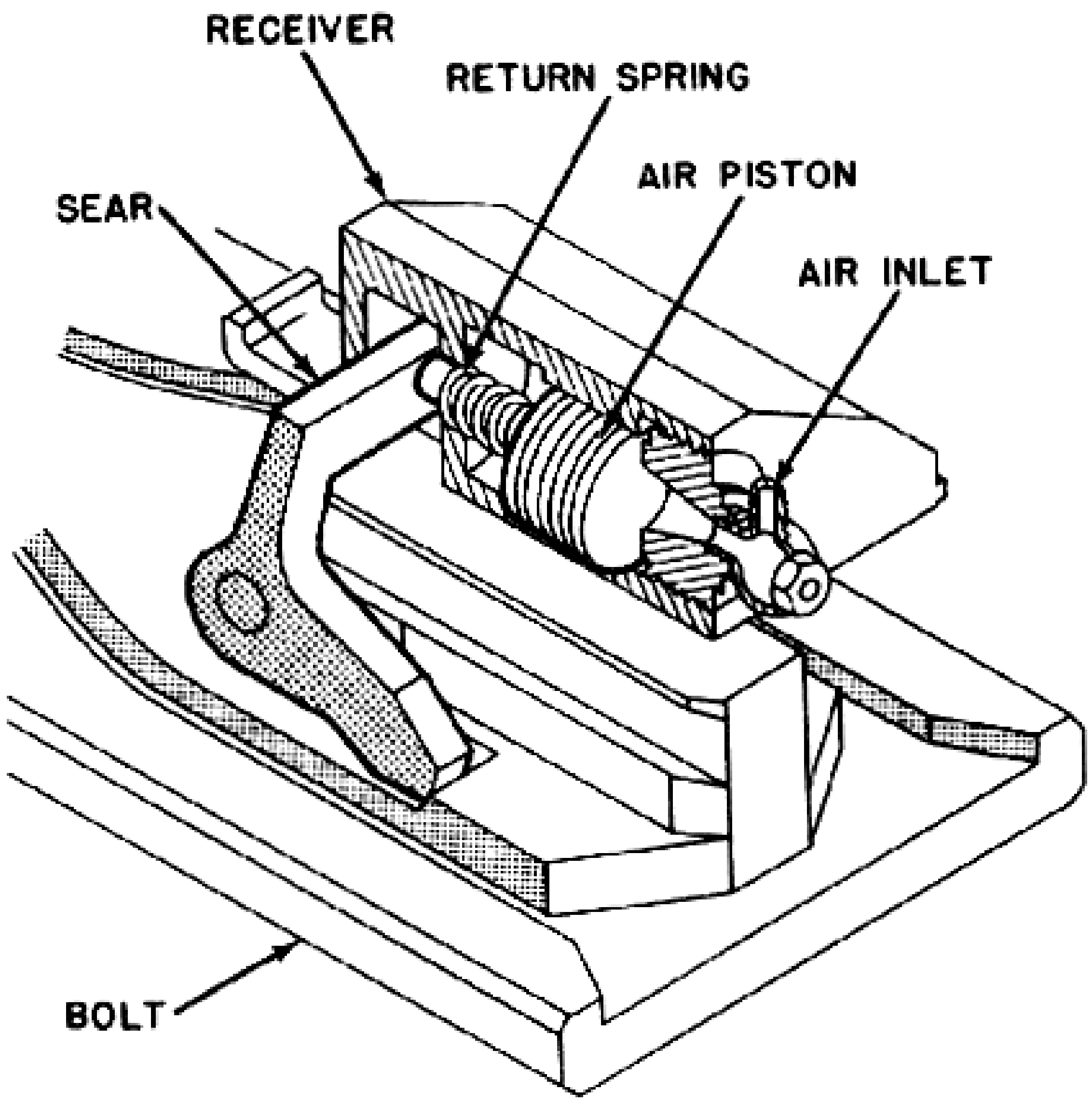

Figure 13–7. Air-Operated Sear.

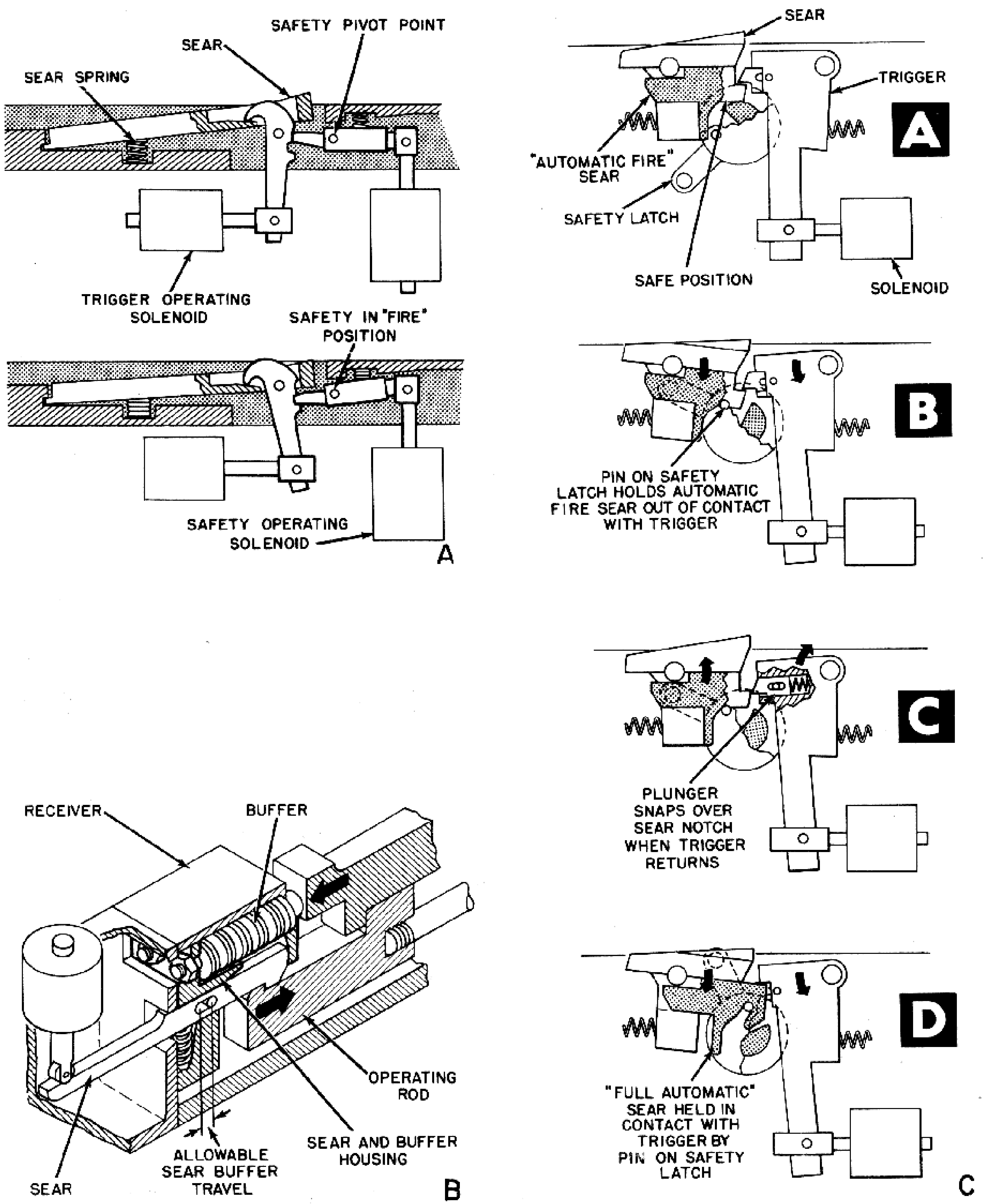

Figure 13–8. Operating Cycle of Sear Mechanism, Sear Buffer and Safety Latch.

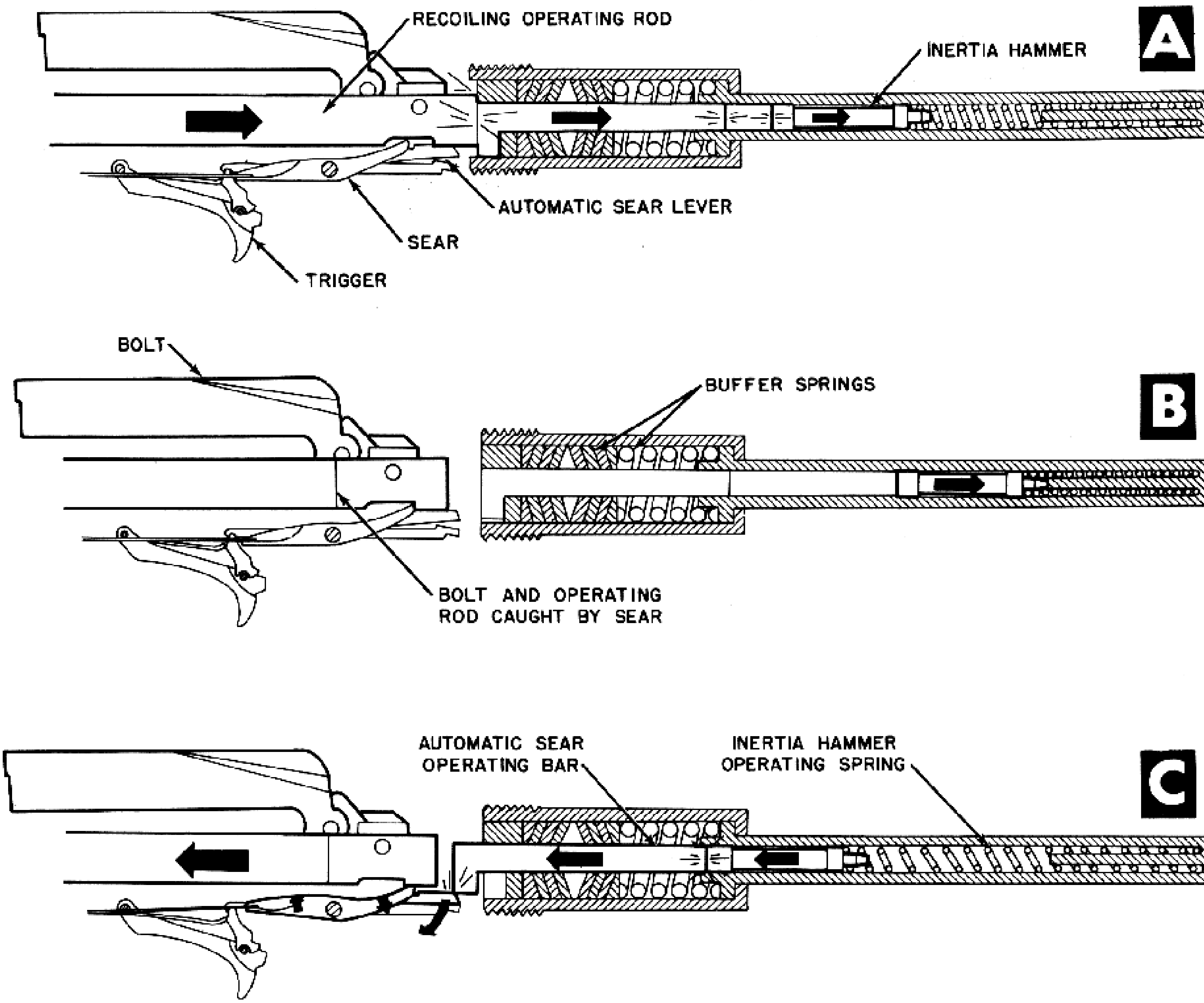

Figure 13–9. Method of Attaining Controlled Rate of Fire.

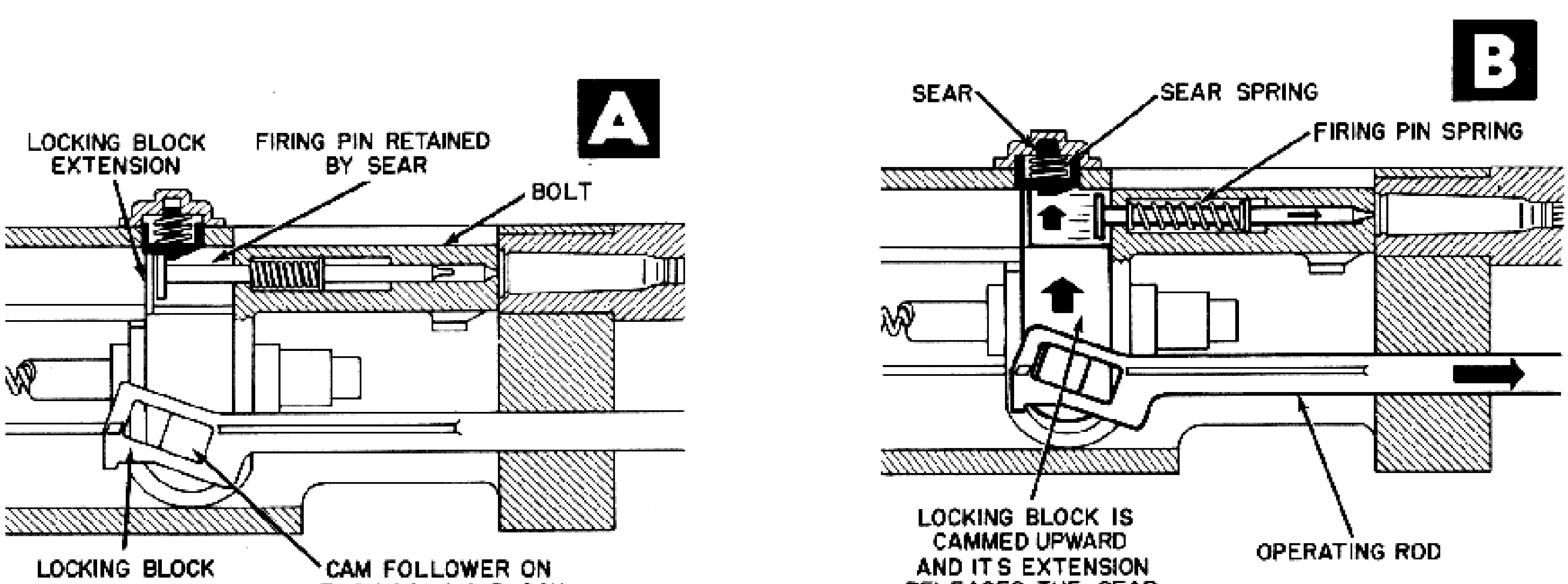

Figure 13–10. Sear Operated by Locking Block.

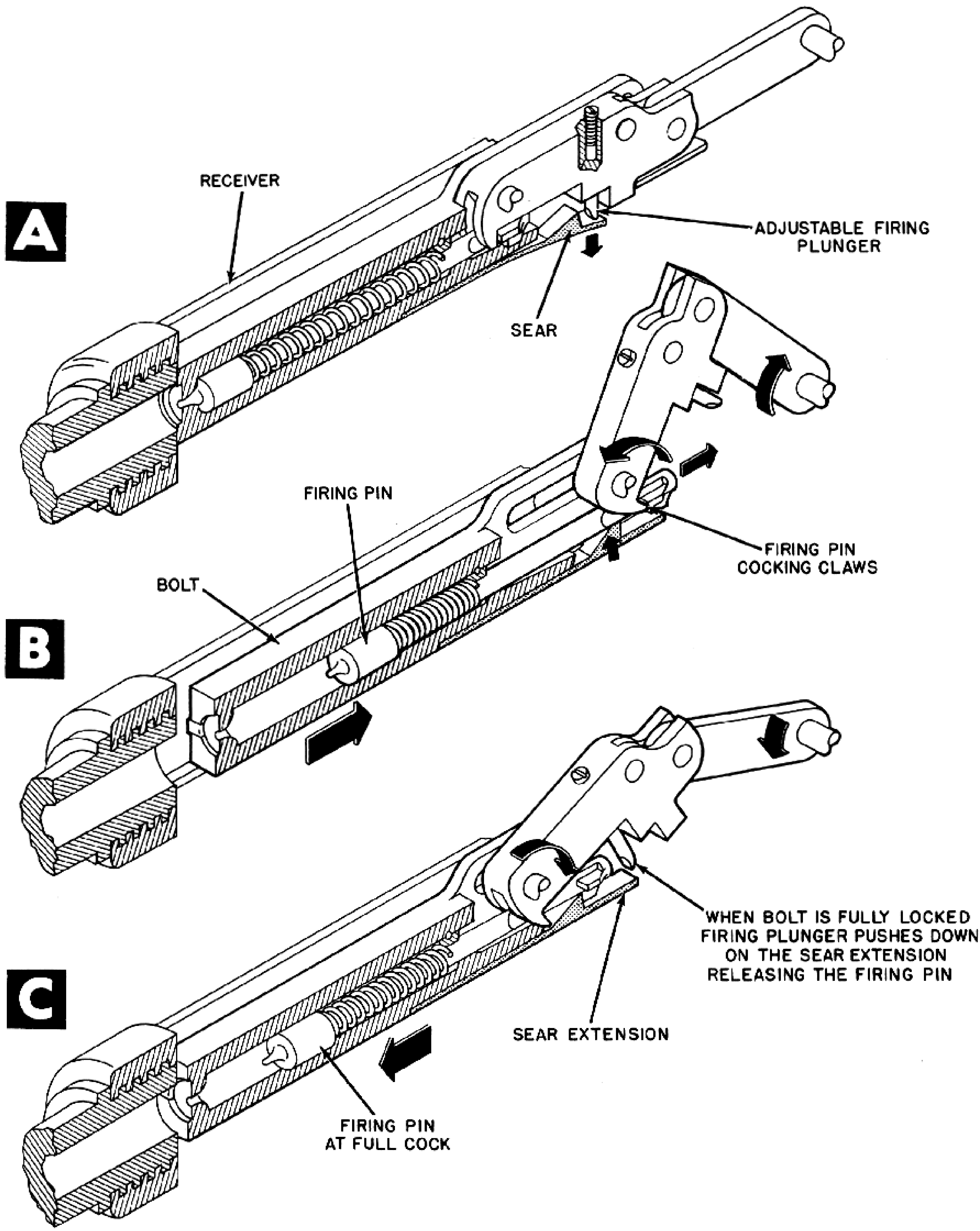

Figure 13–11. Operating Cycle of Sear Mechanism.

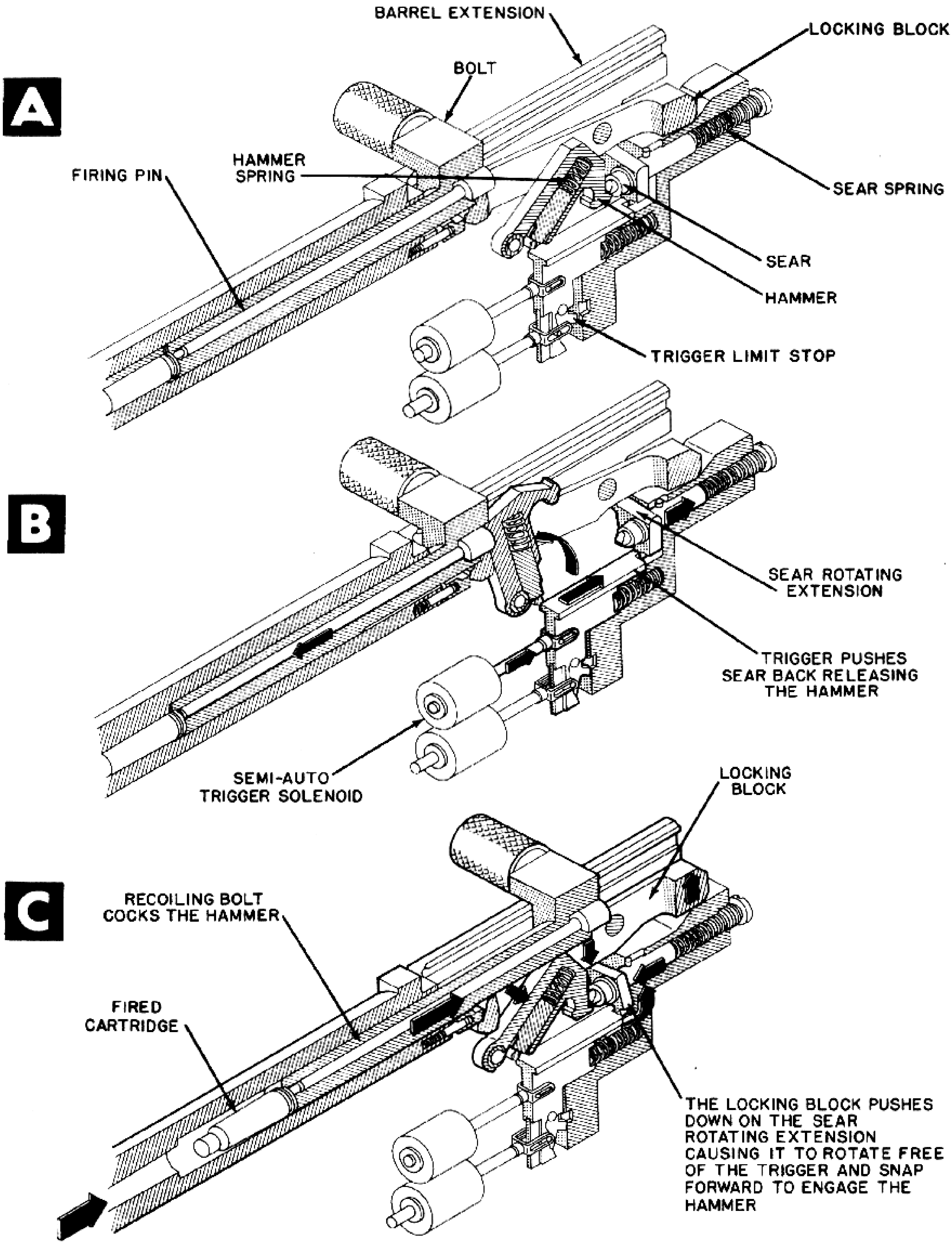

Figure 13–12. Operating Cycle of Sear Mechanism During Semi-Automatic Fire.

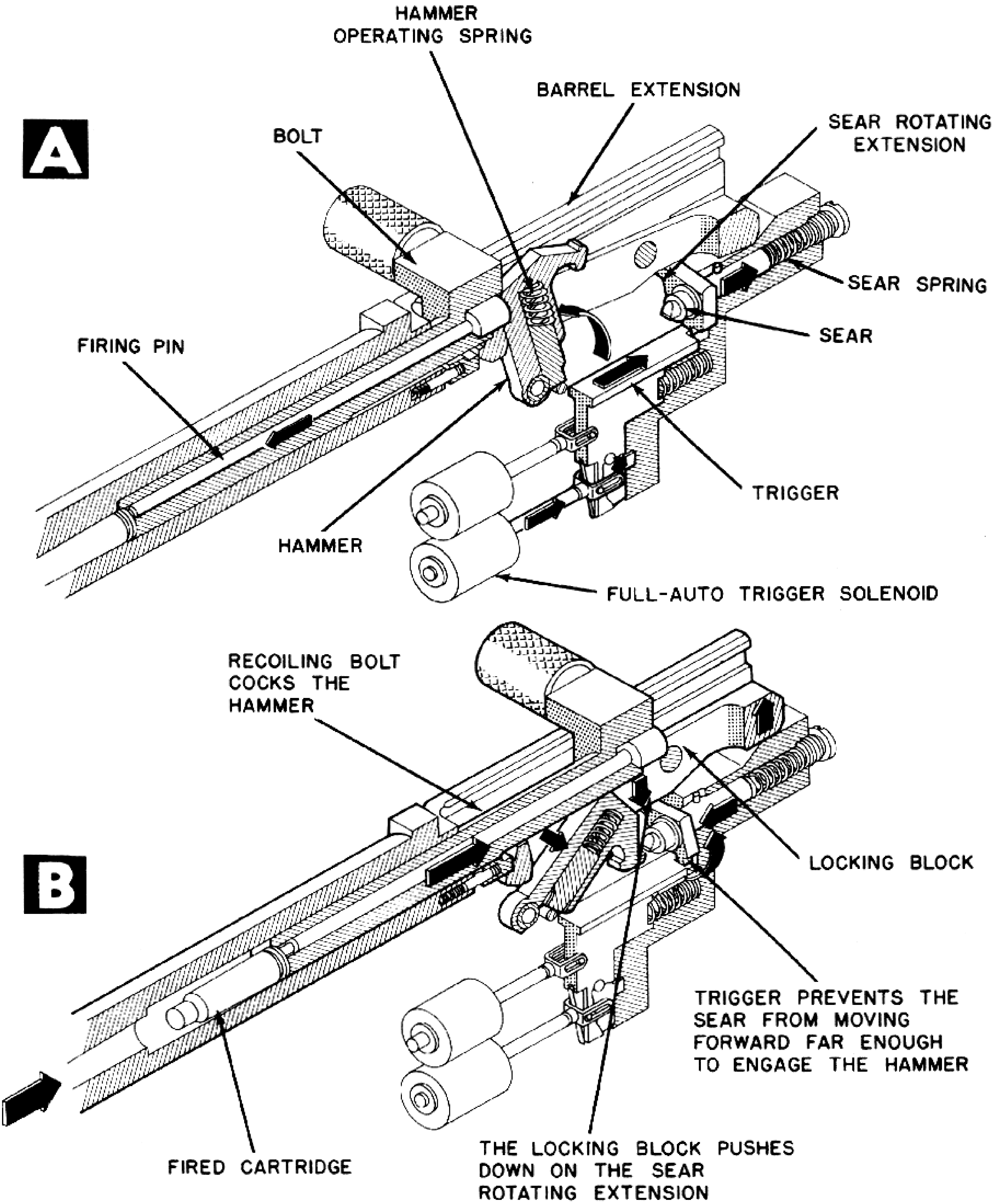

Figure 13–13. Operating Cycle of Sear Mechanism During Full Automatic Fire.

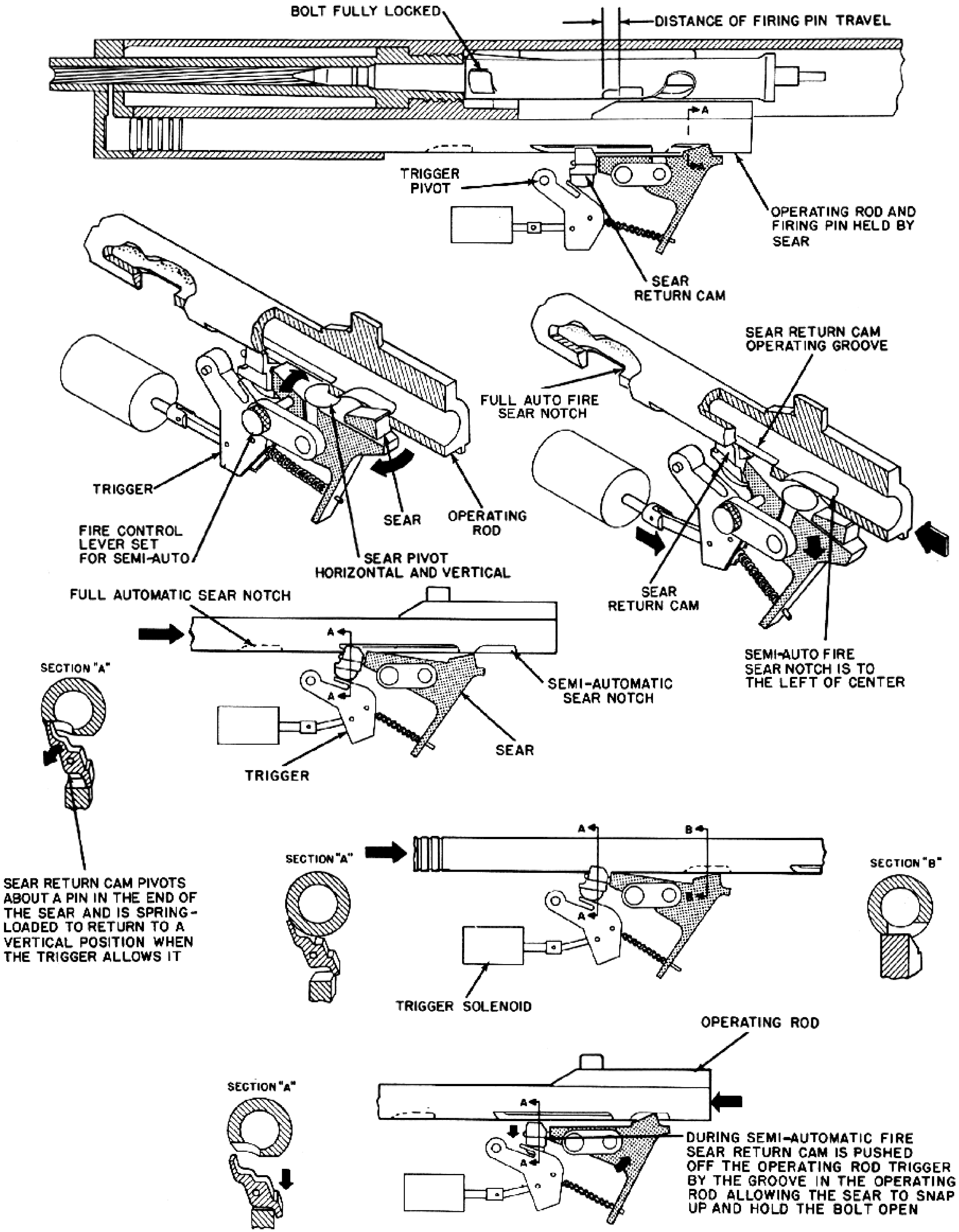

Figure 13–14. Operating Cycle of Sear Mechanism.

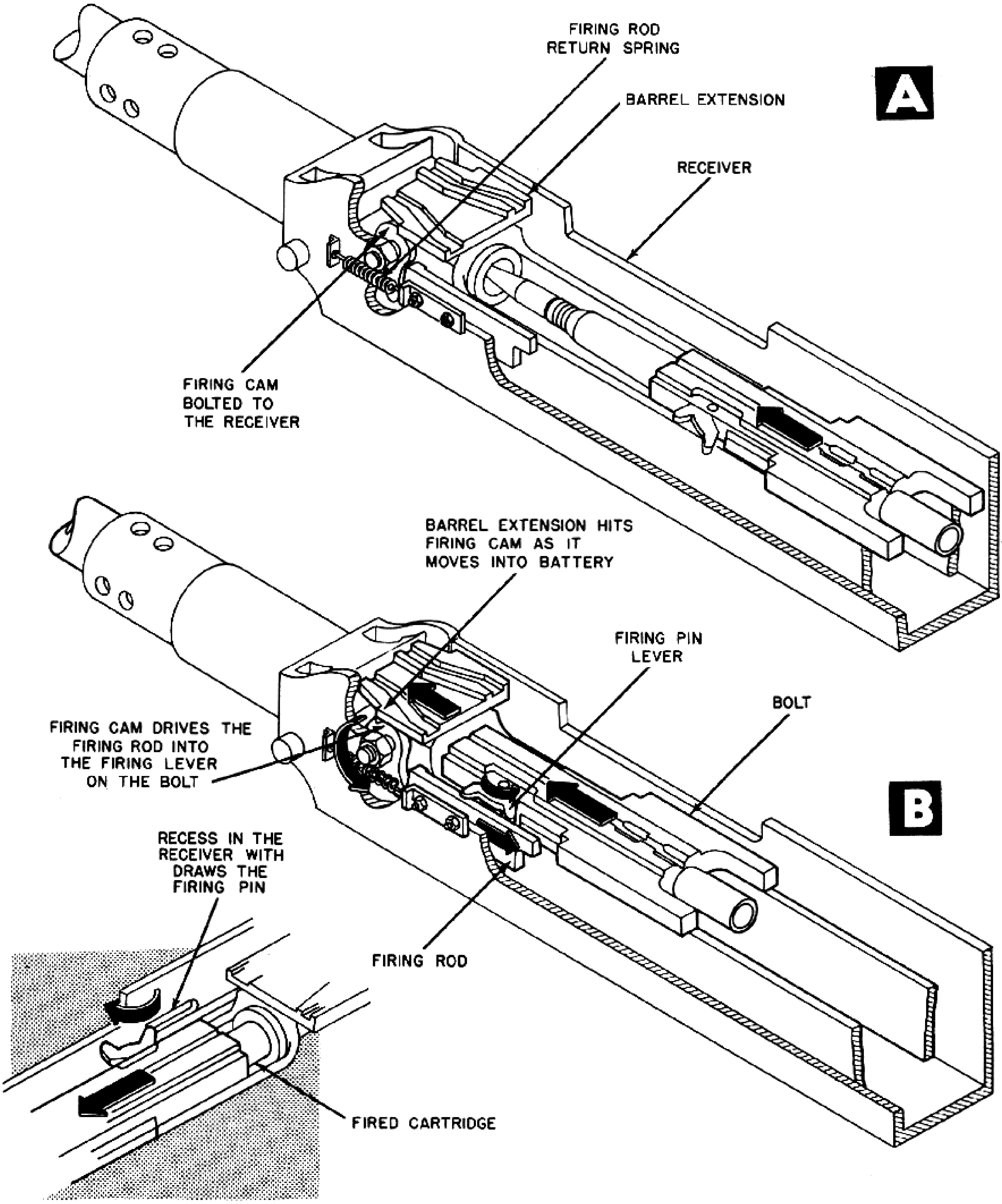

Figure 13–15. Method of Firing During Counter-Recoil.

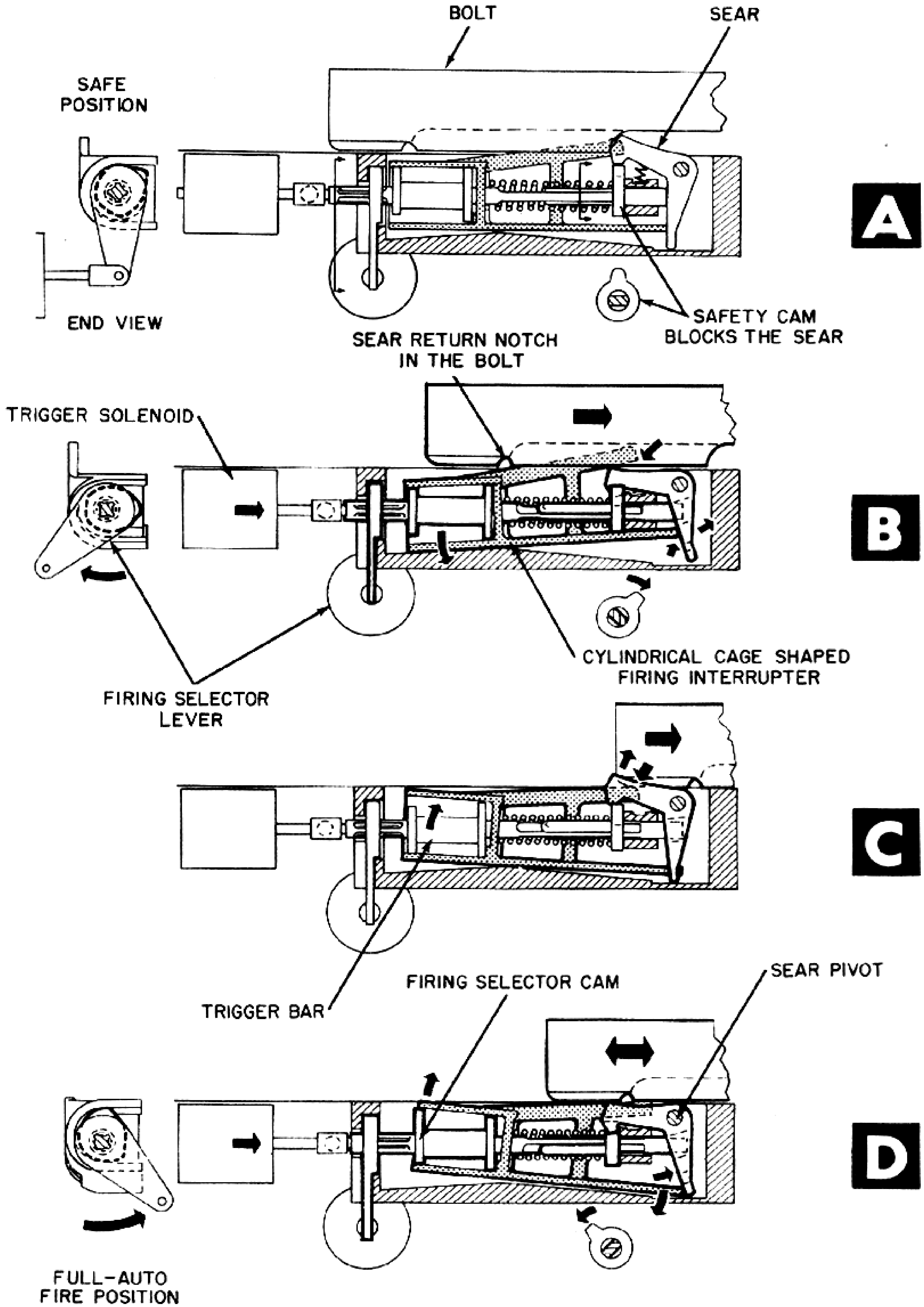

Figure 13-16. Operating Cycle of Sear Mechanism.

Chapter 14

FIRING PINS

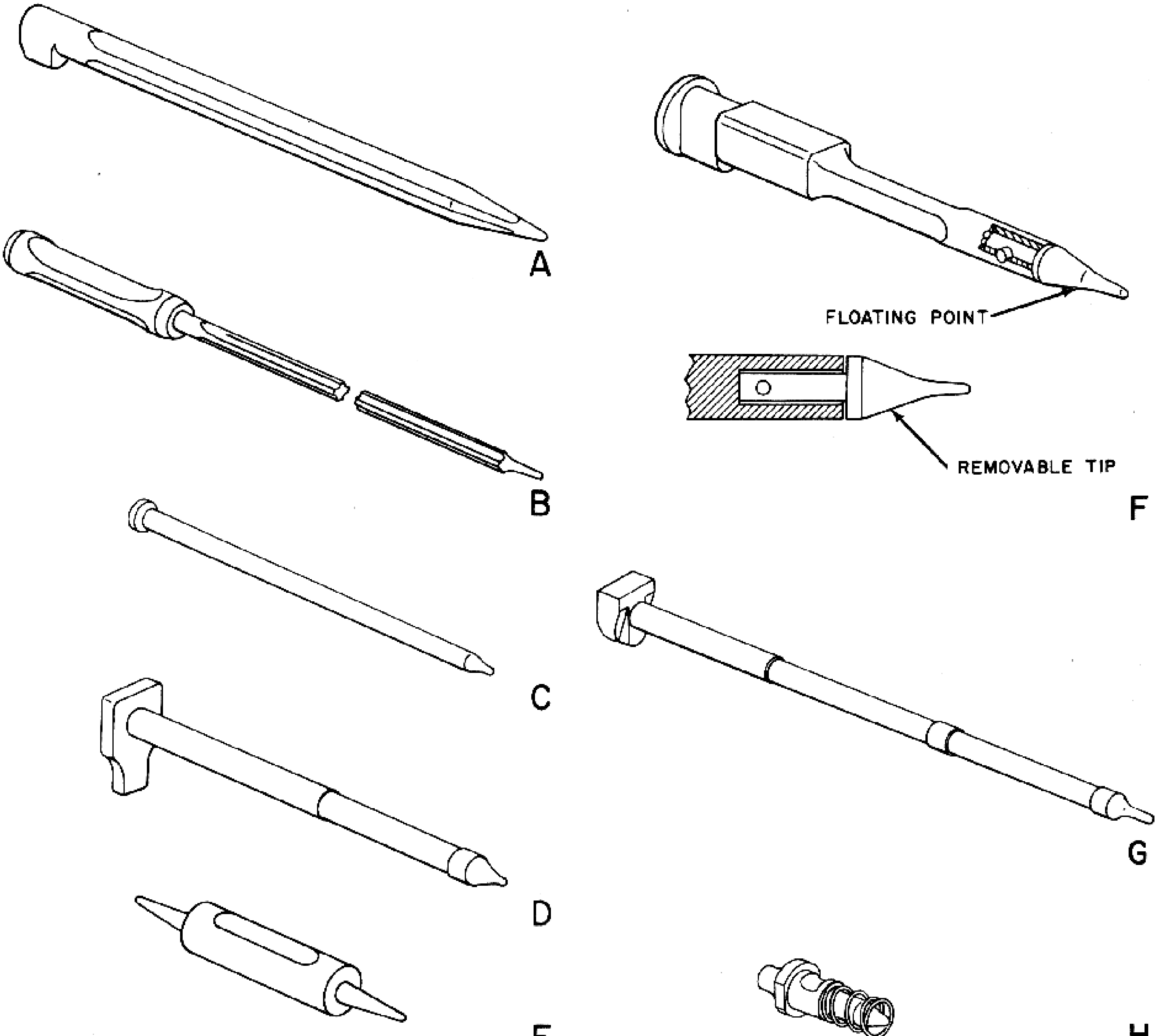

Figure 14–1. Types of Firing Pins.

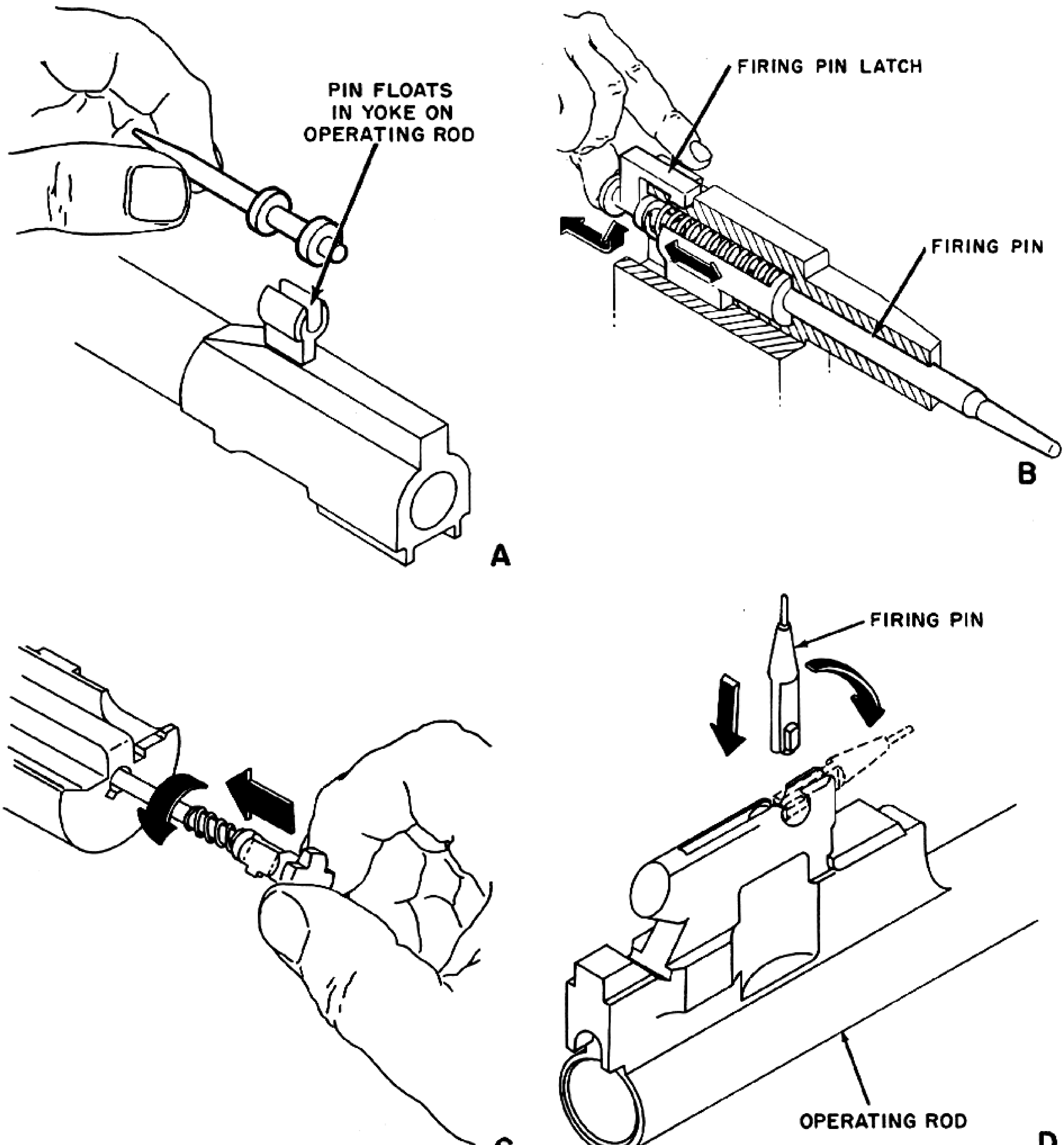

Figure 14–2. Methods of Retaining and Removing Firing Pins.

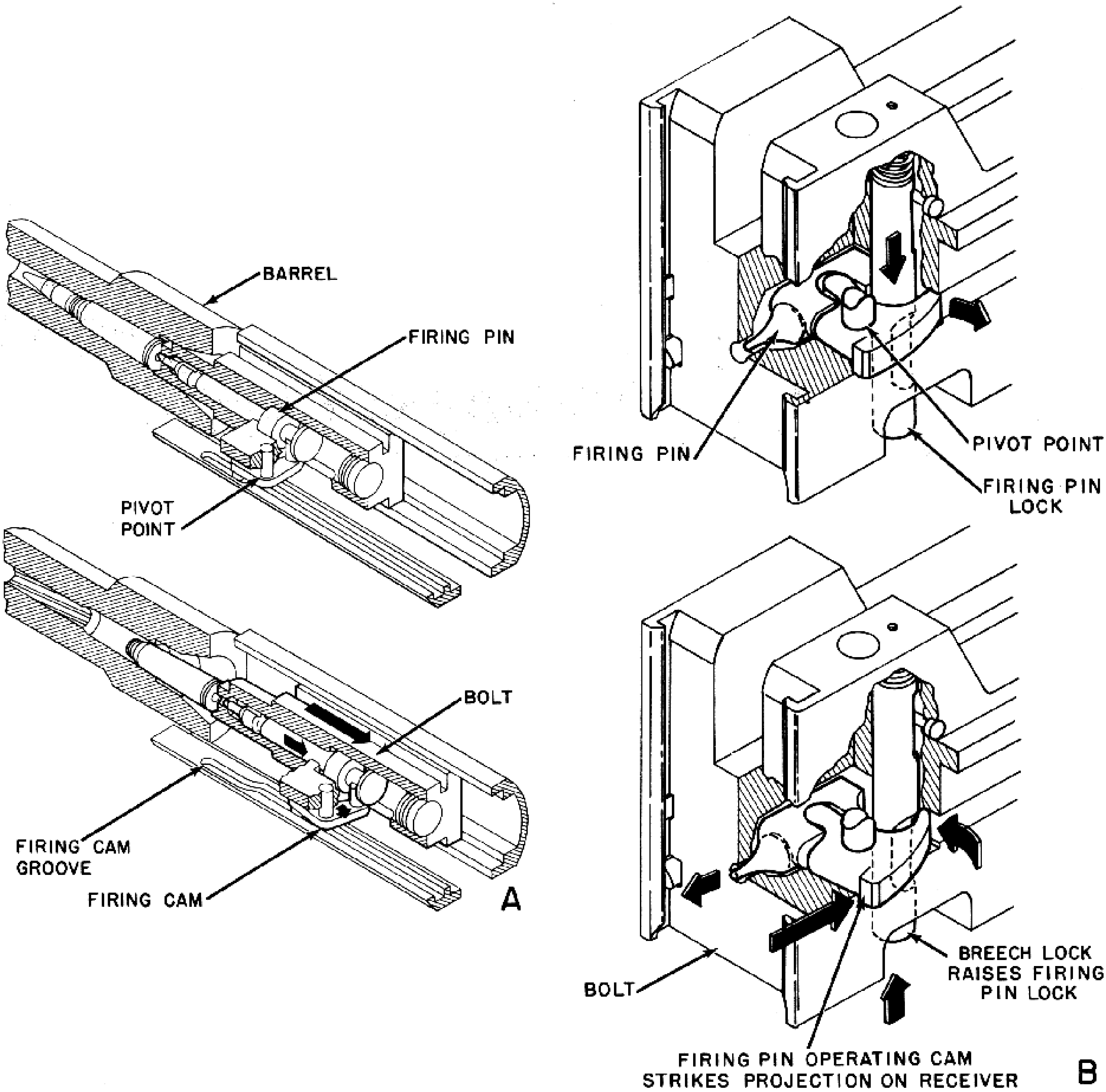

Figure 14–3. Cam-Operated Firing Pins.

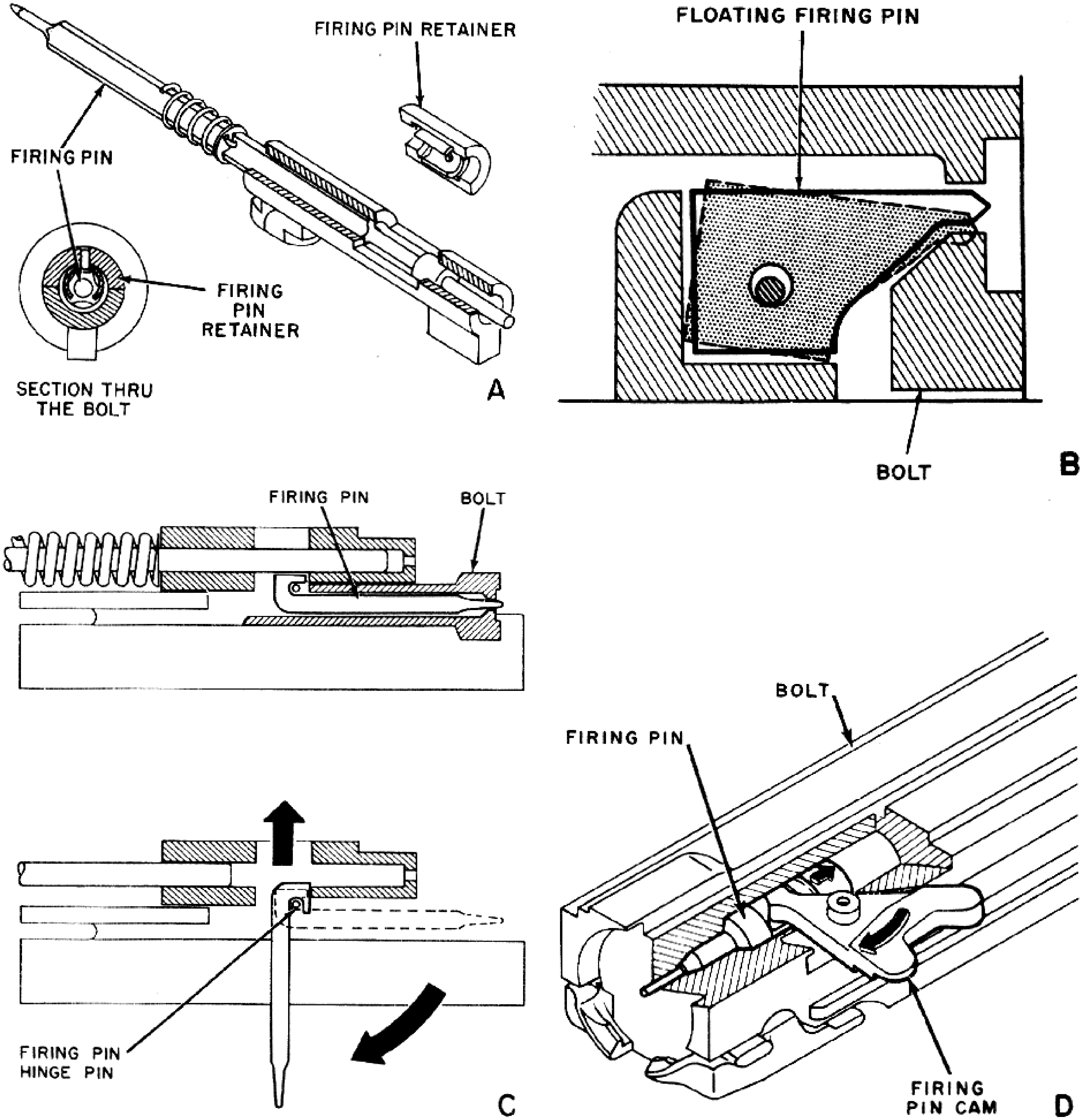

Figure 14–4. Methods of Retaining and Removing Firing Pins.

Chapter 15

BUFFERS AND MOUNTS

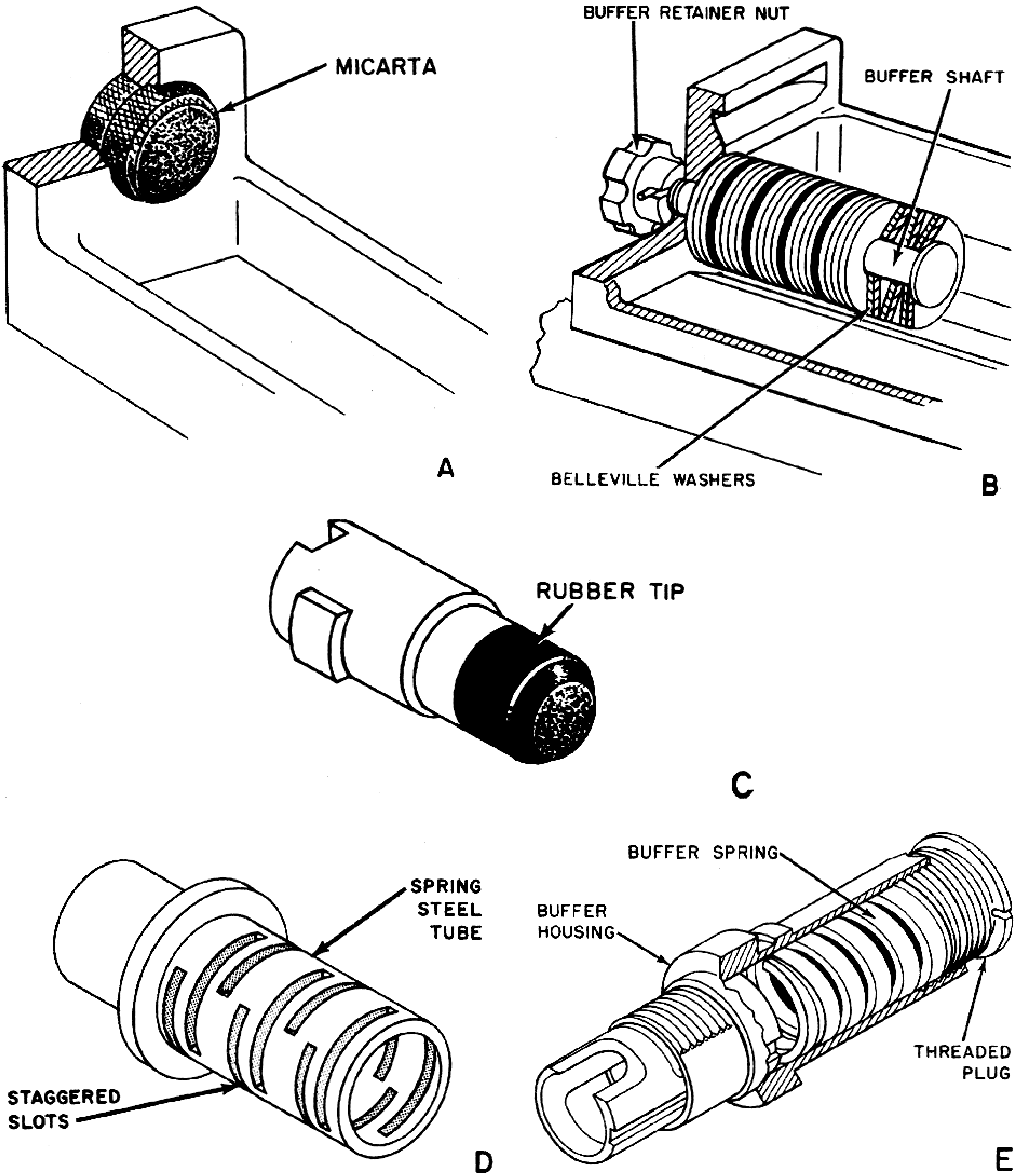

Figure 15–1. Buffer Materials and Buffer Devices.

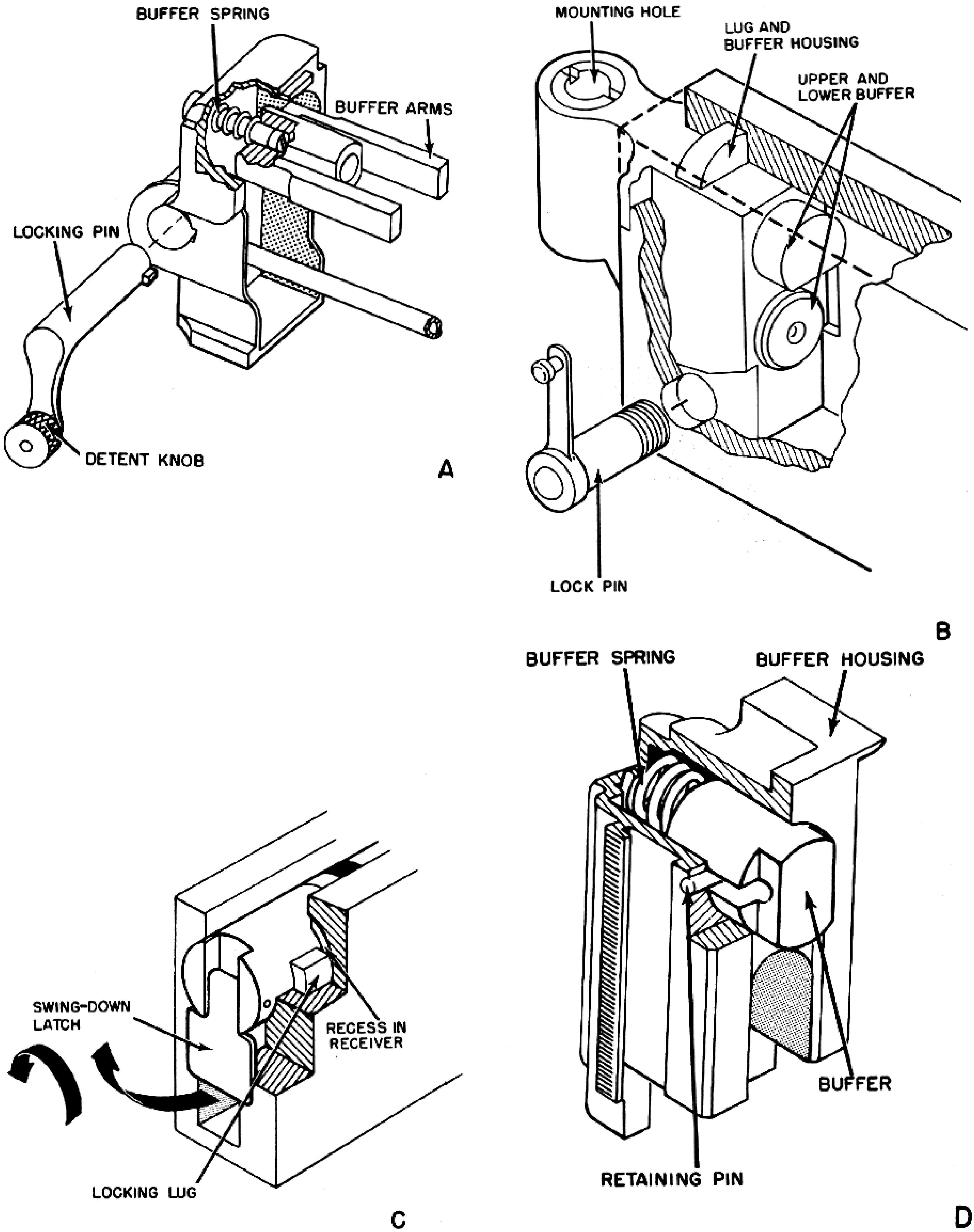

Figure 15–2. Methods of Retaining Buffers.

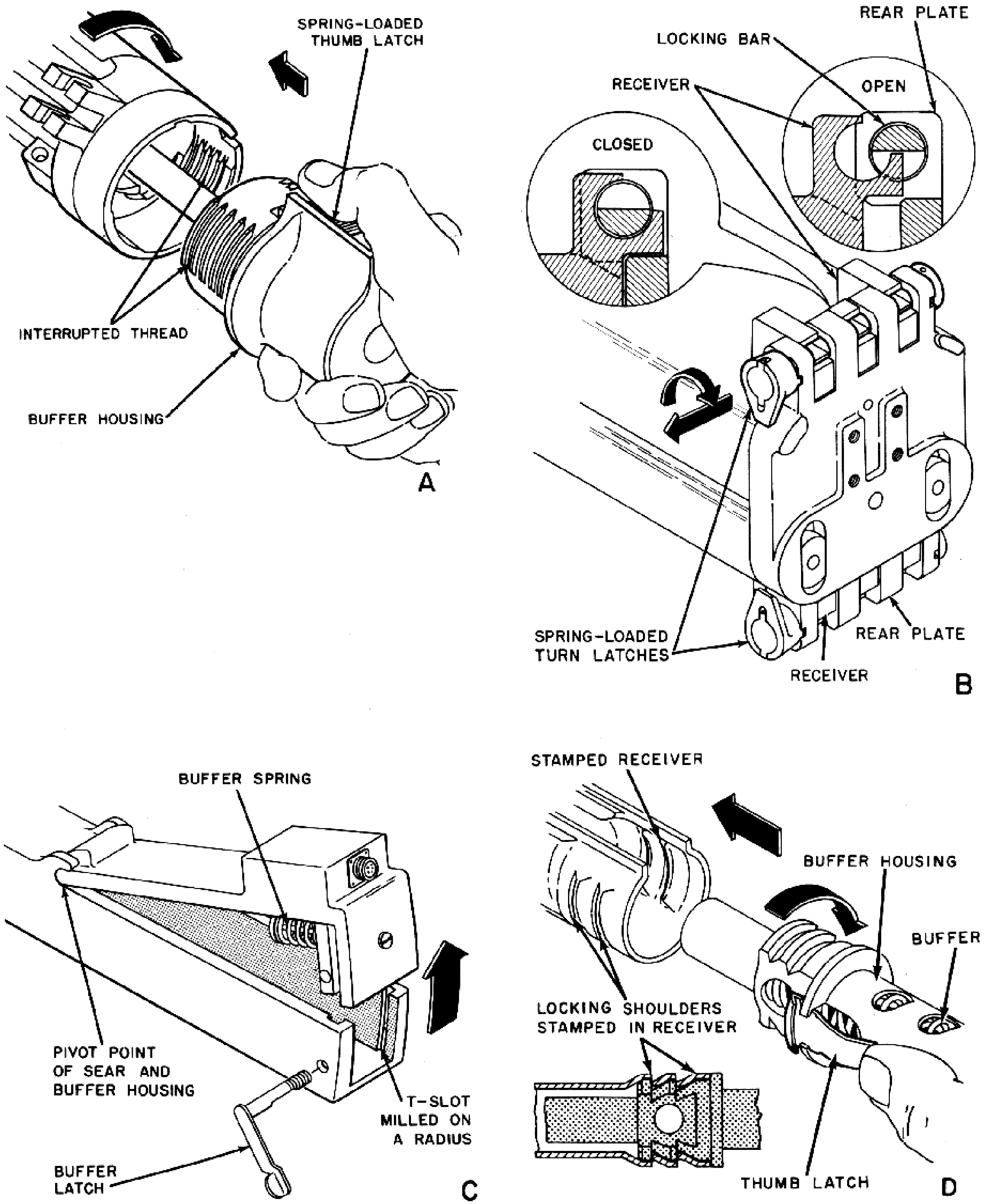

Figure 15–3. Methods of Retaining Buffers.

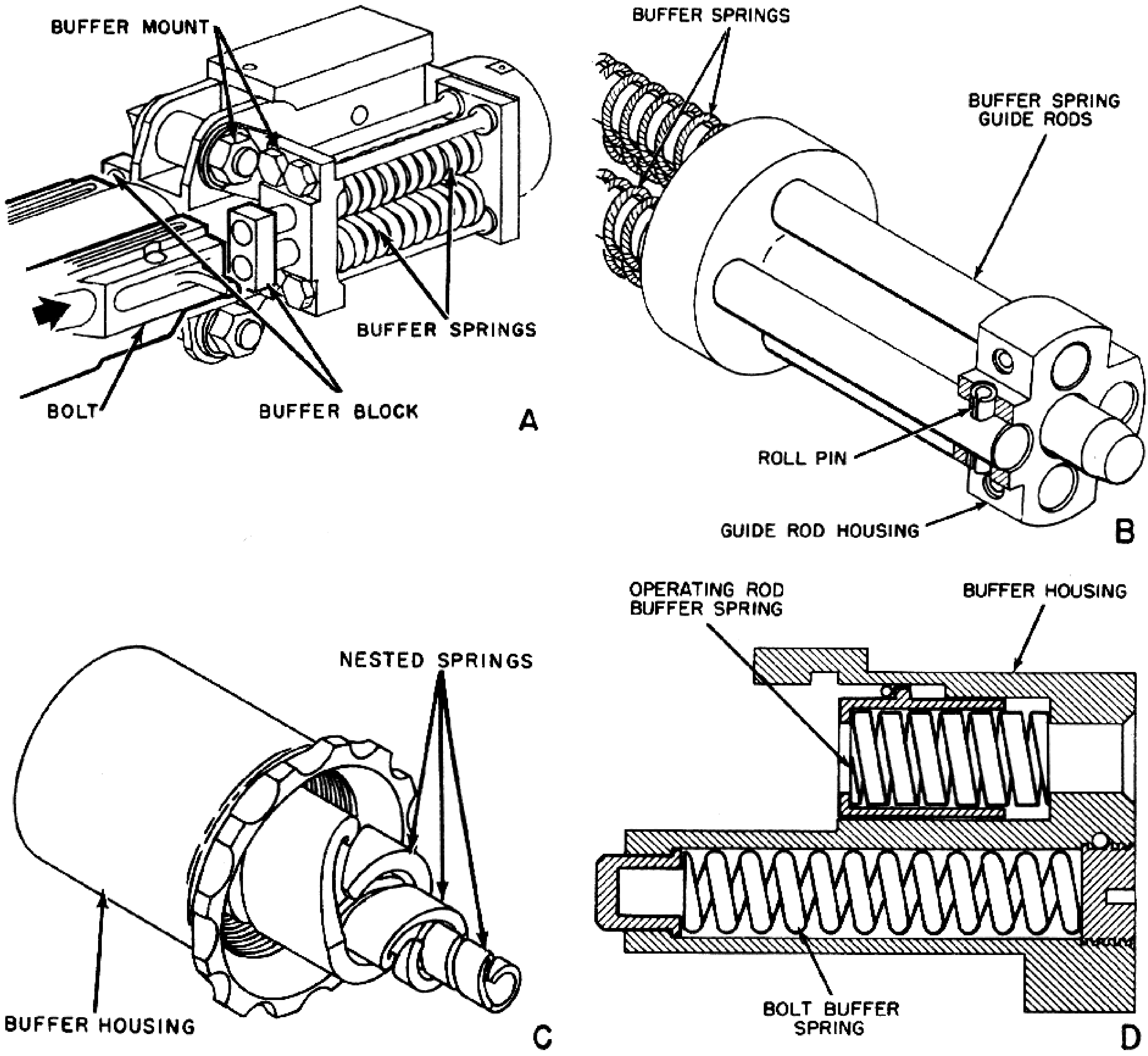

Figure 15-4. Types of Multiple Buffers.

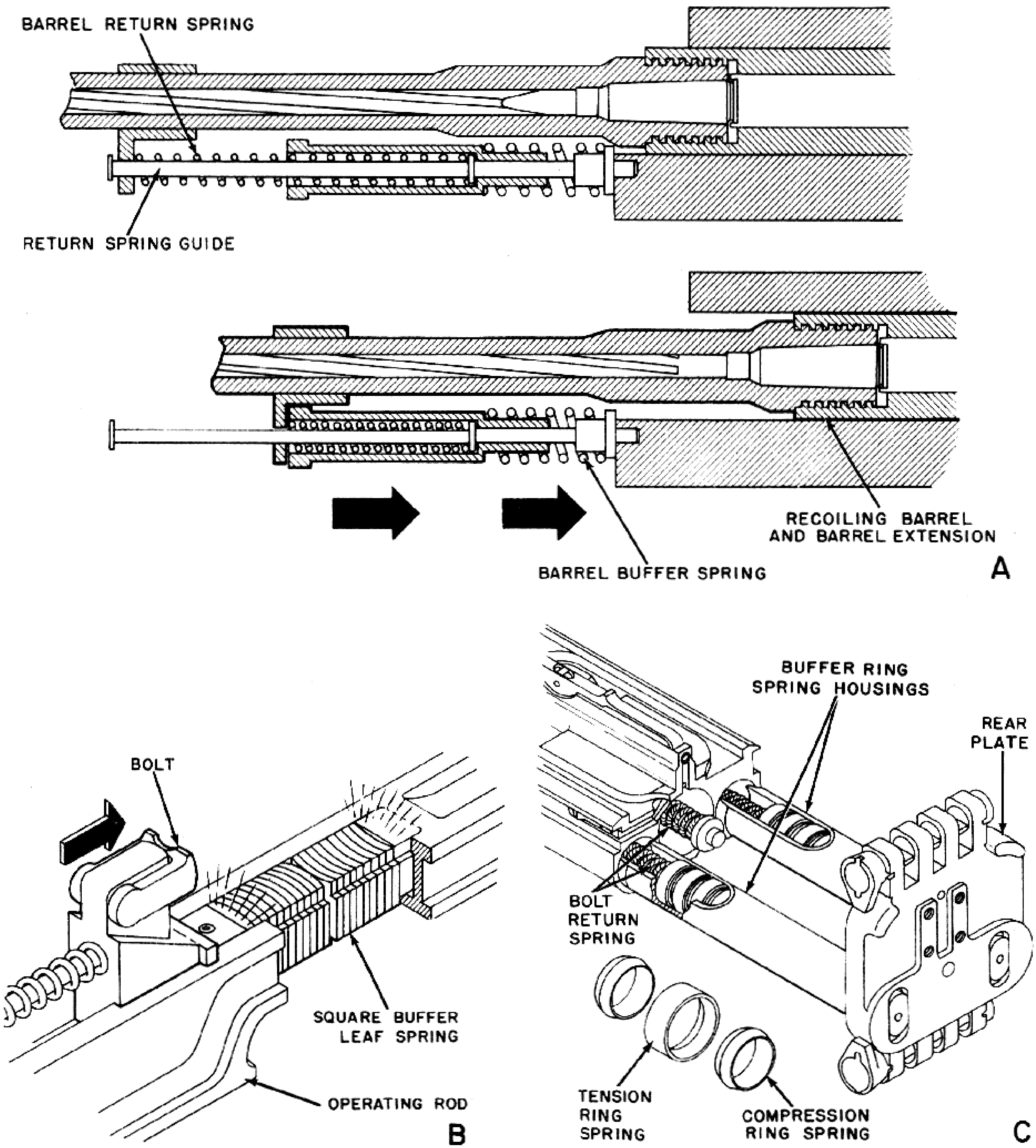

Figure 15-5. Unique Types of Buffers.

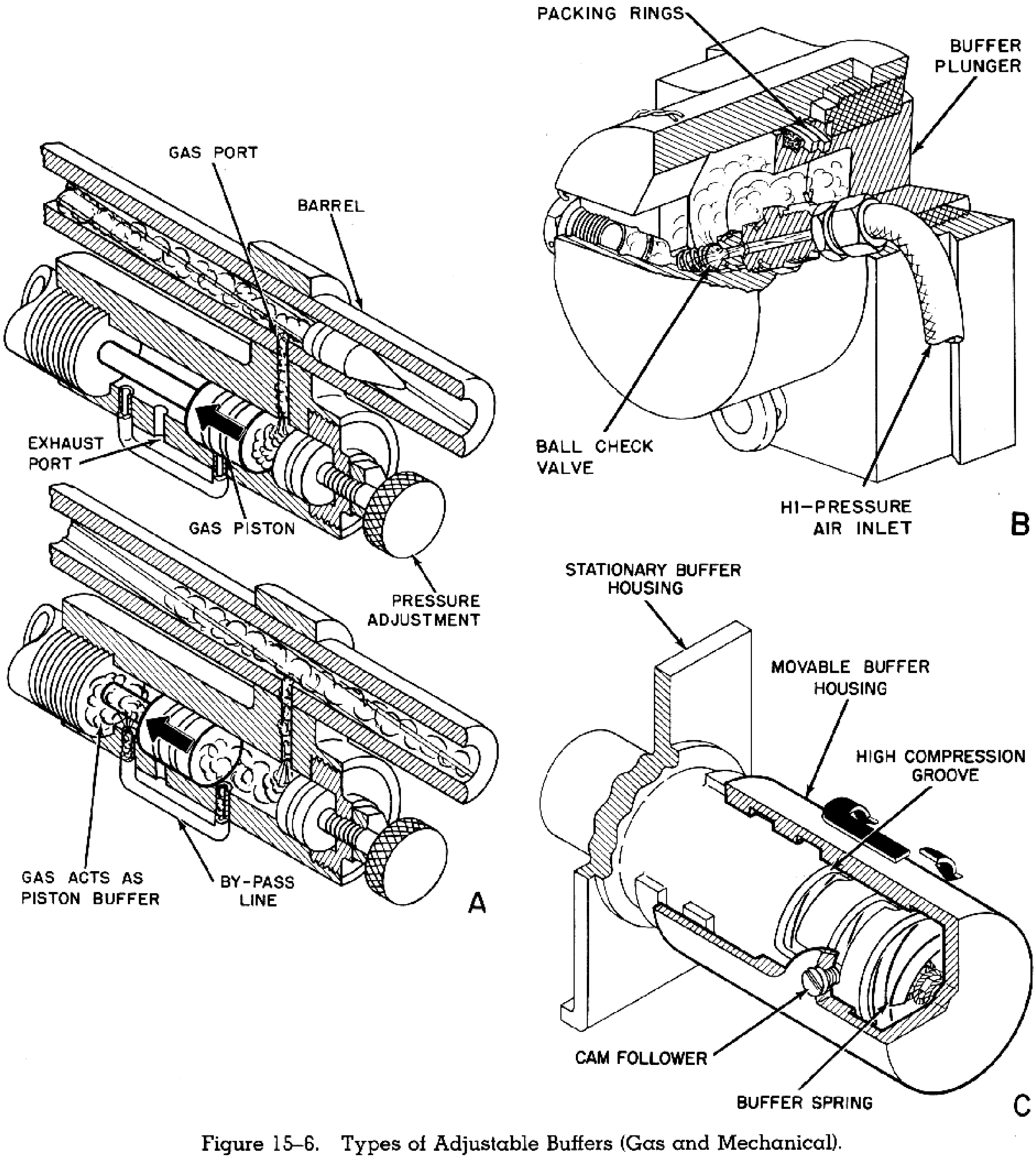

Figure 15–6. Types of Adjustable Buffers (Gas and Mechanical).

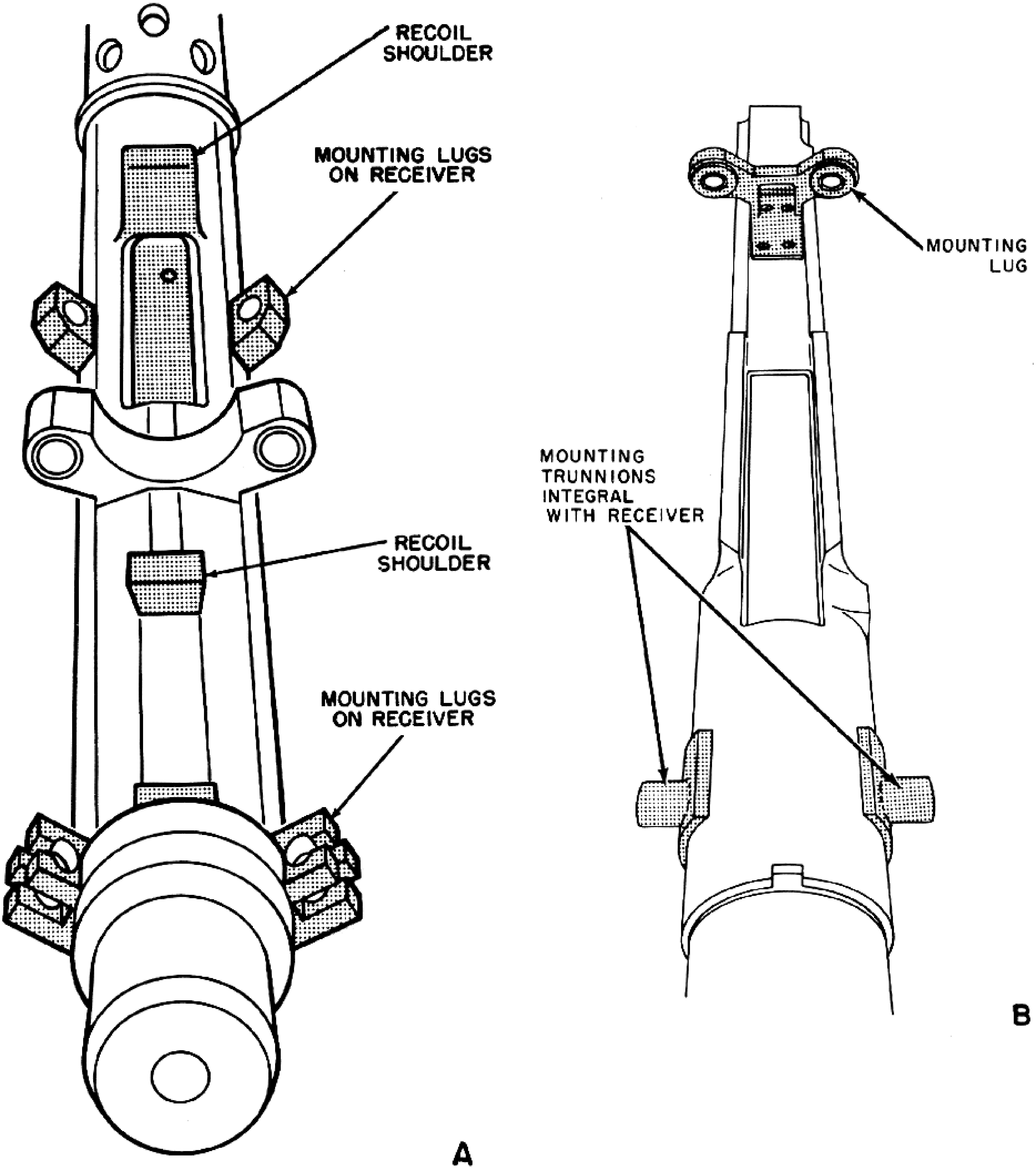

Figure 15–7. Examples of Mounting Lug Placement.

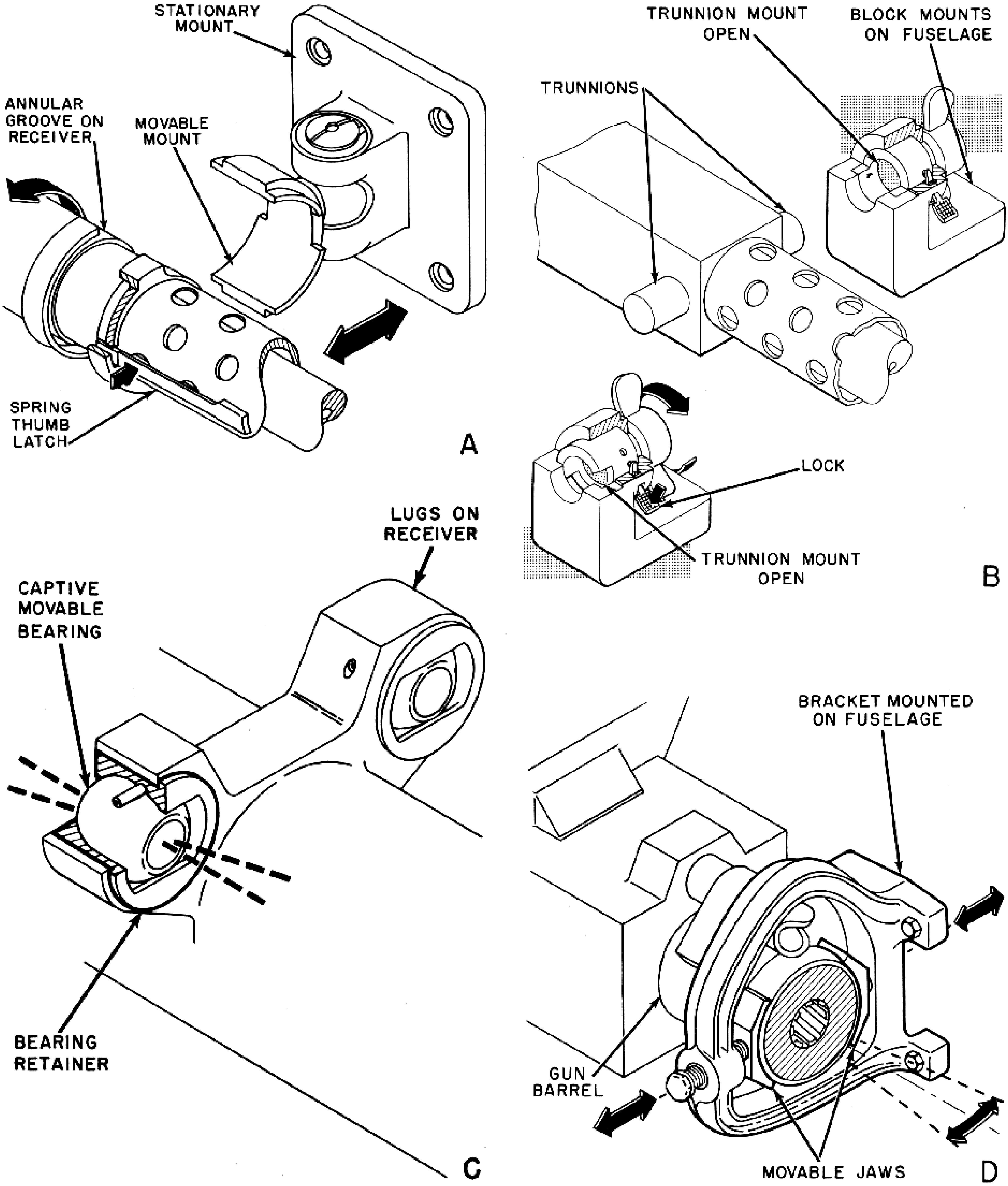

Figure 15–8. Types of Adjustable Mounts.

Chapter 16

CHARGERS

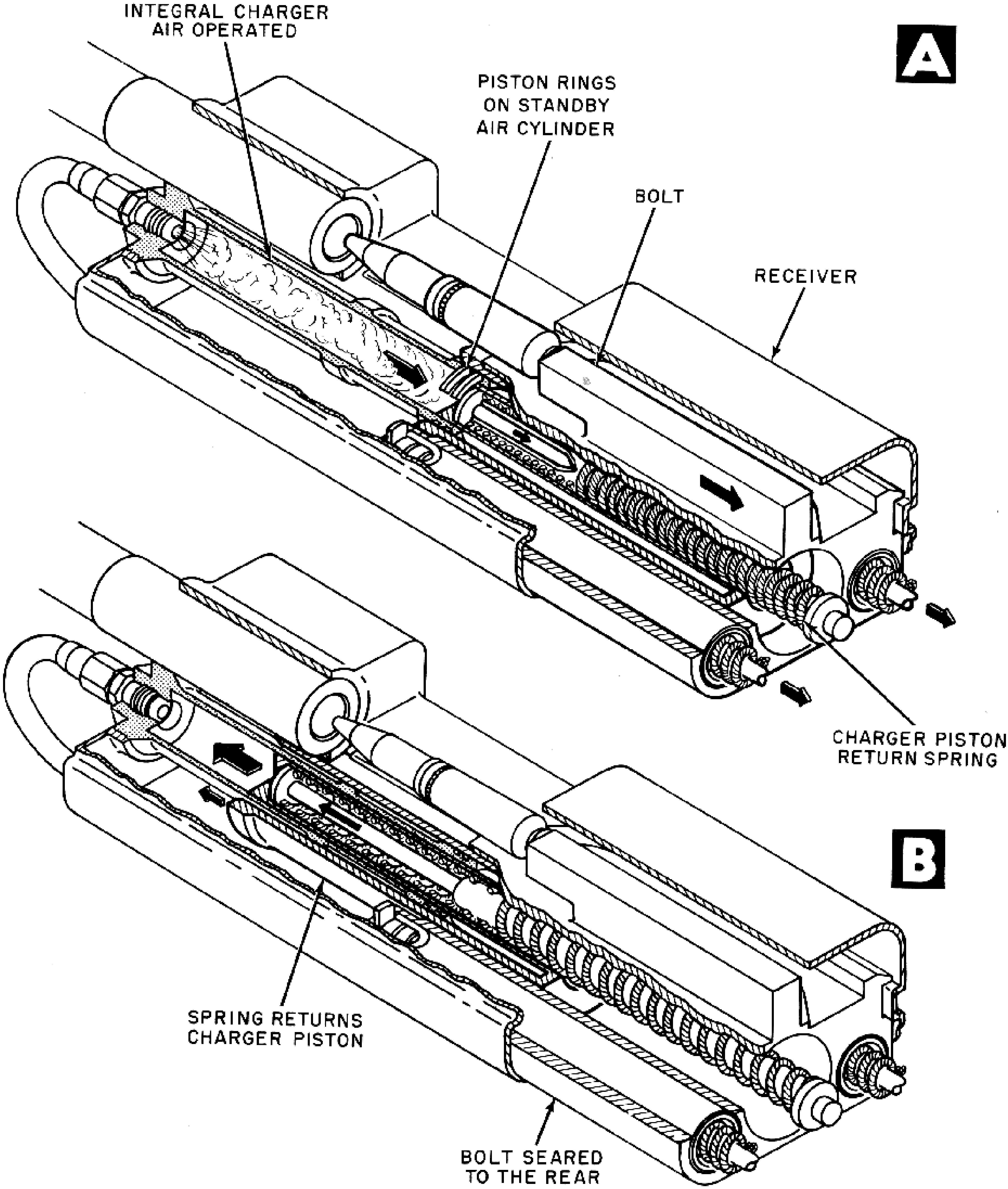

Figure 16–1. Operation of Air Charger.

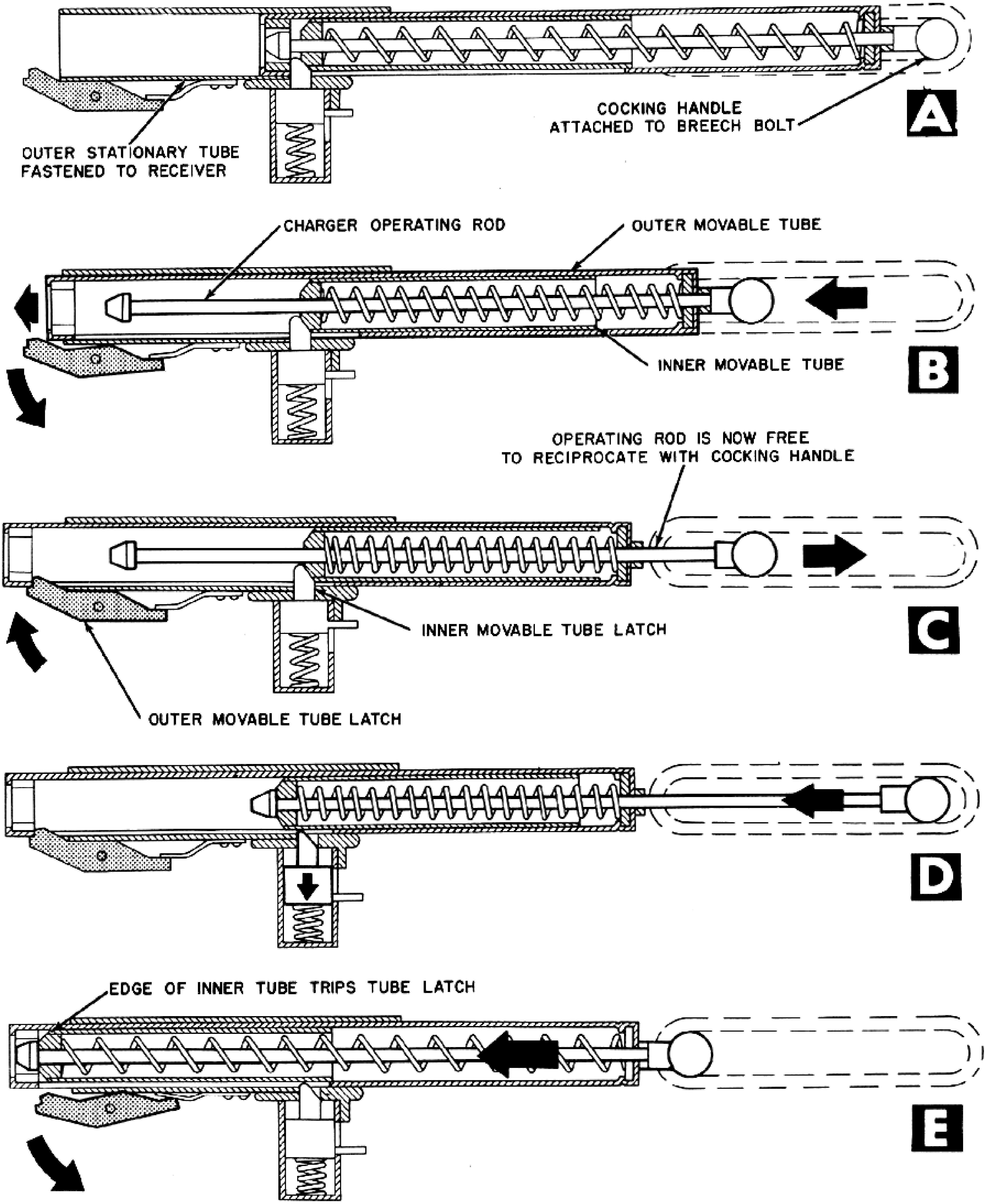

Figure 16–2. Operating Cycle of Self-Cocking Charger.

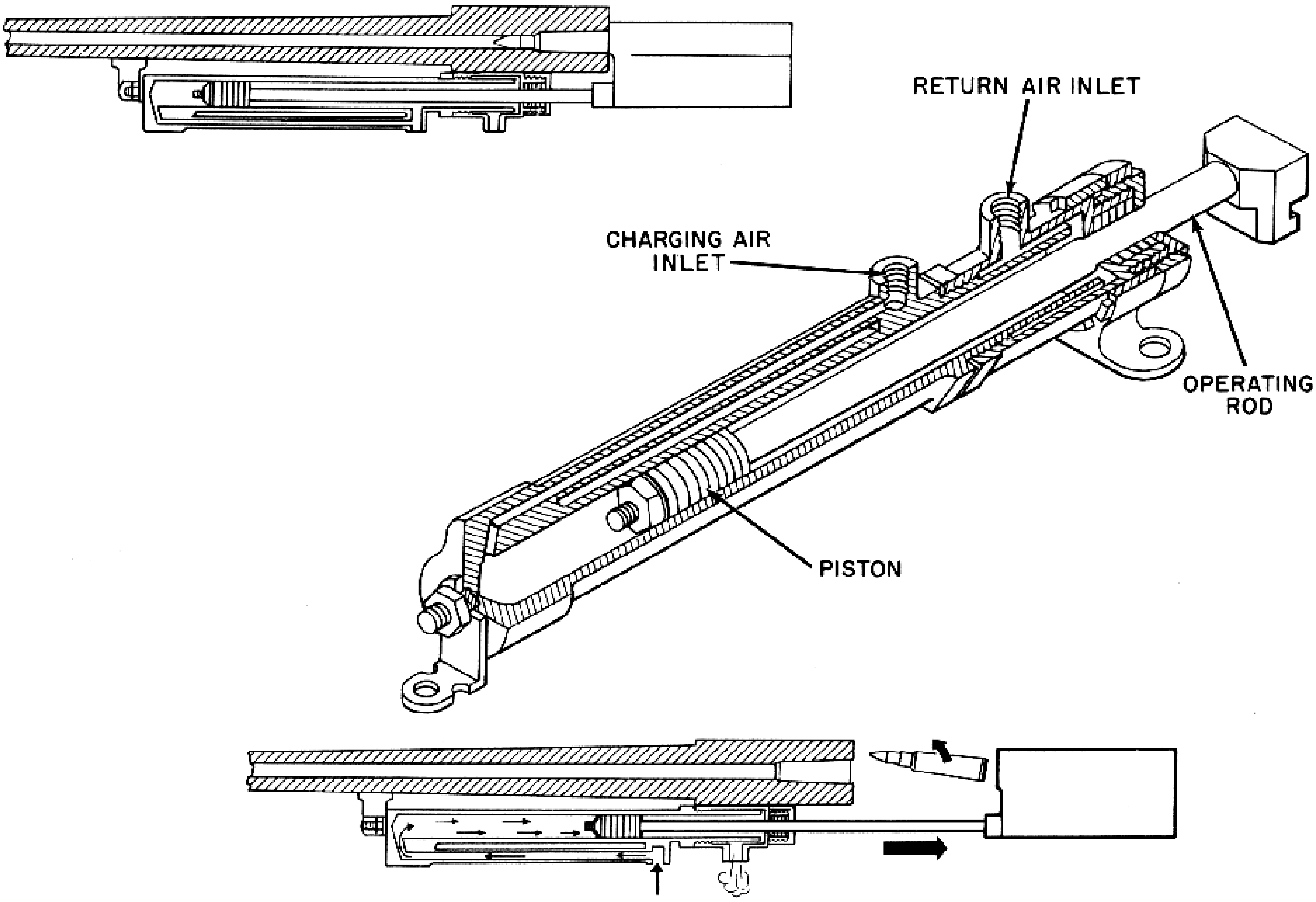

Figure 16–3. Air-Operated Charger—Double Acting.

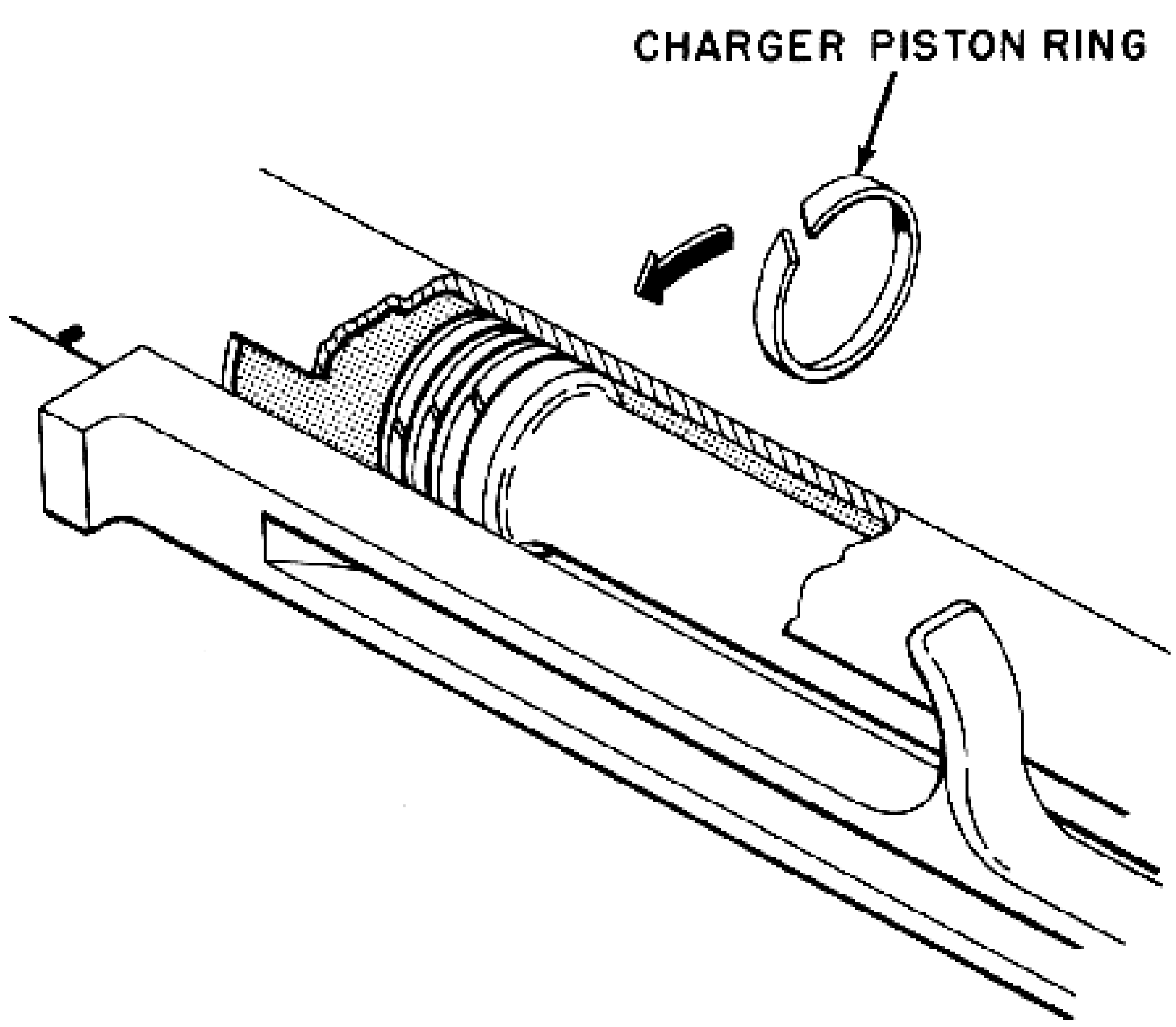

Figure 16–4. Steel Rings Seal Charger Piston.

Chapter 17

FLASH HIDERS

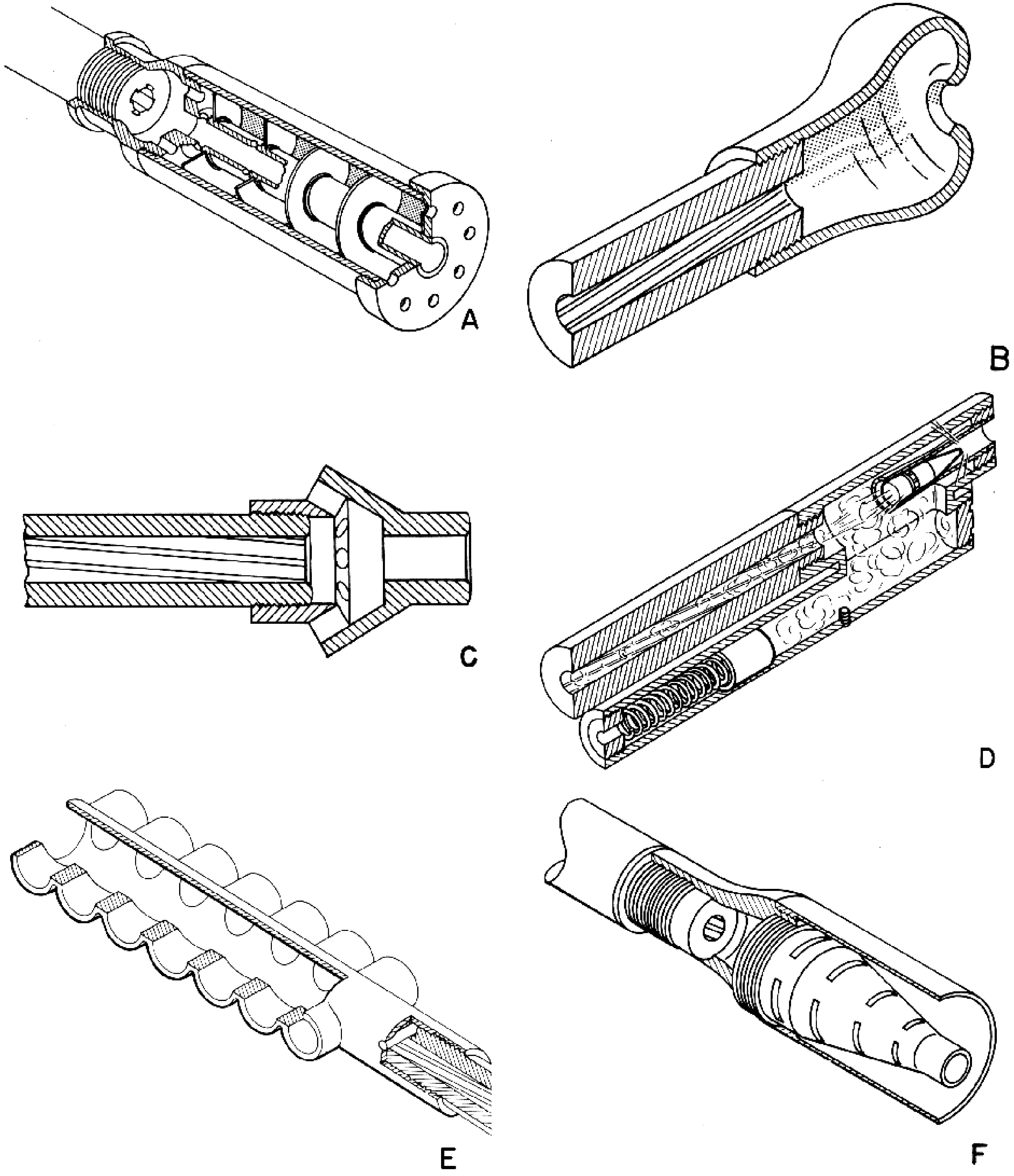

Figure 17–1. Types of Muzzle Brakes and Flash Hiders.

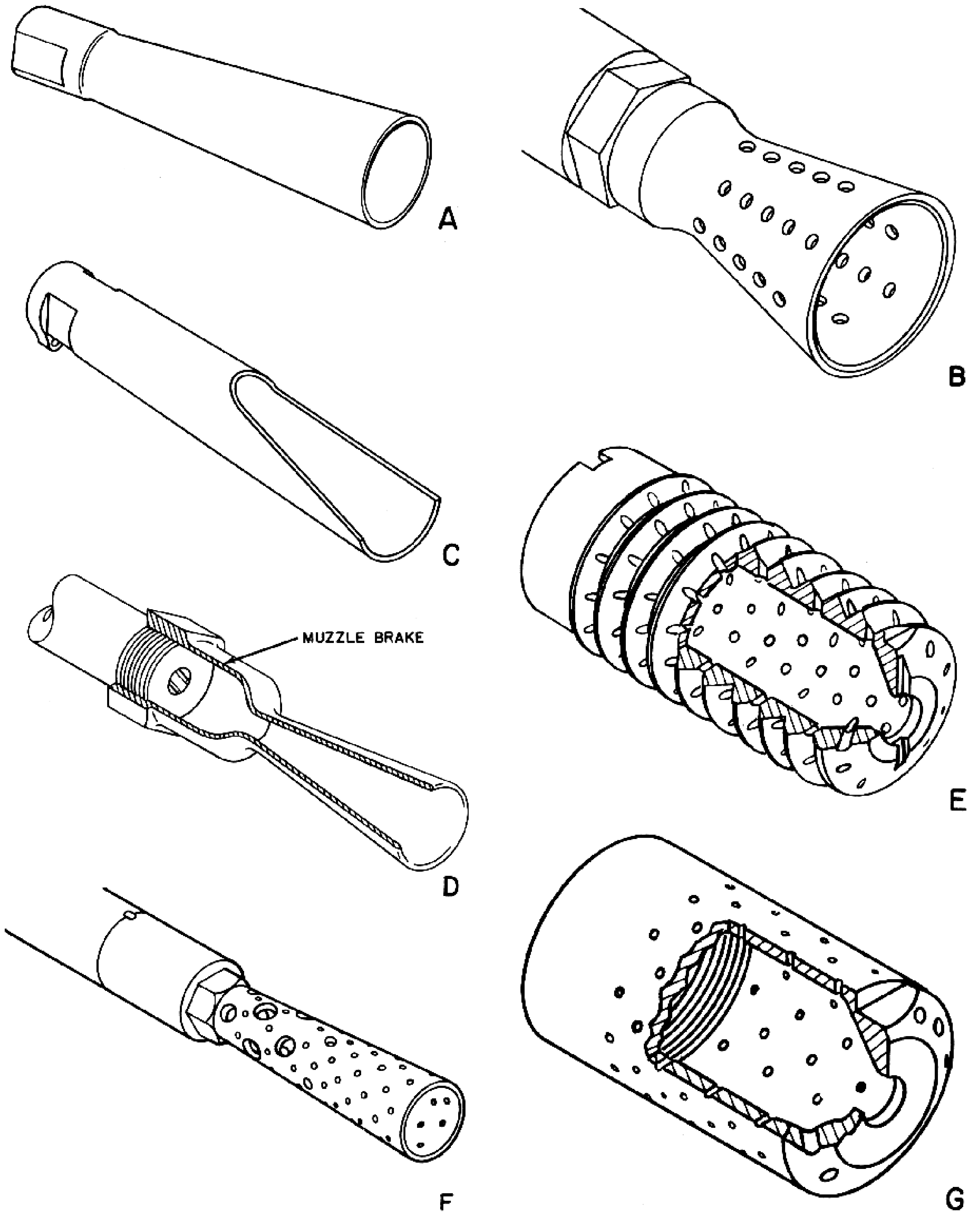

Figure 17–2. Types of Muzzle Brakes and Flash Hiders.

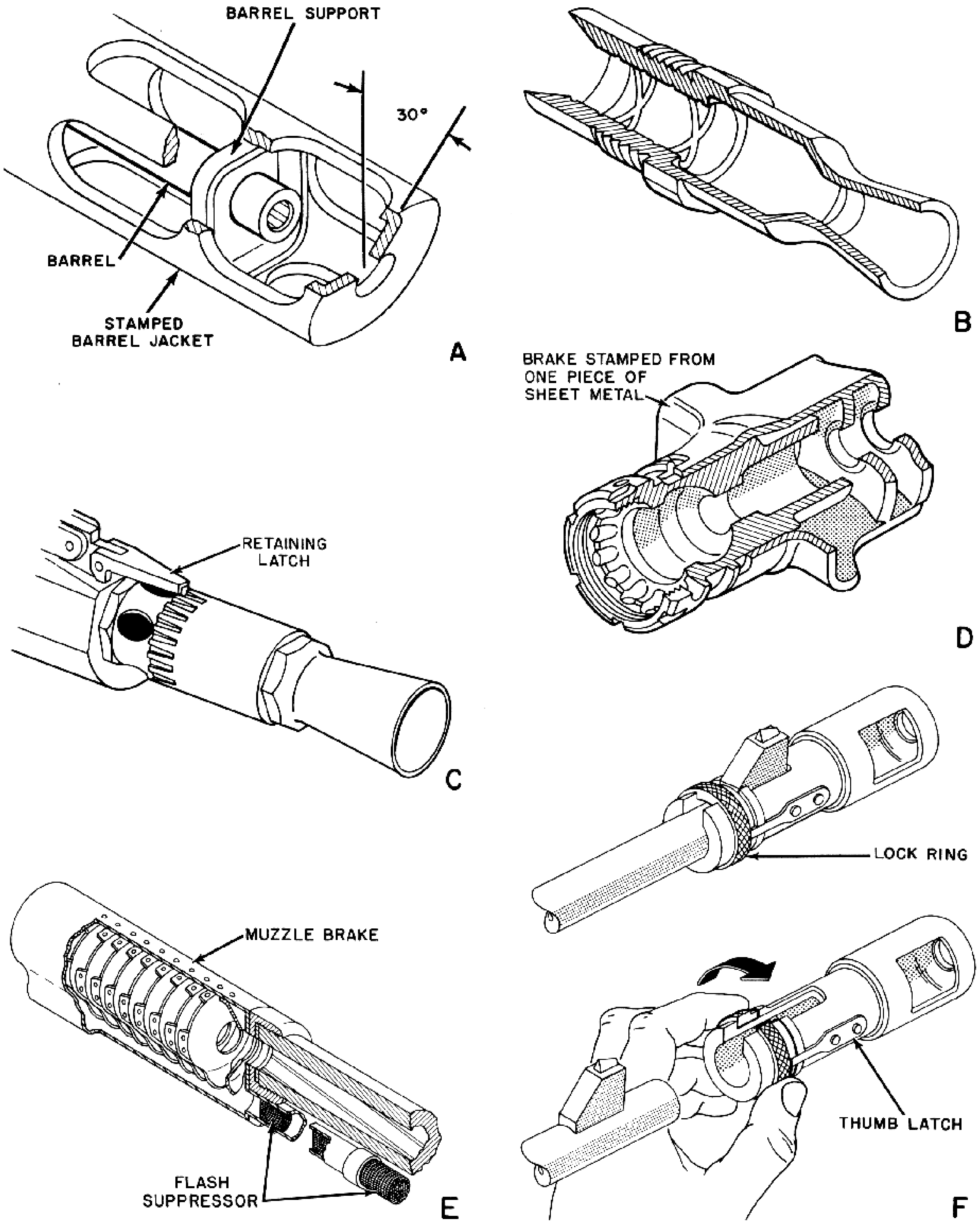

Figure 17–3. Types of Muzzle Brakes and Flash Hiders.

Chapter 18

RETAINING DEVICES AND CONSTRUCTION DETAILS

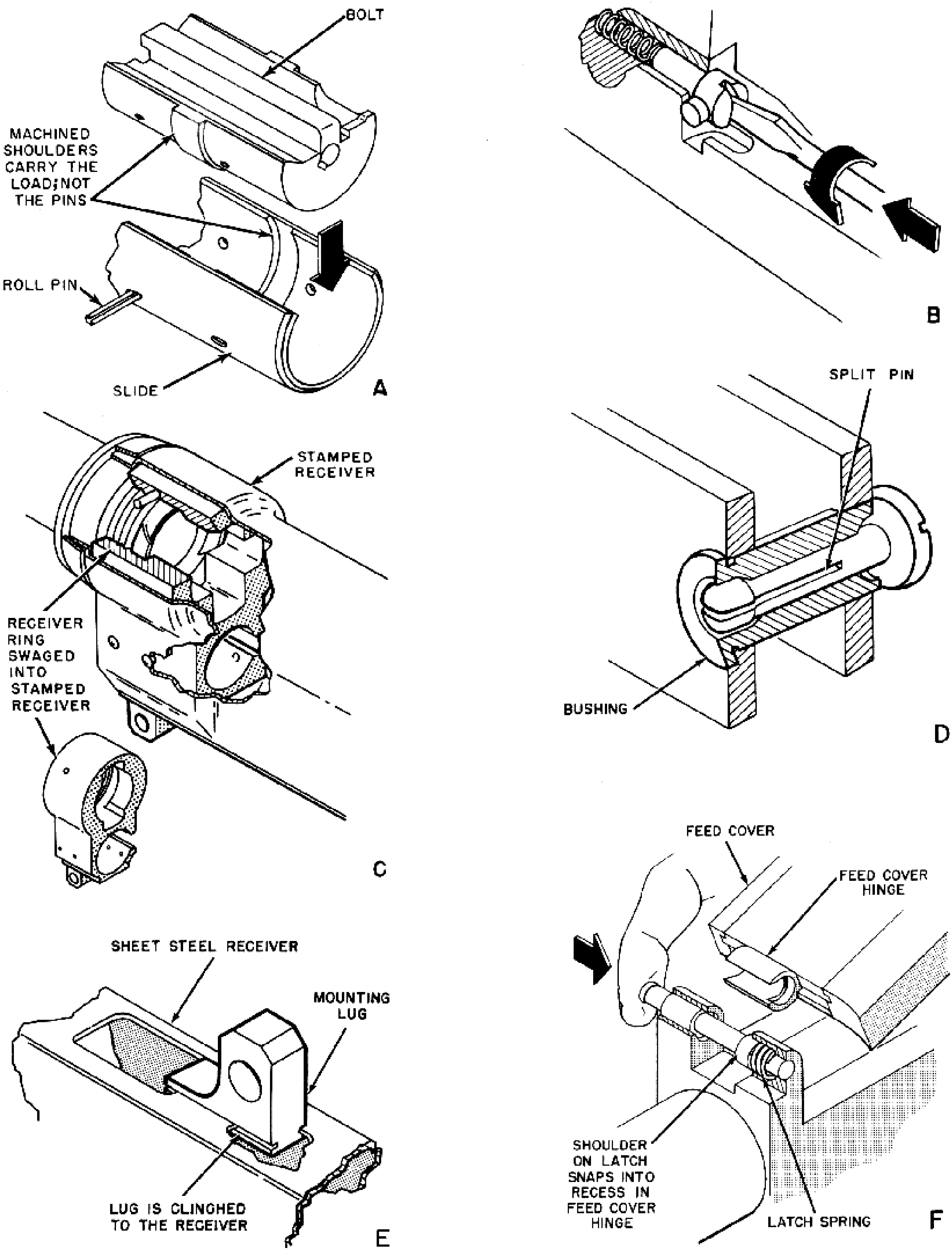

Figure 18–1. Methods of Attaching Machined Parts to Sheet Metal Receivers.

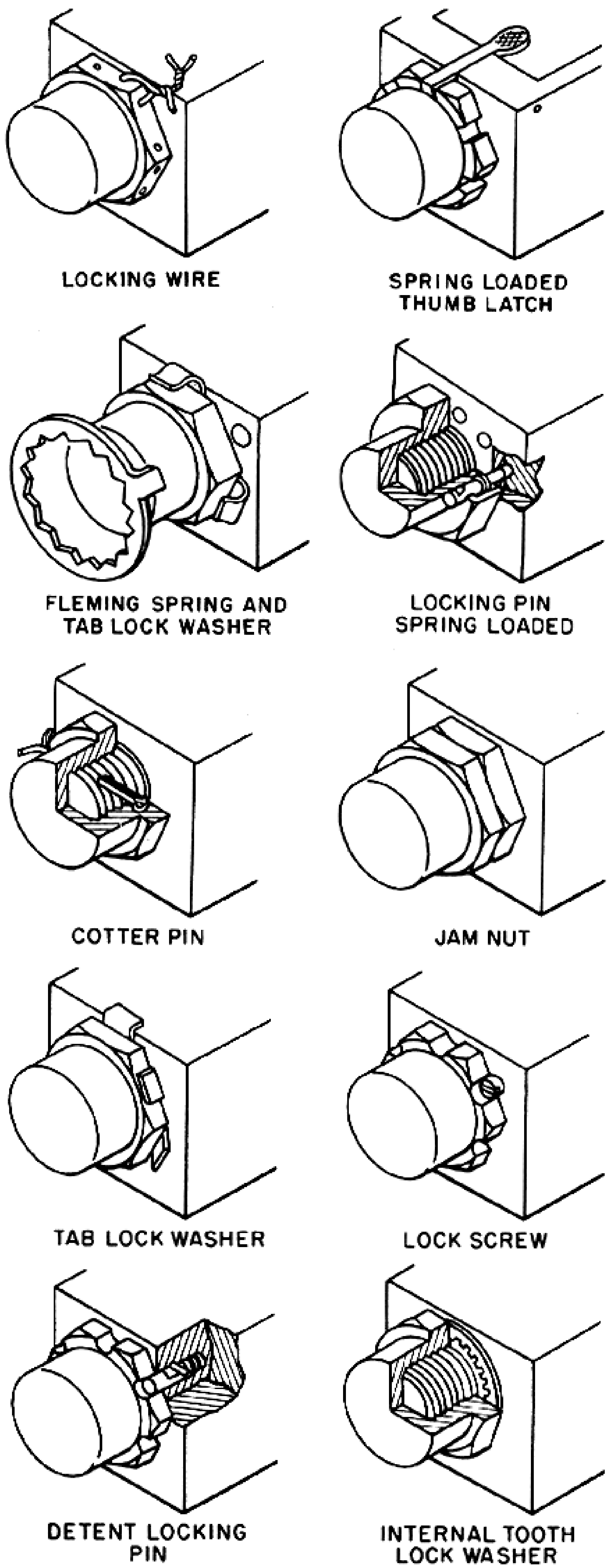

Figure 18–2. Types of Retaining Devices.

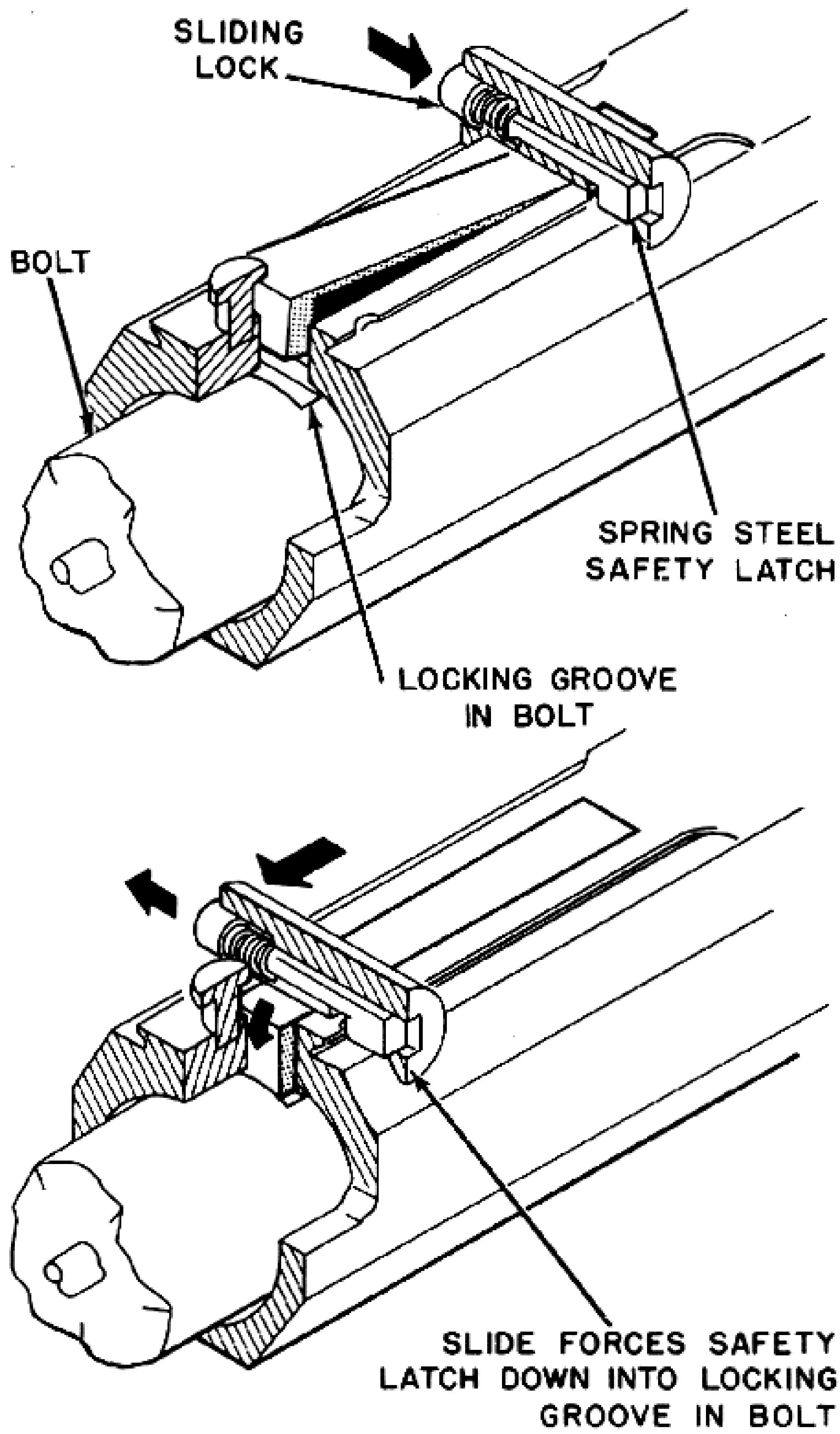

Figure 18–3. Operation of a Bolt Lock.

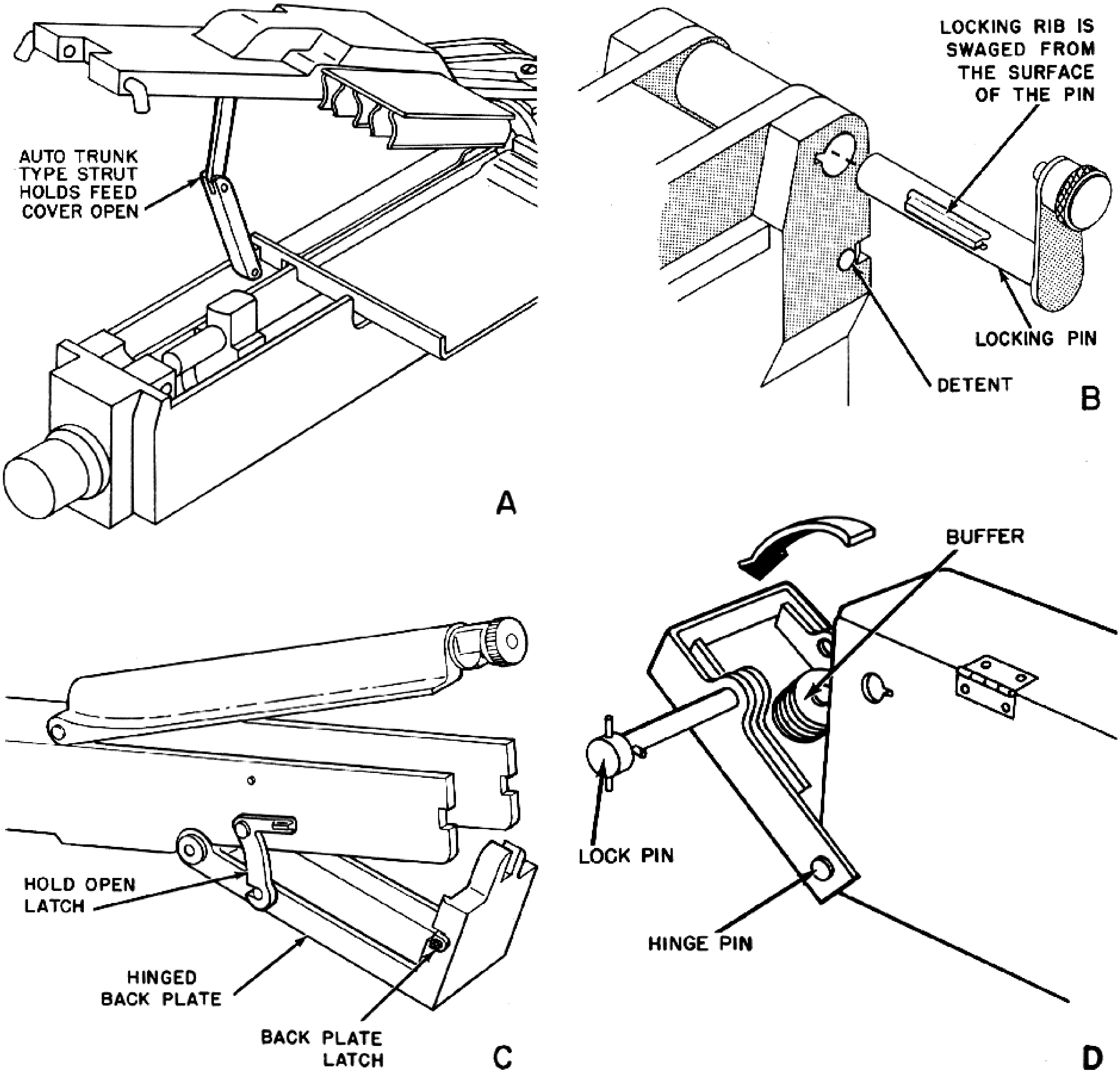

Figure 18–4. Hold Open and Cover Retaining Devices.

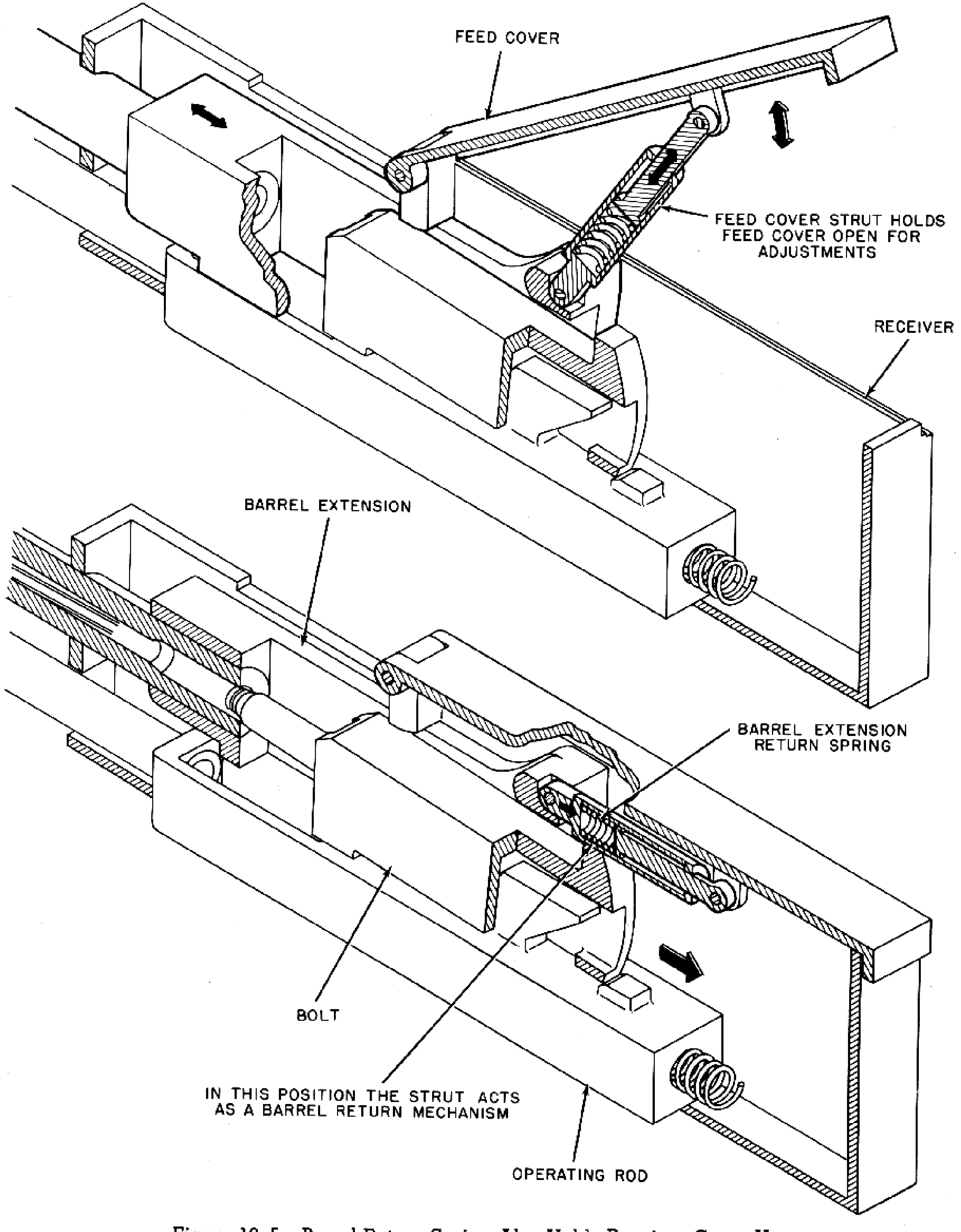

Figure 18–5. Barrel Return Spring Also Holds Receiver Cover Up.

SPRINGS

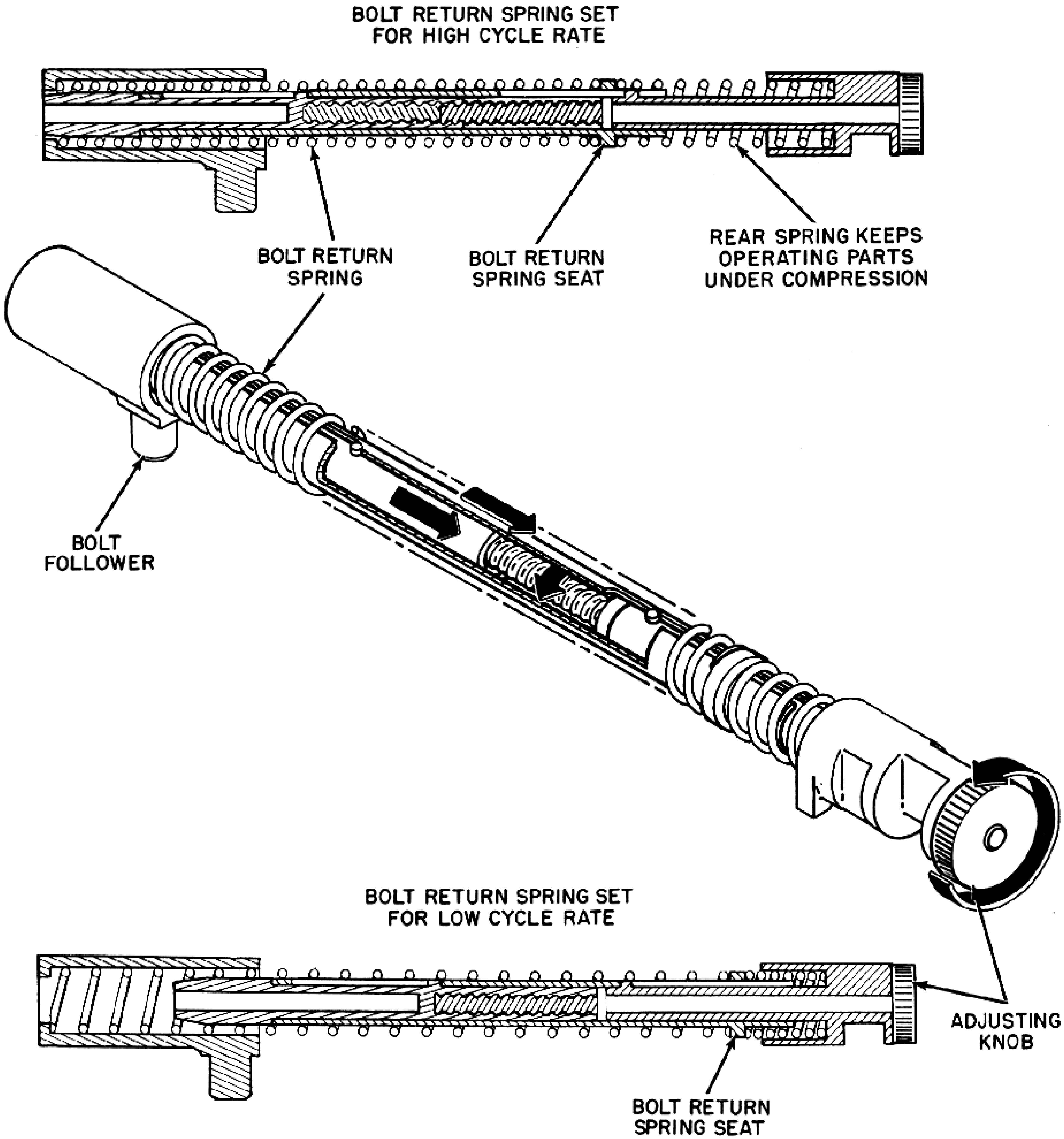

Figure 19–1. Method of Regulating Spring Tension To Change the Rate of Fire.

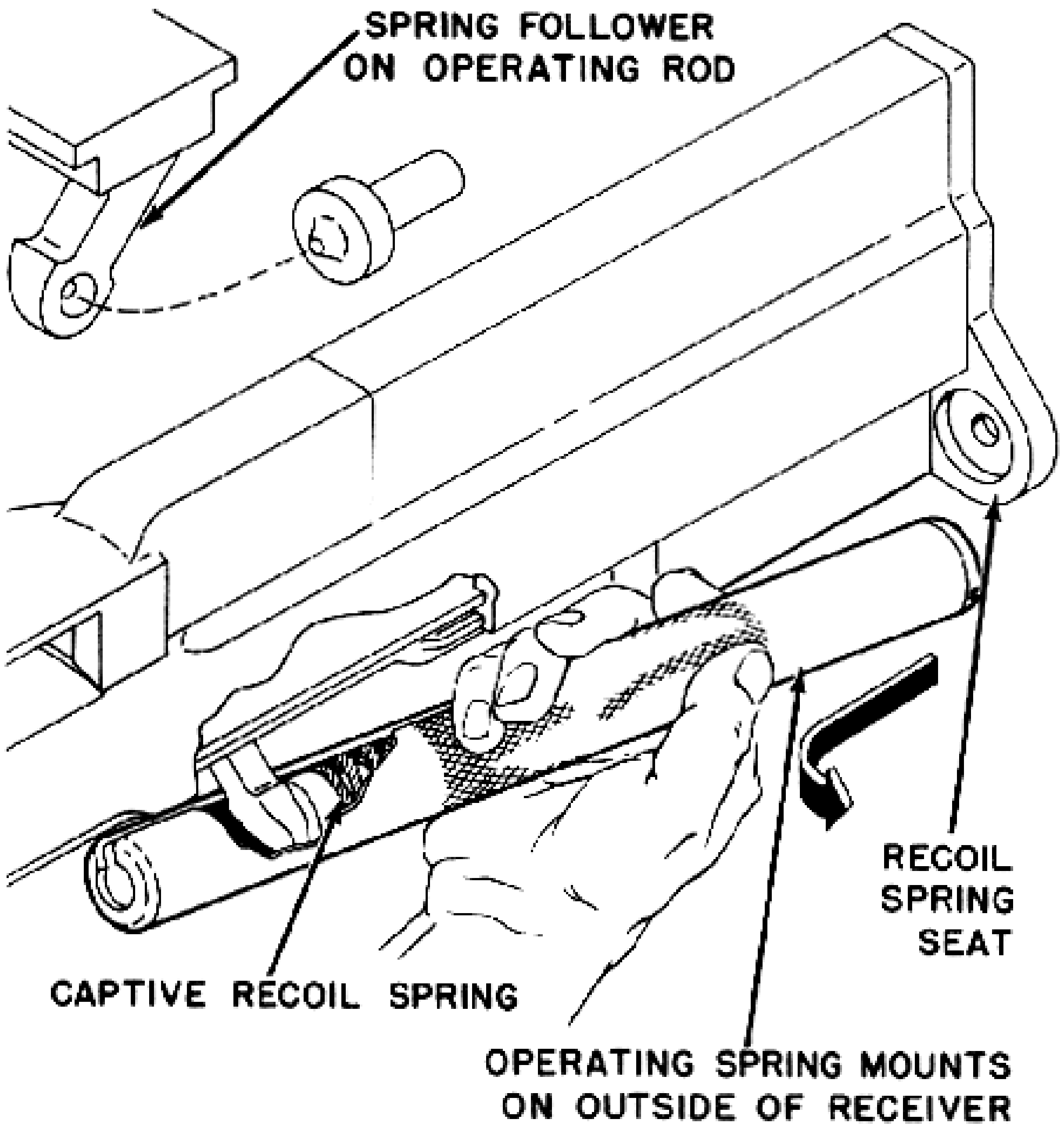

Figure 19–2. Method of Retaining an External Captive Recoil Spring.

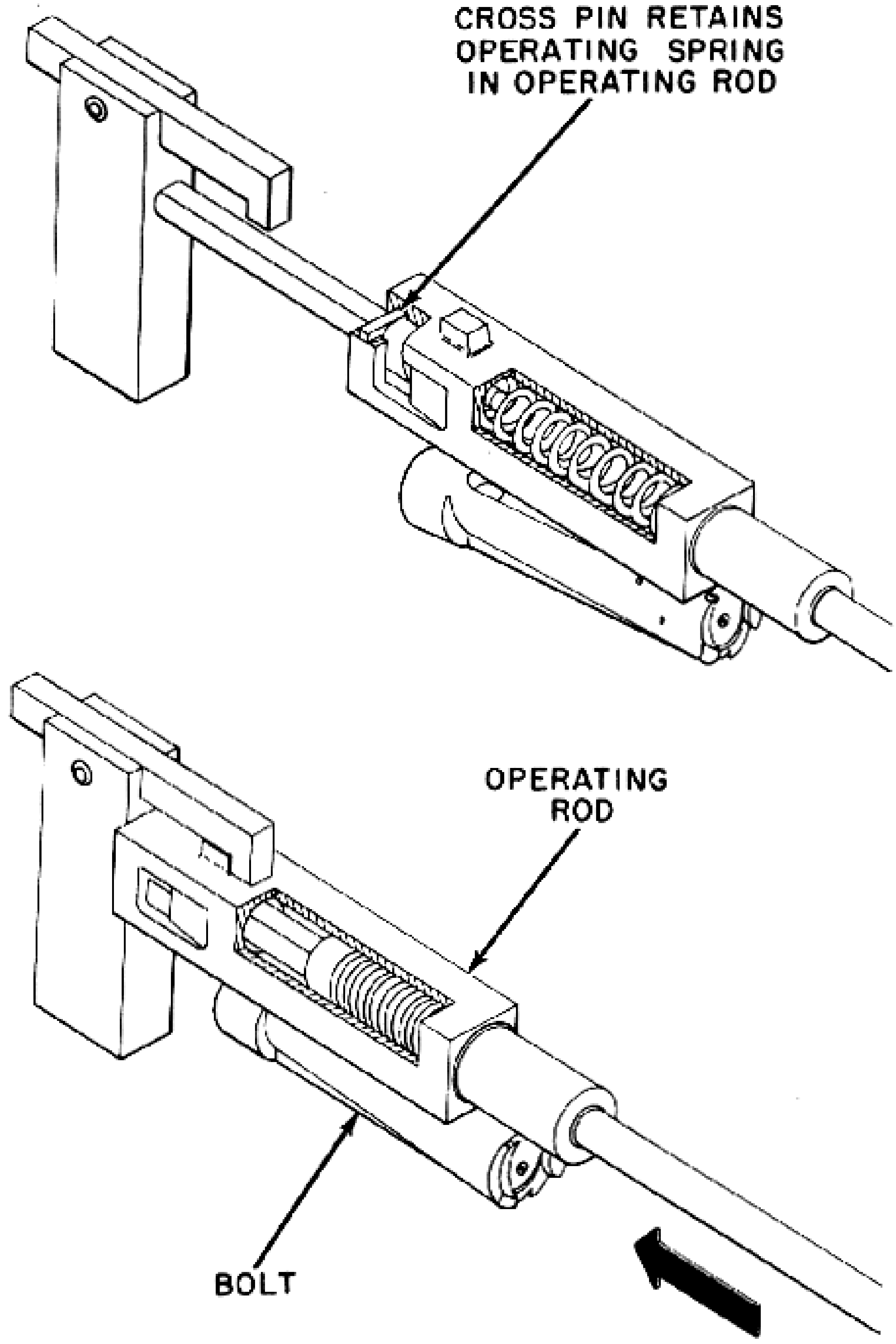

Figure 19–3. Captive Spring Used To Return Breech Bolt and Operating Rod.

Appendix A

SOURCES FOR PART XI

Chapter 6. Locking Systems—Con.

Chapter 6. Locking Systems—Con.

Chapter 6. Locking Systems—Con.

Appendix B

ANNOTATED BIBLIOGRAPHY

Appendix B is a record of the principal sources on automatic weapons. These sources include books, magazine articles, pamphlets, manuals, and official reports and documents. Each entry includes author or issuing agency, title, date, series number, and other identifying data, followed by a brief description of the contents and special features of the work.

For security reasons, many references on recent and proposed weapons under development in the United States and other countries can not be listed in this volume, which has been prepared for general distribution. Other sources which must also be omitted are official correspondence on various weapons and personal correspondence and conversations with inventors, manufacturers, and researchers in the field of ordnance.

The appendix is arranged in two sections. Section I is an alphabetic grouping of general works on machine guns and other automatic weapons. Section II contains works on individual weapons, inventors, or manufacturers and the entries are listed under specific topics, arranged alphabetically.

SECTION I—GENERAL WORKS

Aberdeen Proving Ground
Air Corps—Ordnance conference. 18 Jun 1937.
Conference between representatives of the two services. Discussion of: experimental airplane projects; relative merits of all guns and ammunition; aircraft cannon; machine guns; ballistics; and other topics.

Aberdeen Proving Ground
Ordnance School text. Foreign material, Vol. 1. Feb 1943. (OS 9–61)
Includes chapters on hand and shoulder weapons (German Mauser, 7.92 mm, German antitank rifle, 7.92 mm, Pz. B.39, Schmeisser machine pistol, 9 mm MP40, Bergmann submachine gun, 9 mm) light machine guns (MG34, Breda M1930, Sfitalui light mg, model 1937, French light mg, cal. 7.5 mm, M1924–29, Jap Nambu machine rifle, M1922) and heavy machine guns (Jap heavy mg, cal. 7.7 mm, model 92). Illustrated.

Aircraft armament—Italy. 15 Apr 1922.
(Service report)
A summary of Italian development at time of report, with photographs.

Argentina. Army
Report on machine gun competition. 17 Feb 1939.
Translation of report on tests of seven different European weapons for Argentine government. Colt weapon, already the Argentine regulation machine gun, made best performance.

L'armement de nos avions militaires. (In *l'Aerophile,* 1936, pp. 123, 170, 194, 218)
Series of articles on French air armament. (In French.)

The automatic machine gun in our Navy. (Manuscript) 8 p.
Summary of Navy's use of machine guns in past 50 years.

Balleisen, Charles E.
German mass production methods; the use of stamped components in gun manufacture. (In *Army Ordnance,* Sep-Oct 1946, p. 147)
Translated from Sep 1943 German document of Deutsche Waffen and Munitionsfabriken A. G., Posen. Process used on FLAK 38, MG 151, 30-mm MK 108. Illustrations.

Balleisen, Charles E.
Principles of firearms. N. Y., 1945. 146 p.
"The purpose of this book is to expound the concept that an automatic firearm is a piece of machinery operating in accordance with well-known laws of physics and hence capable of being analyzed and designed in accordance with common engineering practice." A limited number of familiar weapons are analyzed from the viewpoint of a mechanical engineer. Chapters on gun barrel, recoil, functions, systems and existing types of automatic weapons, trigger and sear mechanisms, feeds, sights, design problems, testing, exterior ballistics and gun mounts.
Illustrations; bibliography after each chapter.

Baranski, Gerhard
The systems of automatic weapons. (Chapter 1 of *Textbook for automatic weapons*—Dec 1939)
(BIOS translation BIOS/Gr. 2/HEC/11707/III)
Translation from Rheinmetall publication. Contents: Supply of energy for the loading operation; Locking of the breech mechanism; Closed and open systems; Cartridge feed and loading; Extraction and ejection of case; Device for directing flow of gas at muzzle; Springs and rubber buffers as accumulators; Accelerating devices for breech mechanism; Safety and locking devices in general. Charts and drawings.

Barlow, J. A. and Johnson, R. E. W.
Small arms manual. London, 1942. 232 p.
Covers rifles, machine guns, machine carbines, revolvers, pistols. Summarizes knowledge on British, U. S. and enemy weapons: Identifying data, operation, stripping, stoppages and special features. Drawings included.

Barnes, G. M.
Weapons of World War II. N. Y., 1947.
Ordnance weapons used in WW II displayed by means of developmental and action photos; characteristics and high-

lights of their development also set forth. Brief chapter on aircraft armament (20 mm M3; 37 mm automatic gun, M4; and 75 mm gun, M4)

Bartlett, Wallace A.
Some weapons of war as improved by recent American inventors. Washington, 1883. 98 p.
Includes chapters on small arms, revolvers and machine guns. The latter covers Billinghurst & Requa, Gatling, Hotchkiss, McLean, Gardner & Lowell. Illustrated.

Benét, Laurence V.
Machine guns, their development, limitations and future demands. (In *Army Ordnance*, Mar–Apr 1937, p. 270)
"A succinct review of development and of certain characteristics of the more modern automatic weapons." Author, famous designer and official of Hotchkiss Co.

Blagonravov, A. A.
Basic principles for the planning of automatic weapons. (Translation of extracts from Russian manual.) 1942.
(Mauser Works report no. 1178)
Includes anti-tank weapons, barrel vibrations, life and wear of barrels, supplementary arrangements, systems with non-locking bolts, gas operated weapons, extraction, recoil.

Blagonravov, A. A.
Material'naya chast' strelkovogo oruzha. Kniga pervaya. Moscow, 1945.
Russian volume describing rifles and revolvers. Illustrated. ("Evolution of small arms") (vol. 1)

Blagonravov, A. A.
Material'naya chast' strelkovogo orushiya. Kniga vtoraya. Moscow, 1946. 832 pages.
(In Russian) ("Evolution of small arms," vol. 2) Description, data and drawings of automatic guns of all nations. Also breakdown drawings.

Blagonravov, A. A.
Material'naya chast' strelkovogo orushiya, kn. II. (Infantry weapons, book II) Moscow, 1946.
(I. D. 496228)
Translation of pages 5–42 of subject book. Chapter I, "Machine gun supports and machine gun mounts." Ch. II—"Light machine guns." Russian ms attached.

Blanch, H. J.
A century of guns: a sketch of the leading types of sporting and military small arms. London, 1909.
Section on Maxim is included. Illustrated.

Bond, A. Russell
Guns that fire themselves. (In *St. Nicholas*, Vol. XLV, Apr 1918, p. 538–43)
Excellent elementary article on development and principles of Gatling, Maxim, Browning, Hotchkiss and Lewis guns. Illustrated.

Borden, Wm. A.
Aircraft guns, part II. (In *Army Ordnance*, Jul–Aug 1922, p. 19)
Describes use in WW I. Illustrated.

Bruchiss, Louis
Aircraft armament. N. Y., 1945.
Details on aircraft bombs, aircraft machine guns, aircraft cannon, ammunition, turrets, foreign aircraft weapons, anti-aircraft weapons, gunnery training, future weapons and air warfare. Illustrated.

Budayevskiy, S.
Kurs artillerii. 5th edition. 3 volumes. St. Petersburg, 1907.
Part II—Hand weapons and machine guns. Illustrated. (In Russian)

Budayevskiy, S.
Kurs artillerii. 5 volumes. St. Petersburg, 1912.
Vol. 1—General information as to weapons; v. 2—Rifles, recolvers and firing from same; v. 3—Machine guns, automatic pistols and firing from same; v. 4—Firing problems and firing tables for 3-line guns and machine guns; v. 5—Armament and firing of artillery. Illustrations. (In Russian)

Carré, Henri
The modern machine gun. (In *Current History*, vol. 5, Oct 1916, p. 737–40)
Brief historical article.

Clay, W. L.
Report of visit to European small arms and small arms ammunition factories, year 1929.
A detailed account, with many photographs, of the current (1929) armament used in ten European countries, and a discussion of the production of weapons and ammunition in the factories of these countries. Contains a tabulation of light machine guns used by the various countries.

Coint-Bavarot, R.
Emploi comparé des canons et des mitrailleuses dans la bataille aérienne. (In *Revue de l'armée de l'air*, 6th yr, vol. 1, 1934, p. 123)
Lists characteristics of aerial weapons, adaptation to different types of aircraft and other considerations. (In French.)

Colt's Patent Fire Arms Mfg. Co.
A century of achievement, 1836–1936. (Colt's 100th anniversary fire arms manual) Hartford, Conn., 1937.
A history of the firm which manufactured Gatling gun, Colt-Browning, Maxim, Benet-Mercie, Vickers, and Browning guns. Illustrated.

Colvin, Fred H. and Viall, Ethan
United States rifle and machine guns. N. Y., 1917. Illus., 328 p.
Contains descriptions of operation and mechanisms of Springfield and Enfield rifles; also of U. S. machine rifle, cal. .30, Model 1909, Lewis machine gun and Vickers Model 1915. Illustrated.

Commission Interalliée de Control Aeronautique en Allemagne
Rapport technique. Vol. III. Armement: Bombardement aerien; Tir a la mitrailleuse; Tir au canon. 1923.
Chapters on Gast 2-barrel mg, Becker 2-cm cannon, Szakats cannon. Each with description, operation, breakdown, detailed drawings. (In French)

Corner, J.
The German development of recoilless guns for aircraft. (In *Aircraft Engineering*, Dec 1947, p. 378)
Based on Davis gun, two types were developed by Germans in WW II. (1) 14-inch forward firing gun mounted in Do 217. (2) S. G. vertical firing guns (45-mm and 3 cm). Also experiments with jet guns in aircraft by Rheinmetall, which never went into service. Illustrated.

Crossman, Edward C.
The story of the machine gun. (In *Popular Science* monthly, Vol. 90, 1917, p. 666–70)

Outline of the development of the machine gun from Gatling to Lewis with emphasis on American origins of the various weapons. Illustrated.

Crowell, Benedict
America's munitions, 1917–18. Washington, 1919.
Author was Asst. Secretary of War and Director of Munitions. Chapter on machine guns. Illustrated.

Curti, P.
Automatische waffen. Frauenfeld, Ger., 1939.
(In German.) (122 illustrations)
Discussion of ballistic principles, systems, use for antiaircraft and aircraft installation.

Devouges, Marcel
L'avenement des armes automatiques; technique et emploi des arms, organisation des unités de tir. Paris, 1924.
(In French.) Technique and use of automatic weapons are covered in first part. Second part summarizes development and history of weapons. Illustrated.

Engel, Leonard
The guns grow larger. (In *Popular Aviation,* Jan 1940, p. 10)
Describes trend toward more powerful armament (20 and 37 mm cannon). Illustrated.

Etienne, P.
Secteurs de feux. (In *Revue de l'armée de l'air,* Jul-Dec, 1938, p. 858)
Discusses value of armament on planes to cover all fields of visibility. (In French)

Farrow, Edward S.
American guns in the war with Germany. N. Y., 1920.
Contains chapter on machine guns, with statistics on production. Illustrated.

Farrow, Edward S.
American small arms. N. Y., 1904.
Descriptions of arms of American patent or manufacture.

Farrow, Edward S.
Military encyclopedia; a dictionary of military knowledge. N. Y., 1885.
Brief treatments of military topics, including automatic weapons. Illustrated.
Complete descriptions of most important 19th century weapons.

Faure, A.
Guns for firing from airplanes. 14 Nov 1917. 22 p.
Author comes to conclusion that airplanes should carry 75 mm gun firing at low muzzle velocity to shell ground areas.

Federov, S. I.
Sovremiennoye polozhenie pulemietnavo diela. 1907. 104 p.
(In Russian) "Present status of automatic guns" lecture read in the Society for Promotion of Military Knowledge. Illustrated, with captions translated into English.

Federov, V.
Zvolyupiya strelkovogo oruzhiya. Chast' II. Razvitie avtomaticheskogo sruzhiya. Moscow, 1939.
(In Russian) Describes and illustrates Soviet and foreign automatic weapons.

Fleck, A.
Maschinengewehre, ihre technik und taktik. Berlin, 1909.
(In German) Includes Schwarzlose, Skoda, Bergmann. Illustrated.

Fleck, A.
Maschinengewehre, ihre technik und taktik, neueste fortschritte, jahrgang 1913. Berlin, 1914.
Contains diagrams of Dreyse mg and Berthier mg. (In German)

Fleck, A.
Die neuesten maschinengewehre, fortschritte und streitfragen. Berlin, 1910.
("Latest machine guns; their progress and questions of dispute") (In German) Includes Odkolek mg, Perino mg. Illustrated.

Fleck, A.
Maschinengewehre, ihre technik und taktik. Neueste fortschritte, jahrgang 1912. Berlin, 1913.
Describes development in field of machine guns for the year 1912. Illustrated. (In German)

Fortune (periodical)
Arms and the men. Garden City, 1934. 58 p.
Describes organization and personalities of world's munitions firms. Portraits of leaders.

Fosbery, G. V.
On mitrailleurs, and their place in the wars of the future. (In *Journal of the Royal United Service Institution,* vol. XIII, 1870, p. 539) 17 p.
Observations on Ager, Claxton, French, Gatling and Montigny weapons. Illustrated.

France. Ministry of War
Renseignements sur la fabrication des mitrailleuses en Allemagne. May–Aug 1919.
(C. R. no. 198)
(In French) Lists German machine gun factories during World War I. Brief descriptions of T. u. F. and Gast weapons.

France. Ministry of War
Report on comparative tests of automatic rifles. 20 Feb 1924.
Tests were made in 1923 on Berthier, Browning, St. Etienne, Hotchkiss (belt and magazine types), Madsen and Chatellerault. General estimate given for each. Decision was made to adopt Chatellerault. Drawings and tables.

German aircraft armament. (In *The Aeroplane,* Jun 14, 1940, p. 794).
Describes Rheinmetall guns installed in WW II German guns. Illustrated.

Germany. Luftwaffe
Current aircraft armament of greater Germany (G. D.), Great Britain (G. B.), U. S. A., and the Soviet Union (S. U.). 1 Aug 1944
(OTIB No. 2731)
Translation of aircraft armament comparative chart by Technical Intelligence Branch, Ord Dept. Tabulation gives caliber, designation, construction, feeding mechanism, weight, cyclic rate, vo., kinetic energy at muzzle and mount.

Giardini, Walter
Armi e tiro. Rome, 1943.
Describes Breda-Safat 7.7 and 12.7 mm guns, Scotti-Isotta Fraschini 12.7-mm guns and other weapons used by Italians. Illustrated. (In Italian)

Goddard, Calvin

The machine gun—a period of evolution, parts I–V. (In *Army Ordnance,* May 42–Jan 43)

The following weapons are described and illustrated: Terrel machine cannon, Barnes machine cannon, Ripley gun, Douglass & Brett guns (1864), Gatling gun and cartridges, French mitrailleuse, and Feld gun.

Goddard, Calvin

The machine gun—The period of recognition, parts I–VI. (In *Army Ordnance,* Mar 43–Jan 44)

Describes and illustrates early weapons, including Bailey, Gardner, Gatling, Palmcrantz, Ager, Taylor, Vandenberg, Lowell and Maxim guns.

Goddard, Calvin

The machine gun—Its earliest application. Parts I–IV. (In *Army Ordnance,* Sep 41–Apr 42)

Discussion, with illustrations, of Billinghurst-Requa, Gatling and other Civil War guns, Ager, Montigny, Claxton, Gorgas and Vandenberg.

Gorton, Walter T.

Aircraft machine guns. (In *Aviation,* June 6, 1921, p. 724)

Discussion of development during World War I. Illustrated.

Gt. Brit. War Office

Instructions for use of permanent staff instructors . . . in regard to care, inspection and repair, etc., of small arms, machine guns and bicycles. London, 1933.

Gt. Brit. War Office

Technical intelligence summary no. 74. 28 May 1942.

Contains section on Italian medium machine guns with specifications.

Gt. Brit. War Office

Textbook of small arms. London, 1929. 427 p.

Contains definitions of terms. Chapters on revolvers and self loading pistols, machine guns and light machine guns, small arm ammuniiton, ballistics of small arms. Appendix IX contains details of machine guns of various powers in tabular form.

Gt. Brit. ADI (Tech.)

Soviet aircraft guns. Oct 1949.

A report on aircraft guns used by the Soviet Air Force during WW II. Not intended to include technical details but rather to indicate type of weapon and make comparison with similar weapons of known performance. Includes Shkas 7.62 mm, BS 12.7 mm, Shvak 20 mm, VJa 23 mm and NS 37 mm, also turrets and mountings, maintenance and ammunition. Photographs and tabulation of data on guns and ammunition.

Gt. Brit. Admiralty

20 millimeter anti-aircraft machine guns; summary of Royal Navy's experience with Oerlikon, Hispano and Madsen. 6 Nov 1940–

Preference finally given to Oerlikon.

Gt. Brit. Air Ministry

Handbook of foreign aircraft guns. Nov 1942.

Summarizes German, Italian, Russian and Japanese weapons (MG 15, 17, 81, 131, 151, 151/20, FF MK 101) (Breda, Shkas, Berezin, Shvak, Experimental, Oerlikon). Diagrams. Table on weight of projectiles fired per minute—German and Italian.

Guns, allied and enemy. London, 1940.

Contains 100 photos and diagrams.

Hatcher, Julian S.

Hatcher's note book. Harrisburg, 1947.

A standard reference book for shooters, gunsmiths, ballisticians, historians, hunters, and collectors. Contains brief history of service cartridges, automatic gun mechanisms, development of machine guns, receiver steels & heat treatment, headspace, recoil, notes on gunpowder, gun corrosion, and random notes. Illustrated.

Hatcher, J. S.

Automatic firearms; mechanical principles used in the various types. Part I. (In *Army Ordnance,* Mar–Apr 1933, p. 269)

Describes blowback, retarded blowback and blow-forward principles. Illustrated.

Part II (same, May-Jun 1933, p. 339). Describes recoil operated (short and long) and gas operated types.

Hatcher, Julian S.

The machine gun of the future. (In *Army Ordnance,* v. 1, 1920, p. 39)

Future needs are longer range, more mobile vehicles, more powerful projectiles, better fuses and better powder.

Hatcher, J. S. and others.

Machine guns. Menasha, Wis., 1918.

Part I. Materiel, by Maj. Julian S. Hatcher.

Part II. Practical handling of machine gun fire, by Maj. Glenn P. Wilhelm.

Part III. Machine gun tactics, by Maj. Harry J. Maloney.

Based on notes prepared for instruction at the first U. S. Army machine gun school at Harlingen, Texas.

Part I contains historical chapter and chapters on Chauchat, Hotchkiss, Benét-Mercié, Lewis, Maxim-Vickers, and Colt.

Hawks, Ellison

Aircraft armament, past and present. Southport, Eng., 1943.

Part I. Machine guns and mounting of the synchronizing gear. (From early Lewis to modern Browning) Illustrated.

Hicks, James E.

Notes of French ordnance, 1717 to 1936. n. d.

Brief descriptions of French models of machine guns and automatic rifles. Illustrated.

Hicks, James E.

What the citizen should know about our arms and weapons. N. Y., 1941.

Contains chapter on machine guns. Illustrated.

Heiden, Hermann

Gewehre frei! Weg und ruhm der maschinengewehrwaffe. Berlin, 1938. 215 p.

A historical summary of use of machine guns in warfare. (In German) Contains numerous illustrations & bibliography of German titles.

Hodges, LeRoy

Notes on post-war ordnance development. Richmond, 1923.

Describes development of cal. .50 Browning and progress in aircraft armament (synchronized guns, Browning cal. .50 and 37-mm, Davis non-recoil gun, etc.) Illustrated.

Hohm, Fritz
Die waffen der luftstreitkrafte. Berlin, 1935.
(In German) Illustrations and descriptions of aircraft weapons of Germany and other countries. 247 illustrations.

Holmes, J. T.
Machine guns from Gatling to Browning. (In *Popular Science*, Sep 1945, p. 118)

Japanese 7.7 mm machine gun. (In *International Intelligence Summary*, 20 Feb 1944, p. 8)
Details and illustrations are given.

Johnson, Melvin M., Jr. and Haven, Charles T.
Automatic arms, their history, development and use. N. Y., 1941. Illus. 366 p.
General survey of weapons with history, development, operation and maintenance sections. Contains foldout drawings of various weapons. Index.

Johnson, Melvin M., Jr. and Haven, Charles T.
Automatic weapons of the world. N. Y., 1945. 644 p.
Revision and amplification of "Automatic Arms" (1941). Summarizes most of world's automatic weapons, heavy and light machine guns, pistols, automatic cannon. Many illustrations. Bibliography—p. 625–630.

Johnson, Melvin M., Jr. and Haven, Charles T.
For permanent victory: The case for an American arsenal of peace. N. Y., 1932.
Also published as "Weapons for the future."

Johnson, Melvin M., Jr.
Japanese small arms. (In *Army Ordnance*, Jul–Aug 1944, p. 112)
Types and characteristics of rifles, pistols and machine guns. Illustrated.

Johnson, Melvin M., Jr.
Light machine guns; they should reconcile the demands of mobility and fire power. (In *Army Ordnance*, Sep–Oct 1937, p. 84)
Need is for an automatic mechanism of extreme simplicity which can be adapted to light weapons.

Johnson, Melvin M., Jr.
Rifles and machine guns, a modern handbook of infantry and aircraft arms. N. Y., 1944
"This is primarily a soldier's book." Brief historical review since 1900. Sections on automatic rifles and light machine guns, sub-machine guns, carbines, pistols, aircraft cannon.
For each weapon—pictures, brief history, data, notes on operation, stripping and author's comments.

Johnson, Melvin, M., Jr. and Haven, Charles T.
Weapons for the future: the case for an American arsenal of peace. Washington, 1943. 152 p.
Book indicates lack of preparedness before World Wars I and II in the fields of small arms, machine guns and heavy weapons. Manufacturers had to depend on civilian goods to keep going. Nation urged not to let it happen again.

Keith, C. H.
I hold my aim. London, 1946.
The story of how the Royal Air Force was armed for war. Author served on Ordnance Board in procuring weapons. Personal stories re Darne, Birkigt, Gebauer and other designers. Story of production of Hispano-Suiza in England. Illustrated.

King, H. F.
Armament of single-seaters. (In *Flight*, Dec 21, 1939, p. a)
Contains approximate data for representative aircraft guns. Illustrated.

Lake, V. R.
Patents for inventions relating to machine guns. London, 1895.

Lewis, R. B.
U. S. machine guns, 1895–1944, parts I–V. (In *Army Ordnance*, Jul 45–Mar 46)
Five articles on all official models used by U. S. (1) Gatling to Marlin model 1918 tank gun; (2) Vickers 11 mm aircraft gun, model 1918, to Browning, cal. .50; (3) post-war development of Brownings; (4) continues study of cal. .30 weapons and begins cal. .50; (5) completes cal. .50 types and presents general summary of light machine gun development. Illustrated.

Lilienthal Society for Aircraft Research
Report on technical questions of aircraft weapons Sep 1944 (Report 182, 2nd part)
Translations of papers by German scientists—(1) Requirements for the development of aircraft guns, by Buhler. (2) Mathematics and scientific measurements in the construction of weapons, by Niemann. (3) Devices for research in weapons, by Hackemann and Kusters. (4) Gun-barrel design, by Kruger. (5) Muzzle brakes and recoil boosters, by Grundler.

Longstaff, F. V. and Atteridge, A. H.
The book of the machine gun. London, 1917.
History of machine guns, their use in battle, evolution of tactics, materiel, use by British and other armies and training are topics covered. Contains 84 illustrations and bibliography.

Low, A. M.
Modern armaments. London, 1940.
Contains chapter on small arms.

Low, A. M.
Musket to machine gun. London, 1943.
Non-technical summary of history of machine guns based on secondary sources. Illustrated.

Luftwehr. 1934, 1935, 1937, 1938, 1939
Contains a number of articles (in German) on aircraft armament, including Oerlikon, Madsen, Bofors, Vickers, Hispano-Suiza, American Armament. Many of the articles translated from French, English and American periodicals into German. Many details on Oerlikon weapons.

McClintock, Marshall.
The story of war weapons. Philadelphia, n. d.
Chapter on small arms (from club to Garand); another on automatic weapons; one on artillery (from catapult to howitzer); one on weapons in the skies. Illustrated.

McFarland, Earl
Light machine guns: The need for a new automatic infantry weapon. (In *Army Ordnance*, Sep–Oct 1940, p. 103)
Characteristics to be considered are listed, with invitation to inventors for tests to be held in October 1941 by War Dept.

McFarland, Earl
Report on the instruction received at the Springfield Armory on automatic machine guns. 5 Sep 1916.

Describes training received in handling and theoretical study of Benét-Mercié, Lewis, Colt, Maxim and Vickers machine rifles and machine guns. Lists modifications made in Benét-Mercié since its adoption.

The machine gun. (In *Scientific American,* Aug. 5, 1916, p. 125)
Gives characteristics of the three types used by U. S. Army (Lewis, Maxim, Benét-Mercié) Diagrams.

Marsh, Roger
Weapons 1: Overture to aggression; a pictorial survey of Russian small arms, 1891–1943. Hudson, Ohio, 1950.
Contains drawings and brief text on Russian handguns, rifles, machine guns and ammunition.

Maxim, Hiram S.
Automatic firing guns. I. Historical. (In *Scientific American Suppl.,* May 23, 1896, p. 17002–03)
Observations on Puckle and other early guns.
Also: II. Introduction of rifling (May 30, 1896, p. 17027; 17038–39.) The Peabody-Martin rifle (Jun 13, 1896, p. 17056)

Middle East handbook of enemy equipment (European) Volume II. Small arms and mortars.
Describes Italian machine guns, rifles and other automatic weapons and mortars; also armament from other countries of Europe. Italian guns include Breda, Fiat, Safat, Scotti, Isotta-Fraschini. General data, stripping, operation, etc., are given. Photographs.

Minon, Mariano V.
Prontuario de armamento. Valladolid, Spain, n. d.
Descriptions and pictures of Darne, Semag, Puteaux and other weapons. (In Spanish)

Mleneck, Capitaine
Notes sur les mitrailleuses. Paris, n. d.
Description of early machine guns. Sketches. (In French)

Motor balloon guns; automobile vs. airship. (In *Scientific American,* Jan 15, 1910, p. 48)
Discusses mounting of machine guns on motor vehicles, including McClean-Lissak automatic gun mounted on Packard truck and two German rapid fire guns mounted on armored vehicles—purpose is to fire on airships. Illustrated.

Musgrave, Daniel D.
The automatic weapon. (Manuscript)
Notebook and scrapbook of materials for comprehensive volume on subject. Outline of scope of volume. Pictures of mounts, ammo., data on manufacturers, systems, pictures of weapons (alph.), listing of countries with weapons each is armed with, misc. pictures of weapons in action.

Newman, James R.
The tools of war. Garden City, 1942. 398 p.
Book seeks to explain development of armaments in terms of 3 basic factors—firepower, mobility and armor (defensive power). Well illustrated chapter on machine guns, including picture of da Vinci's designs. Another chapter on "tools of air war" surveys origins of aircraft from classical times through gliders and balloons to Wright and later developments. Many interesting pictures.

Norton, Charles B.
American breech-loading small arms: a description of late inventions, including the Gatling gun and a chapter on cartridges. N. Y., 1872.
Includes picture of Gatling camel gun and detailed early history of Gatling guns. Many pictures.

Norton, Charles B.
American inventions and improvements in breech-loading, small arms, heavy ordnance, machine guns, . . . etc. Boston, 1882.
Chapter X—The Gatling gun (on p. 278, drawing of pack gun on horse that Custer should have had) Details on tests and correspondence re Gatling. Also material on Gardner battery gun and Wilder gun (with picture on p. 400 of Wilder horse battery) (reversible mount on back of horse) Other historic illustrations.

Owen, J. F.
Compound guns, many-barreled rifle batteries, machine guns, or mitrailleurs. London, 1874.
Early treatise on tactics and descriptions of current multiple-fire weapons. Drawings.

Parker, John H.
The machine gun in the U. S. Army. (In *American Review of Reviews,* Jul 1908, p. 739–40)
Summary of article in *Journal of the Military Service Institution* by Capt. John H. Parker on proposed organization of machine gun service in Army.

Parker, J. H.
Tactical organization and use of machine guns in the field. Kansas City, 1899.

Pasrow, Kurt
Taschenbuch der heere. Munich, 1939.
Contains pictures and data on Finnish (Lahti), Italian and other automatic weapons. (In German)

Phillips, Albert E.
Small arms in the A. E. F. (In *Army Ordnance,* Jan–Feb 1935, p. 217)
Shortages and inadequate weapons at beginning of WW I described, together with attempts at solving problem in the field. Illustrated.

Pollard, H. B. C.
A history of firearms. London, 1936.
Chapter on self-loading and automatic arms. Contains table of modern proof marks.

Pontiac Motor Division, General Motors Corp.
Pontiac's anti-aircraft training program. n. d.
Illustrated brochure on school conducted in WW II on 20 mm (Oerlikon) and 40 mm (Bofors) guns and mountings by Pontiac.

Pridham, Major C. H. B.
Superiority of fire; a short history of rifles and machine guns. London, 1945. 146 p.
Carries story of rifles and machine guns from earliest origins to outbreak of WW II. Chapters on earliest quick firing weapons, Maxim, Gatling, and machine guns in aerial warfare (1914–1944) Emphasis on tactical history. Illustrated.

Die principiellen eigenschaften der automatischen feuerwaffen . . . Vienna, 1902. 140 p. 52 figures, 16 illustrated tables.
(In German) "Principal examples of automatic weapons" Based on articles in "Danzer's Armee-Zeitung". Illustrates Roth, Bergmann, Browning, Dormus, Krnka, Luger, Mannlicher, Schwarzlose and other principles. Section on primer actuated blowback (Roth—1902). Also illustrations of Roth mg.

Pynches, T. Le G.
Aircraft armament. (In *The Aeroplane*, Jun 24, 1931, p. 1210)
Summary of present status (1931) of British aircraft armament, including bombing, torpedoes, heavy guns, rifle caliber automatic guns, observer's guns. Illustrated.

Quinat, Capitaine
Les mitrailleuses en France et a l'étranger. Annexe à la premiere partie, historique et description. Camp de Chalons, 1913.
Brief descriptions and illustrations of weapons then current. (In French)

Rea, C. A.
The cannons are coming. (In *Aeronautics*, Oct 1940, p. 60)
Describes early use of aircraft cannon, such as Davis, COW gun, Vickers, etc., in World War I. Illustrated.

Ritchie, Scott B.
Enemy weapons, the collection and analysis of captured materiel. (In *Army Ordnance*, Jul–Aug 1943, p. 96)
Organization of Ordnance Intelligence Unit is described. Collection of weapons at Aberdeen Proving Ground. Contains many German, Italian and Japanese models, representative ones of which are described and illustrated.

Russian small arms (aircraft machine guns) 15 Mar 1945 (ETO TI Report no. 91A)
Brief descriptions and photos of 7.61 mm Shkas, 12.7 mm. BS, 20 mm Shvak and 23 mm VJa.

Smith, W. H. B.
Basic manual of military small arms. Harrisburg, 1945. 351 p.
Covers over 100 foreign and American small arms (pistols, revolvers, rifles, carbines, submachine guns, light machine guns, anti-tank guns, rocket launchers, recoilless rifles). Each described with profuse pictures to illustrate stripping, loading and firing.

Simon, Leslie E.
Report on German scientific establishments. Washington, 1945.
A survey of German military research projects based on investigations by U. S. teams. Includes Hermann Göring Establishment for Ballistics Research and Measurements, Army Artillery Proving Ground, DWM Research Establishment, and others. Illustrated.

Stockbridge, V. D.
Digest of patents relating to breech-loading and magazine small arms (except revolvers) granted in the U. S. from 1836 to 1873, inclusive. Washington, 1874.
Patents classified according to the movement of the principal parts for opening and closing the breech. Drawings for each patent included.

Studler, Rene R.
The aircraft gun problem: Should the rifle or shotgun principle of fire prevail? (In *Ordnance*, Sep–Oct 1952)
Compares use of cal. .50 guns with larger caliber weapons in aircraft as to rate of fire, muzzle velocity and muzzle energy per round.

Tilson, John Q.
Arms, ammunition, airplanes and gas masks. (Speeches delivered in House of Representatives, 65th Congress, 1918) Washington, 1918.
Describes lack of foresight in equipping army at beginning of World War I and program for use of Lewis and Marlin guns in aircraft.

Tombesi, Tito
Armamento aereo. Rome, 1943.
Contains description and characteristics of various Italian aircraft weapons. Illustrated. (In Italian)

Truslow, Neal
The machine gun and its development. (In *Scientific American*, Nov 27, 1915, p. 464)
Summary of development with pictures.

U. S. AEF
Aircraft cannon. Paris, 17 Sep 1918.
So far (1918) only semi-automatic motor cannon has had any use in WW I aircraft. Discussion of French 37 mm automatic cannon, still in production stage.

U. S. AEF
37 mm cannon. 4 Jul 1918.
Contains inclosures: (1) Report of present information available in England with respect to aircraft cannon; (2) Memorandum of conference regarding the status of the different types of 37 mm cannons in France at the present time, Puteaux Arsenal.

U. S. Aeronautical Board
The test and evaluation manual for aircraft guns. Dahlgren, Va., Aug 1947
Manual provides single, uniform method of testing and evaluating aircraft gun-type weapons to provide the best possible index to the effectiveness and characteristics of these weapons when mounted in aircraft and used under all types of service conditions. Techniques of tests and measurements and preparation of reports are covered.

U. S. Army, Air Service. Bureau of Aircraft Production
Handbook of aircraft armament. Washington, 1918.
Section on machine guns (Marlin, Lewis, Vickers) restricted to care and adjustment of machine guns to aircraft installation, with precautions and list of tools. Also sections on yokes, synchronizers, special ammo., small arms. Illustrated.

U. S. General Staff
Selected translations pertaining to the tactical use and value of machine guns. Washington, 1906.
Includes translations of European literature on efficiency and reliability of Maxim gun.

U. S. Marine Corps. Aviation Ordnance School
Aviation ordnance training manual. Quantico, Va., Feb 1943
Section on cannon (20 mm M2 and 37 mm M4). Another on machine guns, cal. .30 and .50. Also small arms and other subjects. Photos and diagrams.

U. S. Military Attaché, London
Aircraft cannon. 11 May 1937
(Report no. 38754)
A summarization of status at time of report of aircraft cannon in various European countries.

U. S. Military Attaché, London
Machine gun developments in Europe. 17 Aug 1927
(Report no. 20156)
Brief comments on trials in Europe of Berthier, Hotchkiss, Knorr-Bremse and Madsen guns. Group of plates illustrating various Madsen guns appended.

U. S. Military Attaché, London
Miscellaneous aircraft armament notes. 28 Dec 1939
(Report no. 40713)
Describes developments re 40 mm aircraft cannon (Vickers), 40 mm aircraft cannon (Rolls Royce), 20 mm cannon (Hispano-Suiza), and .303 aircraft mg (Vickers), all British weapons.
Supplement—MA Report 40672, 6 Feb 1940 (contains additional data)

U. S. Military Attaché, London
Small arms and small arms ammunition. 3 Aug 1929
(Report no. 25633)
Covers ordnance development in England as of 1929 based on visits to armament plants and conversations with military men. Rifles, machine guns, aircraft guns, and ammunition.

U. S. Military Attaché, Paris
Guns for aeroplanes. 20 Dec 1921.
(Report no. 4861–W)
Gives status concerning materiel for armament of airplanes in France at time.

U. S. Military Attaché, Paris
Italian trials of 50 caliber guns. 5 Nov 1928.
(Report no. 14309–W)
In trials of 4 anti-aircraft guns, Hotchkiss 13.2 mm gun obtained best record for continuous hot barrel accuracy. Others were Fiat, Vickers and Browning.

U. S. Military Attaché, Rome
New Italian aeronautical 20 mm guns. 29 Jul 1937
(Report no. 16140)
Interest started in 20 mm guns after abandoning 12.7 mm explosive bullet (forbidden by international agreement). Experimental models being made by Breda and Isotta-Fraschini. No airplanes yet armed with them.

U. S. Military Attaché, Rome
Italian developments in field of machine guns. 12 Jan 1927
(Report no. 10147)
Brief survey of status of development in Italy as of date of report. Appendices are translations of (1) description of Fiat Machine Gun, Model 1926 (cal. 6.5) and (2) description of Fiat 25 mm anti-aircraft machine gun, designed by Revelli. Photos of Model 1926 gun.

U. S. Military Attaché, Valencia, Spain
Machine guns and ammunition. 13 Mar 1937
(Report no. 6400)
Describes armament used by various forces in Spanish Civil War—Russian and Italian planes.

U. S. Naval Liaison Office, Colombo, Ceylon
Japan—aviation guns and ammunition. 18 Oct 1943.
Contains copies of evaluation reports on (1) Japanese 7.92 mm recoil operated, trigger fired, magazine fed air-cooled machine gun (type 98); (2) Japanese 20 mm aircraft cannon ammunition; (3) Japanese type 89 "Kai Tan" 7.7 mm machine gun; (4) Japanese type 89 Mk II 7.7 mm air-cooled mg; (5) Japanese 12.7 mm (Browning type m. g.) (6) Japanese Taisho 11 6.5 mm mg.
Markings included with descriptions and evaluations.

U. S. Navy Department
Report of the Secretary of the Navy, 1894.
(p. 360–84) Report of board appointed for trial of machine guns. Tested: Gatling, Accles, Gardner, Robertson, Maxim Nordenfelt, and Skoda. Majority selected Maxim Nordenfelt; minority report for Gatling.

U. S. Ordnance Dept.
History of machine guns and automatic rifles. Washington, 1922. 64 p.
Contains statistics on weapons available at beginning of World War I. History of Hotchkiss, Chauchat, Colt, Vickers, Lewis, Browning, Marlin and others. Statistics on production during WW I. Illustrated.

U. S. Ordnance Dept. Artillery Div. Industrial Service
Aircraft cannon. Volume 1. Nov. 1944.
Vol. 1 covers M1 and AN–M2 20 mm gun and T31 20 mm gun. Contains general background, procurement and production of guns and related components, and engineering. References included to document text (copies of each attached). 13 photos of Hispano installations; also pictures of T31.

U. S. Ordnance Dept.
All present available data on various types of German machine guns. July 1918.
Compiled by Lt. H. D. Parker. Includes descriptions of light Maxim 1908–15 and Parabellum machine guns.

U. S. Ordnance Dept.
Antiaircraft materiel for machine guns; service handbook. Washington, 1920.
Has pictures of Browning and Lewis guns used as AA.

U. S. Ordnance Dept.
Catalog of enemy ordnance materiel. 1945.
In 2 volumes—I. German section; II. Japanese section. Each section includes tank and motor vehicles, artillery, small arms aircraft armament, ammunition—rockets. Also covers Japanese markings. Page for each item with photo, specifications and description.

U. S. Ordnance Dept.
Handbook of ordnance data. Washington, 1919.
Contains chapter on aircraft armament of U. S. and allies in WW I. Guns, synchronizers, mounts, sights.

U. S. Ordnance Dept.
Japan—Light and heavy machine guns. 9 Sep 1941.
Gives data on characteristics of 4 Jap light machine guns and 2 heavy guns.

U. S. Ordnance Dept.
Notes made at the War College concerning machine guns of various countries. Washington, 1915.
Information arranged according to country, with description of each weapon, then organization and tactical use.

U. S. Ordnance Dept.
Report of the Chief of Ordnance, 1904–05.
Appendix I: "Report of board on test of automatic guns." Assembled at Springfield Armory, 20 Aug 1903, followed by tests at Fort Riley, Kansas. Guns tested: Danish (Madsen), Colt and Vickers. Recommendation that Vickers standard pattern gun be adopted. Tests described, with descriptions and pictures of guns. Madsen gun failed in feed mechanism.

U. S. Ordnance Dept.
Research, development and production of small arms and aircraft armament of the Japanese Army. Tokyo, 1946.
(Ordnance technical intelligence report no. 19)
Reviews research and development on small arms and automatic cannon from 1938 to 1945, describes government proving grounds and arsenals and armament factories during war. Many photographs.

U. S. Ord. Dept. Small Arms Development Branch
Aircraft weapon characteristics. 1 Dec 1947.
Tabulation of German, Russian, U. K., and Swiss weapons, giving characteristics.

U. S. Patent Office
Specifications and drawings of patents for machine guns issued from the United States Patent Office prior to January 1, 1882. Washington, 1882.
Numerical and alphabetical lists, followed by patents themselves.

U. S. War Dept.
Report of Board of Officers convened by War Department Special Orders No. 37–0, 50–0, 78–0 and 79–0, Feb 1920–Apr 1920.
Meeting called to consider development of aircraft machine guns and aircraft cannon. Considered present types of guns with recommendations for future use (Marlin, Vickers, Browning, Lewis). On Browning guns, list of changes to correct present defects (1920) is given. Specifications for aircraft cannon are outlined.

Wharton, James E., and others
Machine gunner's pocket manual; a reference text for officers and enlisted men of machine gun companies in the field. 1931.

Whitehouse, Arch
Twenty years of guns in the sky. (In *Popular Aviation*, Feb 1938, p. 10)
Story of aircraft guns from Strange & Gaskell (Aug 1914) who first fired Lewis gun from air in combat to 1938. Author finds no great advance over WW I. Illustrated.

Wilhelm, Glenn P.
Machine gun cannon, the disadvantages of increased calibers. (In *Army Ordnance*, Mar–Apr 1934, p. 279).
Compares characteristics of cannon of different calibers. Illustrated.

Wimmersperg, Heinrich
Fixed barrel automatic firearms. (In *Army Ordnance*, Jul–Aug 1936, p. 18)
Most principles developed before turn of century. Article presents several little-known systems of technical and historical interest, including Paulson (1886) (gas operated pistol), Schwarzlose (1913), Mannlicher (1893), Sjogren (1900) and Puff (1903). Diagrams compare their systems with recent weapons of Pedersen, Scotti, Heinemann, Mauser, Gerlich and Simson.

Winston, Robert A.
Fixed guns vs. free (In *Popular Aviation*, Jan 1941, p. 16)
Shows value of fixed guns in fighter planes. Illustrated.

Section II—Individual Weapons

American Armament

American Armament Corp.
The AAC 37 mm aircraft cannon. N. Y., Dec 1936
Brochure on Type M (movable) and Type F (fixed) 37 mm aircraft guns. Specifications, description and illustrations of guns are included.

American Armament Corp.
37 mm aircraft gun. N. Y., n. d.
Description and photographs of gun, with operating instructions.

Artillery for the air (In *The Aeroplane*, Mar 29, 1939, p. 402)
Describes American Armament Corporation 37 mm cannon, being peddled in England. Illustrated.

Sagendorph, Kent
Tactical aspect of flexible airplane cannon. (In *U. S. Air Services*, Jan 1941, p. 15)
Gives specifications and features of American Armament turret 37 mm cannon for aircraft. Illustrated with drawings.

B. S. A.

B. S. A. Guns, Ltd.
B. S. A. automatic and semi-automatic machine gun, calibre .5 inch (12.7 mm) Birmingham, 1928.
Descriptive pamphlet with specifications, operation, components, drawings and tables.

Bailey

U. S. Navy Yard, Washington, D. C.
Letter reporting on examination and trial of the Bailey machine gun, dated Feb 11, 1876.
Written by Comdr. Picard, inspector of ordnance. Contains illustrations of weapon. Performance very satisfactory.

Baldwin

U. S. Bureau of Aircraft Production
Report of firing tests of Baldwin 37 mm automatic semi-flexible aircraft cannon. Dayton, O., 1919.
(Cannon test no. 10)
Illustrated.

U. S. Bureau of Aircraft Production
Report of flight test of 37 mm Baldwin gun mounted in Glenn L. Martin gunnery ship. Dayton, O., 1919.
(Cannon test no. 3)
Object to determine effect on the ship of firing gun in air. Results almost negligible. Illustrations.

U. S. Bureau of Aircraft Production
Report on test of 37 mm Baldwin gun mount in the Glenn L. Martin gunnery ship. Dayton, 1919.
(Cannon test no. 2)
Tests showed mount was strong enough to resist force of recoil of cannon. Illustrated.

Beardmore-Farquhar

The Beardmore-Farquhar light machine gun. 1919.
Contains description and operating procedure. Attached is a British report (Grain (Armament) Report no. 123, Oct 1, 1919) on firing trials of the gun at high altitudes. Compared favorably with Lewis gun in every respect.

Test of Beardmore-Farquhar light machine gun. 15 Aug 1919 (?)
Report of British test of gun which does not greatly impress the observer.

U. S. Military Attaché, London
Beardmore-Farquhar machine gun. 16 Aug 1919.
(Report no. 8020)
Includes clipping from *The Times*, 15 Aug 1919 "New machine gun. Favorable tests at Bisley."

Becker

France. Ministry of War
Trials of the German Becker 2 cm gun. 20 Jan 1920.
(Note no. 32A)
Translation of description of trials of weapon at Puteaux Arsenal in 1919.

U. S. AEF
K. Bechèr automatic aircraft cannon (German) 2 Aug 1918.
Description of German 20 mm cannon shot down in combat. 6 photos and cycle of operation.

Beresin

USSR Air Forces
Universal machine gun UB, caliber 12.7 mm; description of construction and use. Moscow, 1941.
(ID translation)
Translated from German. Describes construction, arrangement and functioning, assembly and disassembly, operation of Beresin aircraft guns (UBS-synchronized) (UBK-airfoil) (UBT circular track).

Bergmann

U. S. War Dept.
Summary report on Bergmann machine gun, mod. 1915 n.A. and Dreyse machine gun. 1 Apr 1919.
(Summary report no. 197)
Characteristics and description of two captured German guns. Exterior and components are illustrated.

Bofors

Aktiebolaget Bofors.
The Bofors concern. Stockholm, 1947.
Brochure giving history and products of this armament plant. Photos and plates of plant and weapons.

Aktiebolaget Bofors
25 mm automatic gun L/64. Bofors, Sweden, 1939.
Characteristics and data on a/a gun. Photos.

Aktiebolaget Bofors
40 mm automatic naval gun L/60. n. d.
Brochure giving characteristics and data on 40 mm Bofors, with drawings of weapon.

AB Bofors, Stockholm, Sweden
20 mm automatic aeroplane gun, L/70. 1953.
(NA Stockholm Report 72–53)
Pamphlet inclosed with NA Report. Completely mechanical loading system. Normal rate of fire is 750 rpm. Designed for band feeding with de-banding during operation. Photograph, detailed drawing and description of HE 20 mm shell.

U. S. Bureau of Ordnance
40 mm. A.A. gun production—History of. 19 Nov 1945.
(Memorandum for files)
Details of negotiations and production of Bofors 40 mm anti-aircraft guns.

U. S. Bureau of Ordnance
40 mm Bofors gun. 1945.
History of negotiations for Bofors 40 mm a/a gun by U. S. Navy, its adoption and production in the U. S. during World War II. Complications of contract are described. Section on use and performance. Appendix contains 1940 contract and manufacturing rights data.

U. S. Military Attaché, Stockholm, Sweden
Bofors 20 mm anti-aircraft and anti-tank gun. 10 Jun 1940.
(Report no. 1293)
General description of gun and 4 types of mounts.

Breda

Aberdeen Proving Ground
First report on Italian gun, medium machine (A. F. W.) 8 mm (0.3150 inch) Model 38, Breda and 16th report on Ordnance program no. 5826. 16 Apr 1943.
Air cooled, gas operated, magazine feed with quick change barrel. "Nothing outstanding or new about the gun." Illustrated.

Germany. Luftwaffe
7.7 mm mg und 12.7 mm mg (Ital.) Breda "Safat" Berlin, 1944.
Description, operation and maintenance. Illustrated. (In German)

Societa Italiana Ernesto Breda
Breda anti-aircraft and anti-tank machine gun caliber 20 mm. 1934.
Description, functioning, mounting, numerical data, ammunition and illustrations.

Societa Italiana Ernesto Breda
"Breda" light mitrailleuse. n. d.
Description and operation of light Breda machine gun, which will be transportable and workable by one man. Illustrated.

U. S. Military Attaché, Rome
The Breda 37 machine gun. 28 Dec 1938
(Report no. 16,892)
Data and description of 8 mm gun.

Brixia

Brescia Metallurgical Works
1920 model automatic "Brixia" machine gun. Brescia, Italy, 1920.
Translation of handbook for this weapon. Illustrated.

Browning

Aberdeen Proving Ground
Data on Japanese aircraft machine guns, 12.7 mm (fixed mount) (Browning type) 31 Jul 1943
(O. P. no. 5826)
Description and pertinent data on gun from Japanese bomber. Photos of weapon and components.

Allen, Henry B.
The caliber .50 machine gun—its conception. (In *Army Ordnance,* Mar–Apr 1945, p. 271)
Personal story of examination of Hotchkiss ½-inch gun being tested secretly by French in 1917, which led to its being sent to U. S. for tests which resulted in request for similar weapon with higher velocity—the Browning cal. .50.

Application of Browning gun to airplanes. (In *Scientific American,* Aug 3, 1918, p. 100)
Describes tests of heavy Browning, with water jacket removed, as synchronized aircraft gun.

Boeing Aircraft Co.
Study of modified cal. .50 machine gun. 28 Aug 1945. (Report no. D-7145)
Proposes modification of Browning M-2 cal. .50 gun with the view in mind of providing a more compact and generally satisfactory weapon, specifically for aircraft work. Drawings and photos.

Bond, P. S.
Rifle company weapons: The light machine gun; the 60 mm mortar. Washington, 1941.
Covers training, drill marksmanship and technique of fire for Browning light cal. .30 mg, M1919A4. Illustrated.

Browning Arms Co.
Browning guns and other Browning products.
(Catalog no. 53)
Contains pictures of founders of firm, biographical sketch of J. M. Browning, and plate showing all of Browning weapons.

Browning, J. M. & M. S., Co.
A history of Browning guns from 1831. Ogden, Utah, 1942.
Illustrated.

Chinn, George M.
Assembly and maintenance of the caliber .50 Browning aircraft machine gun. 1944.
Prepared to acquaint the ordnance man in the proper use of the field gages for the assembly and maintenance of the cal. .50 gun. Field kit is manufactured by A. & R. Shop, NAS, San Diego, Cal., and contains minimum number of gages necessary to insure optimum performance in the field. Illustrated.

The Colt automatic gun. (In *Scientific American Suppl.*, Feb 8, 1896, p. 16770)
Has picture of mounting on horse-drawn police patrol wagon. Describes weapon recently adopted by Navy.

The Colt automatic gun. (In *Scientific American*, Aug 19, 1905, p. 140)
Illustrations and description of gun.

Estep, Edwin R.
From front page to front trench. (In *Leslie's*, Jun 8, 1918, p. 796)
Describes success of Browning machine guns with American troops. Illustrated.

General Motors Corp., AC & Frigidaire Divs.
How the gun works: Caliber .50, M2 Browning machine gun. 1943.
(Desk chart FGD)
Set of charts showing graphic operation of M2 cal. .50 gun.

General Motors Corp., AC & Frigidaire Divs.
Training manual, caliber .50, M2 Browning machine gun. Jan 1944.
Manual is devoted principally to the aircraft basic gun. Includes description, specifications, functions, assembly, headspace, maintenance, malfunction analyzer, ammunition, parts list, etc. Many illustrations of components with disassembled chart of complete gun.

General Motors Corp., Frigidaire Div.
Notes on materiel for T25E3 machine gun, caliber .50. 31 Jan 1945.
Deals with changes incorporated in T25E3 as compared with M2 Browning, cal. .50. Increased belt pull, improved feeding and elimination of oil buffer, in addition to increased rate of fire. Photos of weapon and its components.

Green, Samuel G.
Notes on development of Browning machine guns. 25 Aug 1950.
Story of development of cal. .30 and .50 Browning guns in period from 1918 to 1933, particularly the part played by Springfield Armory and Dr. Green.

Grenell, L. H. and others
Progress report on examination of enemy materiel: Metallurgical examination of a Japanese aircraft 20 mm "Browning type" machine gun. 19 Jun 1945.
(OSRD 5228)
Contains details of fabrication, material, treatment and workmanship on weapon taken in China from Jap "Frank" plane. Photos and tables.

Lescarboura, Austin C.
Machine guns by the thousands. (In *Scientific American*, Jan 23, 1917, p. 62-63)
Describes organization and production of Marlin-Rockwell during WW I to produce Colt-Marlin gun. Illustrated.

Mitchell, John B.
Browning—"Gun man" for U. S. (In *Forum*, 1918, p. 545-555)
Contains biographical details. Illustrated.

Preliminary facts concerning the Browning guns. (In *Scientific American*, Mar 9, 1918, p. 1)
Early report on BAR and water-cooled heavy gun. Illustrated.

Rock Island Arsenal
Notes on the 37 mm automatic gun, T5. 1937.
The T5 gun is an experimental design to determine military characteristics of automatic cannon. Based on Browning principle. Contains description, tabulated data, carriage, gun assembly and recoil mechanism, feed mechanism, firing mechanism, etc. Many detailed illustrations.

Rock Island Arsenal
Notes on the 37 mm Browning automatic gun T9. 1939.
Contains illustrations of gun, link belts, and magazines. Notes cover construction and operation of Browning antiaircraft weapon.

Samoyoa, Francisco
Reglamento tactico de ametralladoras y fusil ametrallador. Guatamala, 1944.
Describes Browning-Colt .30 cal., Model 1942. (In Spanish) Illustrated.

Springfield Armory
Report on test of Browning machine gun and Browning automatic rifle, barrels rifled with an accelerated twist. 12 Jan 1922.
Performance not as satisfactory as uniform twist rifling now used in service barrels. Photos of barrels and bullets included.

Studler, René R.
A new aircraft machine gun; the M3 weapon increases aerial firepower fifty per cent. (In *Army Ordnance*, Mar-Apr 1946, p. 186)
Outstanding special components are described. Photo.

U. S. AEF, Chief Ordnance Officer
Defective material and breakages in Browning machine guns and rifles. 25 Aug 1918.
Report of defects found by 79th Division ordnance personnel in Browning weapons. Soft bolt lock shoulders and leakage of water jackets especially noted.

USN Aviation Training Division
Aircrewman's gunnery manual. 1944.
(OPNAV 33–40; NAVAER 00–80S–40)
Manual for training of aerial gunners. Instructions on Browning cal. .50 gun M2, sights and sighting, and turrets. Detailed illustrations.

U. S. Ordnance Dept.
Gun, automatic, 37 mm, M4. Base shop data. Rock Island Arsenal, 1944.
Diagrams included.

U. S. Ordnance Dept.
Handbook of the Colt automatic machine gun, cal. .30. Washington, 1917.
Illustrated.

U. S. Ordnance Dept.
Handbook of the Colt machine gun, model of 1917, cal. .30. Washington, 1917.
Illustrated.

U. S. Ordnance Dept.
Instruction charts for gun, machine, cal. .30, Browning, M1. Aircraft, fixed and flexible. Washington, 1935.
Diagrams of weapon and components, including sectionalized drawings.

U. S. Ordnance Dept.
Report of the Chief of Ordnance, 1895–96.
p. 75, Appendix 3. Test of Colt automatic single-barrel machine gun, caliber .30, at the Springfield Armory, Mass. on 26 Apr 1895, and following days. Decision—not suitable for ordinary service and has no place in land armament. Description and pictures of weapon.

U. S. Ordnance Dept.
Report of the Chief of Ordnance, 1899–1900
Appendix 13 (p. 147–64) Report of board of officers on test of Colt automatic gun. Tests started 1 Nov 1899. The board found the Colt automatic gun, cal. .30, model 1899, suitable for the service. Illustrated. Detailed description.

U. S. War Dept.
Basic field manual. Browning automatic rifle, caliber .30, M1918A2. Jun 1943.
(FM 23–15)
Deals with training marksmanship and technique of fire of BAR. Contains diagrams.

U. S. War Dept.
Report of board of officers convened by War Dept. Special Orders no. 37–0, 50–0, 78–0 and 79–0. Feb–Apr 1920.
Meeting called to consider development of aircraft machine guns and aircraft cannon. On Browning guns, a list of changes to correct present defects is given. Specifications for aircraft cannon are outlined.

Carr

U. S. Naval Proving Ground, Indian Head, Md.
Report on partial test of Carr machine gun. 18 Jul 1901.
Describes weapon and results of test, marred by splitting of cartridge cases.

Chatellerault

France, Ministry of War
Report on comparative tests of automatic rifles. 20 Feb 1924.
Tests made in 1923 on Berthier, Browning, St. Etienne, Hotchkiss, Madsen and Chatellerault. Decision: adopt Chatellerault. Drawings and tables.

U. S. Military Attaché, Paris
Chatellerault machine gun. 7 Nov 1928
(Report No. 14,320–W)
Describes development and present status of weapon (1928) including its failure in trials in Yugoslavia and Roumania.

U. S. Military Attaché, Paris
Chatellerault machine gun. 8 Apr 1940.
(Report no. 25,620–W)
Describes light machine gun, M1924/29; Tank, armored car and fortress machine gun M1931; Aircraft machine gun, M1934. Special mention made of coiled spring made of three lengths of piano wire twisted together—attributed to Russians.

Chauchat

France, Ministry of War
Instruction provisoire du 1 Feb 1916 sur le fusil mitrailleur, modele 1916. Paris, 1922.
Illustrated manual on Chauchat gun. (In French)

Corsini

Corsini, A.
Report on the "Corsini" automatic machine gun. 2 Feb 1922.
Translation of Italian manual describing Corsini mg, Model 1921. Inventor claims weapon can be fired without appearance of either flash or detonation. Operates by gear; no recoil.

Darne

Darne Co. (Etablissements Darne)
Darne machine guns for aircraft, infantry, cavalry, tanks, anti-aircraft service, etc. St. Etienne, France, n. d.
Brochure on various models of Darne machine guns. Photographs of weapons.

Darne Co.
Historique de la creation de la mitrailleuse systeme Darne. St. Etienne, n. d.
(In French) Contains photos of weapons.

Darne Co.
Provisional manual for the use of the new Darne airplane machine guns, model for turret or wing of airplane and model synchronized for fire through the propeller. St. Etienne, France, 1925.
1925 types are described with operating instructions, assembly and disassembly.

Klaguine, A.
Résumé of the advantages offered by the "Darne" aviation arms. Paris, n. d.
Weapon is compared with Gast, Lewis and Vickers guns for aircraft use.

U. S. Military Attaché, Paris
Darne aircraft and land machine guns. 28 Mar 1929
(Report no. 14,860–W)
Characteristics and brief descriptions of weapons. (Supplemental information given in MA Paris Report 14,960–W 25 Apr 1929, and Report 15,389–W, 30 Aug 1929)

Davis

Crossman, Edward C.
A gun without a "kick". (In *Popular Science* monthly, vol. 90, 1917, p. 532)
Description of Commander Cleland Davis's recoilless aircraft cannon. Illustrated.

The nonrecoil gun. (In *Scientific American Suppl.*, Apr 21, 1917, p. 252)
Possibilities of the gun mounted on aircraft are discussed. Size varies from small to 3-inch bore. Illustrated.

Degtyarev

U. S. Military Attaché, Helsinki, Finland
Degtyarev 7.62 mm LMG model 38. 26 Feb 1941.
(Report no. 289)
Brief description of gun and its action.

U. S. Military Attaché, Riga, Latvia
Degtyarev light machine gun. 23 Dec 1933.
(Report no. 8579)
Based on official manual of Estonian general staff. General data, description, operation, etc. of 7.62 mm light Russian gun. Contains pictures.

U. S. Military Attaché, Riga, Latvia
Organizational equipment: Degtyarev light machine gun. 23 Dec 1933.
(Report no. 8579)
Contains general data, description and usage. Drawings and photo.

U. S. Ordnance Corps.
Users' guide for Soviet light machine guns (Degtyarev type) Oct 1950.
(STF 9–206–1)
Brief description of Degtyarev type guns (DP, DPM, Company, DT and DTM), ammunition and instructions for maintenance in the field. Photos of guns and components.

U. S. Theatre Service Forces European Theater
Russian Degtyarev heavy machine gun, cal. 7.62 mm, model 1939. 4 Aug 1945.
(ET Ordnance Technical Intelligence Report no. 379)
Detailed description, functioning of weapon. Photos show gun assembled and disassembled.

USSR. Armed Forces
7.62 mm light machine guns DP and DPM. 1940.
(ID Translation 588934)
Translated from Russian manual. Contains tactical and technical characteristics of 2 guns, description, components, operation, assembly, correction of stoppages, cartridges, and storage.

USSR. Narodn'yi Komyssaryat Oboron'i
Nastavlenie po strelkovomu delu (NSD–38) Ruchnoi pulemet D1. Moscow, 1941.
Manual on Degtyarev. Illustrated (In Russian)

Dreyse

Portugal. Ministry of War
Instruçoes para o uso da metralhadora llgeria Dreyse 7 mm, 9m/938. 1941.
Instruction book (In Portuguese) on Dreyse gun. With diagrams.

Rheinische Metallwaaren-u. Maschinenfabrik, Dusseldorf
Machine gun "Dreyse"—short description. n. d.
Brief summary of features of gun and principles underlying it. Drawings and photographs.

U. S. A. E. F.
Report on Dreyse machine gun, giving description and action. 27 Feb 1919.
Contains translation of German pamphlet "Leitfaden für das Dreyse M. G." giving nomenclature, action, description of weapon and its parts.

U. S. Military Attaché, Berlin
The light machine gun 13 (Dreyse) 30 Oct 1935.
(Report no. 14,356)
Operation shown by means of series of photos. Diagrams show tactical use.

U. S. War Dept.
Summary report on Bergmann machine gun, mod. 1915 n. A. and Dreyse machine gun. 1 Apr 1919.
(Summary report no. 197)
Characteristics and description of two captured German guns. Exterior and components illustrated.

Fiat

U. S. Military Attaché, Rome
Equipment, general, Fiat machine gun. 9 Jun 1928.
(Report #L. 11064)
Summarizes data on SAFAT light machine gun, Fiat light mg—Model 1928, Fiat 12 mm anti-aircraft mg, and Fiat aircraft mg—model 1928–A.

U. S. Military Attaché, Rome
Italian developments in field of machine guns. 12 Jan 1927.
(Report no. 10147)
Contains translation of description of Fiat Machine Gun, Model 1926 (cal. 6.5 mm) and description of Fiat 25 mm a/a machine gun designed by Revelli. Photos of Model 1926 gun.

Furrer

Mariotti, Carlo
Unser leichtes maschinengewehr (L. M. G. 25) Bern, 1942. 36 p.
Manual on Swiss LMG 25 (Furrer) 7.45 mm. (In German)

U. S. Military Attaché, Berlin
Data for Ordnance Dept. 22 Mar 1933.
(M. I. D. 2296–367/8)
Inclosures: Data for light machine gun model 1925 (Swiss Furrer) with photographs.

U. S. Military Attaché, Bern
Intermediate caliber automatic cannon. 23 Feb 1939.
(Report no. S–2)
Reports on new Swiss 20 mm Furrer cannon under development for aircraft.

U. S. Military Attaché, London
Furrer machine gun. 15 Feb 1928.
(Report no. 21202)
Describes production and performance.

Walker, Otto
Patent application for machine gun. May 1924.
Light machine gun (Swiss) related to Furrer gun.

Gardner

Farley, J. P.
Report on the Gardner gun to Commanding Officer, National Armory. Nov 5, 1875.
Examination and firing done at Pratt and Whitney plant.

Gardner, W.
Machine guns and how to use them. Washington, 1882. (Ordnance Notes- No. 198)
Reprint from the *Journal of the Royal United Service Institution.*

The Gardner machine gun. (In *Scientific American Suppl.*, Jul 8, 1882, p. 5415–16)
Describes weapons adopted by British navy, with diagrams.

The Gardner machine gun. (In *Scientific American Suppl.*, Apr 19, 1884, p. 6905)
Illustrates single, 2 and 5 barrel Gardners.

Gt. Brit. Admiralty
Handbook for the 0.45″ Gardner gun (2 barrels) London, 1894.
Illustrated.

Kimball, W. N.
The improved Gardner machine gun: Rules for operating, dismounting and shifting the piece. Aug. 1881.
Manuscript copy prepared by Naval inspector at Pratt and Whitney plant.

Pratt & Whitney Co.
The improved Gardner machine gun, for service ashore and afloat; history of the invention, description of the gun, official reports of recent trials, general description, etc. Hartford, n. d.
Reports successful tests in 1879 and 1880 by Navy.

U. S. Navy Yard, Washington, D. C.
Report of board convened to conduct experiments with Gardner machine gun and cartridges. Jun 24, 1879.
Description and drawings show changes and improvements over previous gun model. Appendix has firing record.

U. S. Ordnance Dept.
Gardner machine gun. Washington, Mar 17, 1880. (Ordnance notes no. 124)
Report of trial of Gardner gun by ordnance board. Purchase of a limited number recommended. Drawings and target records.

U. S. Navy Yard, Washington, D. C.
Report on trial of Gardner machine gun. Nov 17, 1876.
Contains drawings. Prepared by Lt. Comdr. Crowninshield and Lts. Stone and Buckingham. Tabulations show record of firing.

Gast

Gast machine gun. 1922.
Description and illustration of weapon, together with translations of correspondence of German army officials at end of WW I and later on procurement and effectiveness of weapon.

Gatling

The Gatling gun. (In *Scientific American Suppl.*, Jun
The Gatling gun. Its positive feed: high angle fire and use in war. n. d.
Brochure with illustrations.

The Gatling gun. (In *Scientific American Suppl.*, Jun 7, 1884, p. 7022–23)
Describes latest Gatling gun with 6, 8 and 10 barrels. Illustrated.

Gatling Gun Co.
The Gatling gun; official reports of trials, description, general directions, targets, etc. Hartford, 1878.
Illustrated.

Gatling's battery gun: manufactured by Colt's Firearms Manufacturing Co., with official reports, official target records of the U. S. A. Ordnance Department, recommendations, description, etc. Hartford, 1867.
Illustrated.

Hopkins, Owen J.
Drill manual for the Gatling gun. Columbus, O., 1900.
Illustrated manual.

Marvin, J. D.
Gatling guns; instructions for use and care of. Washington, 1875.

Norton, Charles B.
American breech-loading small arms: a description of late inventions, including the Gatling gun and a chapter on cartridges. N. Y., 1872.
Includes picture of Gatling camel gun and detailed early history of Gatling guns. Many pictures.

Norton, Charles B.
American inventions and improvements in breech-loading, small arms, heavy ordnance, machine guns, . . ., etc. Boston, 1882.
In Chapter X—details and illustrations on Gatling gun tests and correspondence. Includes picture of packhorse mounting.

Parker, John H.
History of the Gatling gun detachment, 5th Army Corps, at Santiago. Kansas City, 1899.
Contains picture of battery of Gatlings at Baiquiri before starting to front. Author is famed "Gatling Gun" Parker.

Report on Gatling gun, May 30, 1868.
Board of Naval officers reporting to Hon. Gideon Welles, Secretary of the Navy, declares the weapon "has no known superior" for special service on vessels of war. Targets included.

Springfield Armory
Rules for the inspection of Gatling guns in detail. Springfield, 1875. Illustrated.

U. S. Adjutant General's Office
Description and service of machine guns used in The United States Army. Washington, 1896. (Artillery Circular K)
Lists Gatling guns in service in 1896.

U. S. Navy Yard, Washington, D. C.
Report of trial of Gatling's gun or battery, May 20, 1863.
Manuscript report of trial of Rear Adm. John A. Dahlgren by Lt. Comdr. Jos. S. Sherrett. Gun stood limited test admirably.

U. S. Ordnance Dept.
Report of the board of officers . . . on Gatling guns of large caliber for flank defense. Washington, 1874. (Ordnance memorandum no. 17) Illustrations.

U. S. Ordnance Dept.
Report of the Chief of Ordnance, 1896–97.
Appendix 2, nomenclature and description of the Gatling gun, caliber .30, model 1895. (p. 61–72) With sketches and diagrams.

Gazda

Aberdeen Proving Ground
Test of 20 mm Gazda gun. March 1944.
(Memorandum reports 1–4)
Results of firing of first 389 rounds are given. Interlock assembly failed to function after 125 rounds. Other malfunctions occurred. Second test—5–9 March 1944. Malfunctions again occurred. Third test—10–13 March 1944. Hammer broke during test. Gun withdrawn by inventor. Ballistic results of tests are given.

Gazda, Antoine
Airpower only through firepower. (From *Minuteman,* Sep 21, 1943)
Wants bombers equipped with 20- and 23-mm cannon as protection against enemy fighters. Photo.

Gazda Engineering
"Gazda" system 4-stroke flywheel-inertia locked automatic cannon far aircraft. Providence, R. I., n. d.
Weapon is compared with 20-mm Hispano automatic cannon by means of drawings. Chief difference is in the breech closing. Gazda system is characterized by flywheel inertia locking and pre-percussion. Illustrated.

Gazda Engineering
The "Gazda" 20 mm 23 mm automatic antiaircraft cannon. n. d.
Weapon compared with Oerlikon gun. Drawings showing weapon and components, also four stroke action.

New Oerlikon-Gazda cannon mechanical miracle of war. (In *Minute Man,* 10 Aug 1943)
Describes Gazda's career and establishment of plant in New England. Photos.

Goryunov

The Soviet 7.62 mm heavy machine gun, Model 1943, Goryunov. (Translated from Soviet document "Infantry weapons and equipment, Book 2", Moscow, 1946, pp. 766–776)
(ID No. 633680)
Ordnance Intelligence translation. Contains principles of operation. Drawings of gun and components.

USSR
Nastavlenie po strelkovomu delu—Stankovyi pulemet sistemy Goryunova. (Small arms manual—machine gun system Goryunov, model 1943) 1946.
(ID Translation 1141257)
Ordnance Intelligence translation. Covers construction, operation, stoppages, maintenance, rules of fire, etc. for Goryunov heavy machine gun.

Hispano-Suiza

Aberdeen Proving Ground
86th partial report on functioning and mechanical test of machine guns and machine gun accessories and 1st partial report on test of Hispano-Suiza 20 mm automatic cannon, type 404, Birkigt patents. 1938.
Illustrated. Tested Jun 21 to Aug 5, 1938.

De Moyer, Robert
20-mm automatic guns and materiel: Record of Army Ordnance research and development. Dec 1945.
Record of adoption, modification and development of Hispano-Suiza by U. S. since 1940, and its components. 122 illustrations from official sources, including components and accessories. Data on M1 and AN–M2 guns. (Bibliography at end of each chapter.)

Foreign Ordnance Receiving Depot, Naval Powder Factory, Indian Head
Preliminary report on Gun, Machine, aircraft, 20 mm Hispano-Suiza—Italian. 1945.
Almost identical with U. S. AN–M2 cannon. Illustrated.

Hispano-Suiza S. A. Geneva, Switzerland
Canons automatiques de DCA., armement de bord pour avions, marine, etc., armes automatiques d'infanterie, munitions. Geneva, n. d.
Photographs and descriptions (In English) of Type 804 H-S AA cannon 20 mm, Type 626 mounting for AA cannon, magazine type 804 (drum type), triple mounting type 630–3, type 804 aircraft cannon, belt feed mechanism, twin magazine type 504, type 830 30 mm AA cannon, firing tests and ammunition. Many photos.

Hispano-Suiza (Suisse) S. A., Geneva
Canons automatiques de DCA, armement de bord pour avions, marine, etc., armes automatiques d'infanterie, munitions. Geneva.
Illustrated catalog and description of armament made by Hispano-Suiza. (In French)

Hispano-Suiza (Suisse) S. A., Geneva
30 mm automatic gun, type HSS 825.
Manual on aircraft gun which can be equipped with a 30 or 20 mm barrel and will function for either caliber without alteration. Rate of fire 1000 rpm. Photos and diagrams.

Hispano-Suiza (Suisse) S. A., Geneva
20 and 30 mm cannons for AA and infantry. Types HSS 804 and 831. 1953.
Description and illustrations of subject cannon.

Miller, W. E.
Antique and veteran. (In *Road and Track,* Jun 1950, p. 30)
Contains description of origin of Hispano-Suiza name.

Les moteurs-canons Hispano-Suiza. (In *Revue de l'Armée de l'air,* 7th year, 2nd vol., 1935, p. 827)
Review and analysis of Birkigt patents 771,806, 771,807, 771,808, 773,040, 778,335, all French patents. (In French)

Société Francaise Hispano-Suiza
Notice sommaire sur le canon Hispano-Suiza type 404. 1937.
(In French) Includes data, operation and precautions.

U. S. Army
Gun, automatic, 20 mm, M1 and M2. (U. S. Army Specification No. 51–12–48A, 5 Jan 1942)
With Amendment 4, 31 Jan 1944.

U. S. Bureau of Ordnance
"Ordwell" Ordnance, his story. All weather doctrine for operation and maintenance of the 20 mm aircraft machine gun M3. 21 Sep 1951.
(OP 1910)
Compilation of latest techniques and procedures as determined through service usage for maintenance of M3 (Hispano) under all weather conditions. Illustrated.

U. S. Bureau of Ordnance
20 mm aircraft gun and accessories. 3 Nov 1941.
(F41-1(HG))
A review of the status of the subject gun and accessories as of 3 Nov 1941. Covers feeds, trigger controls, chargers, etc.

U. S. Bureau of Ordnance, Mn6
20 mm M-2 automatic guns, technical data on. Memorandum dated 4 Jun 1942.
Includes technical data based on GM (Oldsmobile Div.) engineering records, problems encountered in servicing the M-2 automatic guns, and 4 failure reports.

U. S. Dept of the Army
List of all parts of gun, automatic, 20 mm, AN-M2 and M3. Jan 1948.
(ORD 9 SNL A-47)
Alphabetical list of all parts required to make a complete weapon. Exploded views are included.

U. S. Military Attache, London
Aircraft cannon effectiveness. Aug 27, 1940.
(Report no. 41546)
At time 20 mm Hispano-Suiza cannon had not shown superiority in effectiveness over Browning .303 machine guns.

U. S. Military Attaché, London
B. M. A. R. C. 15 mm and 30 mm aircraft guns. 19 Mar 1945.
(Report no. R1632-45)
Data on two guns being sent to Aberdeen for testing. Modifications of Hispano-Suiza gun by British Manufacture and Research Co., Ltd. (BMARC). Unfavorably reported on by RAF due to their weight and failure to live up to specifications.

U. S. Military Attaché, London
Molins class "B" 20 mm aircraft gun. 22 Apr 1943.
(Report no. 56096)
Firm has made 3 high-speed films showing action on Molins modified Mark II aircraft gun. Report describes contents of films. Fires 1050 rounds per minute.

U. S. Military Attaché, London
Molins high speed 20 mm aircraft gun. 23 Apr 1943.
(Report no. 56186)
Supplement to MA 56096, giving further details on modifications to Hispano-Suiza 20 mm gun. Certain parts need strengthening to prevent recurrent stoppages, particularly locking plate and breech block.

U. S. Military Attaché, London
Molins high speed 20 mm gun. 17 Aug 1943.
(Report no. 59981)
Relates to redesign of 20 mm Mark II gun to increase rate of fire. Modifications should be considered in connection with U. S. gun.

U. S. Military Attaché, Paris
Hispano-Suiza aircraft cannon Type 404. 11 Mar 1937.
(Report no. 23256-W)
Gives detailed characteristics of Hispano 20 mm gun. Also data on procurement by Great Britain.

U. S. Military Attaché, Paris
Wing mounting of Hispano-Suiza cannon. 1 Aug 1939.
(Report no. 25137-W)
Specific details are given for wing mounting of Type 404 Hispano in single-seater fighter Bloch 150/151.

U. S. Military Attaché, Paris
Hispano-Suiza automatic cannon. 25 Jan 1940.
(Report no. 25469-W)
Gives characteristics of 23-mm cannon then under development. Mentions 30-mm cannon but no details available.

U. S. Naval Proving Ground, Dahlgren, Va.
Report of firing tests of Hispano-Suiza-Birkigt 20 mm aircraft cannon, type 404. No. 10868. Dahlgren, Jun 3, 1941.
Illustrated. Tests held Jul 1940.

U. S. Naval Proving Ground, Dahlgren, Va.
20 mm automatic gun, T34. 15 Jun 1945.
Report on tests for comparison of T31 (M3) and T34 guns for service use. Data on cyclic rates, malfunctioning, and breakage. Parts breakage excessively high; extraction failures; failure of driving springs. Tables and photos.

U. S. Naval Proving Ground, Dahlgren, Va.
20 mm automatic gun T34—Ground testing, partial report. 6 Oct 1947.
2 T34 guns tested from Feb to Sep 1947 for functional characteristics, including cyclic rates of fire, recoil travel, dispersion on rigid and non-rigid mounts, muzzle velocities and parts life. Tabulations, graphs, photos.

U. S. Naval Proving Ground, Dahlgren, Va.
20 mm automatic gun T31 (M3)—modified. 9 Aug 1945.
Results of tests on modified gun for rate of fire, recoil and endurance. Modifications include changes in gas cylinder sleeve and vent plug orifice; also Chinn type muzzle booster. Unreliable performance and excessive parts breakage.

U. S. Naval Supply Depot, Mechanicsburg, Pa.
20 mm gun modifications, additional clarification of. 28 Jan 1944.
Lists modifications by part number, nature and revision number.

U. S. Ordnance Committee
Chamber for 20 mm automatic guns M1 and M2, modification of. Apr 13, 1942. 22 p.
(Item 18144)
Discusses British request for modification of chamber of gun to conform to British chamber which is 2 mm shorter. Recommends that no change be made in American gun and that guns made in U. S. for British use be tested as is before decision to make them with British chamber.

U. S. Ordnance Dept.
Gun, automatic, 20 mm, M1 and M2. Base shop data. Rock Island Arsenal, 1943.
Contents: Dismantling; magazine; receiver; tube; assembly. Illustrations and diagrams.

U. S. War Dept.
20 mm automatic gun, M3. Jun 1947.
(TM 9-229)
Contains instructions required for identification, use, care, inspection, maintenance and rebuild of M3 gun and of equipment used therewith. (Combination blowback and gas-operated aircraft weapon.) Drawings and diagrams of weapon and components.

Hotchkiss

Bache, René
600 wooden bullets a minute. (In *Technical World* magazine. Sep 1913, p. 714-15)
Describes tests on Benét-Mercié mounted in Farman plane.

Borup, Lt. H. D.
Hotchkiss revolving cannon, Washington, 1886. (Ordnance memorandum no. 27)
Contains drawing of mechanism and ammo.

France. Ministry of War
Instruction pour les unites de mitrailleuses d'infanterie. Paris, 1932
Drawings and description of Hotchkiss M 1914. (In French)

Gt. Brit. War Office
Handbook of the .303-inch Hotchkiss machine gun (provisional). London, 1917.
Illustrated.

Handbook of provisional instruction for companies using the machine gun, mod. 1907 F (French . . . St. Etienne). Machine gun—tripod—accessories. Turin, 1917.
Handbook prepared for use by troops in Italy.

Hotchkiss Ordnance Co., Ltd.
Descriptive catalog of war material. London, 1893.
Contains nomenclature.

The Hotchkiss automatic machine gun. (In *Scientific American Supplement*, Jun 19, 1897, p. 17906–07)
Description of gun with pictures of components.

The Hotchkiss automatic machine guns. France, 9 Feb 1922.
(Service report)
Describes new machine rifle and 13 mm machine gun, both under development. Photographs.

Hotchkiss machine revolving cannon. (In *Scientific American Supplement,* Mar 7, 1891, p. 12647–48)
Describes 47-mm cannon for ship mounting and flank defense. Illustrated.

Ide, John J.
Guns on aeroplanes. (In *Scientific American*, Apr 11, 1914, p. 318)
Short article and photo of M. Loiseau's installation of Hotchkiss gun on Deperdussin plane.

Instruction sur la mitrailleuse automatique Hotchkiss (modèle 1899) Paris, 1899.
In French. Drawings and diagrams.

Koerner, Alfred
The Hotchkiss revolving cannon. Paris, 1879.
Description and illustration of cannon.

A light machine gun. (In *Scientific American*, Apr 25, 1914, p. 348)
Brief article on Benét-Mercié's adoption by U. S. Army. Photograph.

Mitrailleuse Hotchkiss d'aviation, calibre 13.2 mm. n. d. (In French) Describes aircraft machine gun, giving data, ballistic tables and illustrations of gun mounted in Hispano-Suiza motor. Diagram of gun.

U. S. Military Attaché, London
Hotchkiss 25 mm machine gun. 16 Feb 1931.
(MA Report 17,170–W)
Incloses report by Naval Attaché on subject gun. Numerical data, description, operation.

U. S. Military Attaché, London
Japanese 6.5 mm (.256 in) L. M. G. Taisho 11 (1922) model—Nambu. 7 May 1942
(Report no. 47,772)
Data, description and operation of gun, with drawings of components.

U. S. Military Attaché, Paris
Machine guns: developments by the Hotchkiss Co. 12 Nov 1929.
(Report no. 15,662–W)
Describes completion of 25 mm full automatic gun (a/a or a/t) Appendices give descriptive data, photographs, etc.

U. S. Military Attaché, Paris
Visit to Hotchkiss plant (25 mm cannon and 13.2 gun) 23 Feb 1937.
(Report no. 23,212–W)
Description of two guns being developed for aircraft use by Hotchkiss plant.

U. S. Navy Yard, Washington, D. C.
Report on Hotchkiss revolving cannon. Dec 27, 1876.
Test of 5-barrel cannon. Recommends that gun in lighter form would be a valuable addition to naval ordnance, e. g., to repel the attacks of torpedo boats. Report made by Lt. Comdr Crowninshield.

U. S. Ordnance Dept.
Handbook of the automatic machine rifle, caliber .30, model of 1909, with pack outfits and accessories. Washington, 1912.
Illustrated manual on Benét-Mercié.

U. S. Ordnance Dept.
Report of the Chief of Ordnance, 1899–1900.
Appendix 14, Report of board of officers on test of Hotchkiss automatic gun. Meetings started 7 Dec 1899. First tests ended with severe erosion of gun barrel. Second series 3 May 1900 with new barrel. Suitably passed prescribed tests. Illustrations.

Very, Edward W. (Lt., USN)
The Hotchkiss revolving cannon. Paris, 1885.
Descriptions and illustrations of the systems, with firing tables, proving ground tests and official reports. Covers 37 mm naval guns, 37 mm field guns and 40 mm flank defense guns.

Japanese

Aberdeen Proving Ground
Japanese 7.7 mm heavy machine gun type 01 (1941) (FMAR–698) 1945.
(OR&DC 6073)
Japanese gas operated (modified Hotchkiss) air-cooled gun firing only rimless ammunition. Photos.

Aberdeen Proving Ground
Initial data on gun, machine, 7.7 mm (.303 inch) aircraft (flexible mount) type 89—Japanese and gun, machine, 7.7 mm, aircraft (flexible mount) dual type 89 (Jap). 5 Jun 1943.
(O. P. No. 5826)
Description and photographs.

Grenell, L. H. and others
Examination of enemy materiel: Metallurgical examination of a Japanese 7.92 mm Type 98 flexible a/c machine gun. 25 Jul 1945.
(OSRD No. 5516)
Metallurgical analysis of Jap copy of MG 15 aircraft machine gun. Photos and tables.

Aberdeen Proving Ground
Test of Japanese 7.7 mm paratroopers machine gun, model 99 (1939) (FMAR 542) 30 Mar 1945.
(OR&DC #5733)
A modification of the Japanese Model 99 light machine gun. Photograph.

Aberdeen Proving Ground
Test of gun, light machine, cal. 7.7 mm, Type 99 (1939). 31 Jul 1943.
(O. P. 5826)
Describes captured Japanese weapon. Photo.

Hopkins, S. A.
Japanese light machine gun, Type 99. n. d. (In *The Ordnance Sergeant*)
Illustrated description with nomenclature.

Johnson

Johnson Automatics, Inc.
Log of the Johnson aircraft belt-fed machine cannon, 20 mm. 1944.
Lists firing tests during month of Apr 1944.

National Defense Research Committee, Div. I
20 mm Johnson aircraft cannon, project 10 for Bureau of Ordnance, U. S. Navy. Tentative technical manual. 1 Dec 1943.
Manual for 20 mm aircraft belt-fed machine cannon made by Johnson Automatics, Inc., covering description, operation, maintenance.

Knorr-Bremse

Description of a new fully-automatic fire-arm Model LH33, according to Swedish patent application no. 4908/1933. 1933.
Description, parts list and photos. Also describes 20 mm heavy machine gun, M/LH, corresponding in construction with LH33.

Description of a new light machine gun of system L. H. 33 according to English patent 430641. 1936.
With illustrations, parts list.

L. H. 33 machine gun. Mar 1941.
Sectional drawings.

U. S. Military Attaché, Berlin
Light machine gun LMG 35/36. 15 Dec 1936.
(Report no. 15,021)
Describes demonstration of German weapon invented by Hans Lauf.

Krieghoff

Bridge Tool & Die Works
Notes on materiel: Gun, machine, light, cal. 7.92 mm T–44. Dec 1944.
Conversion of German FG–42 (Krieghoff) paratrooper gun, with MG–42 belt feeding mechanism.

U. S. Naval Powder Factory, Indian Head, Md.
Gun, machine, cannon, aircraft, 20 mm experimental (1938–I)—German. 1 May 1946.
Brief description of incomplete captured German Krieghoff cannon. Photo.

U. S. Naval Powder Factory, Indian Head, Md.
Gun, machine, cannon, aircraft, 20 mm experimental (1941)—German. 27 Mar 1946.
Preliminary report on incomplete assembly of experimental aircraft cannon (Krieghoff). Operation summarized; photograph.

U. S. Naval Powder Factory, Indian Head, Md.
Machine, cannon, aircraft—20 mm experimental (1942 III)—German. 9 Apr 1946.
Photograph and preliminary report on experimental German aircraft cannon (Krieghoff). Operation is briefly outlined.

U. S. Naval Powder Factory, Indian Head, Md.
Machine, cannon, aircraft—20 mm experimental (1944)—German. 9 Apr 1946.
Preliminary report on captured German cannon, incomplete, constructed of heavy steel, crudely machined. Brief description and photo of air-cooled belt-fed gas and blowback operated Krieghoff.

U. S. Naval Powder Factory, Indian Head, Md.
Machine, cannon, aircraft—20 mm experimental (1944 V)—German. 9 Apr 1946.
Similar in appearance to 1944 experimental 20 mm Krieghoff described in another report. Operation outlined. Photograph.

Lahti

U. S. Military Attaché, Riga
Finland—20 mm gas operated machine gun for airplanes. 20 Sep 1936.
(Report no. 10215)
Additional information on L–37 Finnish machine gun with photos.

U. S. Military Attaché, Riga
20 mm gas operated machine gun for airplanes. 16 Jun 1936.
(Report no. 10102)
Describes L–37 machine gun used in Finnish Air Force and designed by Finnish government rifle factory.

Valtion Kivääritehdas (State Rifle Factory)
The L/S machine rifle, model 26/32. Jyväskylä, Finland, 1933.
Unique feature—permits firing of cartridges of different calibers. Brochure describes and illustrates this weapon.

Lewis

Claudy, C. H.
The romance of invention—VIII: The one-man machine gun and its inventor. (In *Scientific American*, Feb 14, 1920, p. 160)
Describes Col. I. N. Lewis and the success of his gun in WW I. Illustrated.

Crozier, William
Ordnance and the world war. N. Y., 1920.
Describes trials of Lewis gun by U. S. Army (Gen. Crozier was Chief of Ordnance dept.) First tests unsuccessful, but later acceptable and adopted. Defense of government against accusations of Lewis supporters.

Detail drawings and descriptions of the Maxim and Lewis rapid fire machine guns. (In *Scientific American*, Feb 6, 1915, p. 130–37)

The inspection and tests of Lewis machine guns. (In *Scientific American*, Nov 25, 1916, p. 475)
Illustrated account of manufacture.

Jacklin, G. and Whipp, Derek
The .303 Lewis gun. London, 1941. 48 p.
Simplified instruction manual with a number of drawings.

Lewis, Isaac N.
Operation and tactical use of the Lewis automatic machine rifle. N. Y., 1917.
Illustrated manual.

Morrison, Robert
To fire from the skies. (In *Technical World* magazine, Sep 1912, p. 200–202)
Story of first firing of Lewis gun from plane at College Park, Jun 1912. Illustrated with pictures of Lewis and pilot and gunner in plane.

Our future "flying batteries". (In *Literary Digest*, Sep 21, 1912, p. 461–62)
Describes first test of Lewis gun in air at College Park, Md., Jun 1912. Illustrated.

Pridham, C. H. B.
Anti-aircraft defense against low-flying enemy aircraft. A handbook for light machine gunners. London, 1941.
Describes use of Lewis guns in torpedo boats, speed boats and launches. Illustrated.

Pridham, C. H. B.
Lewis gun mechanism made easy. Aldershot, 1942. 22 p.
Manual for rapid training. Diagrams.

Savage Arms Corp.
Hand-book of the Lewis machine gun (airplane type), Model 1917–18, cal. .30. Utica, 1919. 63 p.
Illustrated.

Savage Arms Corp.
Hand-book of the Lewis machine gun, model 1917, cal. .30. Utica, N. Y., 1919. 63 p.
Illustrated.

Savage Arms Co.
Lewis automatic machine guns: the vital factor in the European war. N. Y., 1917.
Excerpts from official reports, items of personal experience and news clippings on the part played by these guns in war. Illustrated.

Wheatley, William J.
The Lewis gun for aeroplanes. (In *Scientific American*, Jul 6, 1912. p. 12)
Illustrated. Report of first trial at College Park, Jun 1912.

Lowell

U. S. Naval Experimental Battery, Annapolis, Md.
Report of board assembled to examine and test Lowell battery gun, model of 1879. Feb 24, 1879.
Description of gun and test, with appended firing record. Illustrated.

U. S. Naval Experimental Battery, Annapolis, Md.
Report of board assembled to witness the trial of Lowell battery gun. Oct 3, 1876.
Contains tabulation of firing and drawings. "We think . . . its mechanism brought to a nearer state of perfection than in any other machine gun with which we are acquainted."

U. S. Naval Experimental Battery, Annapolis, Md.
Report of test of Lowell battery gun on 13th and 14th of Jul 1877. Jul 16, 1877.
50,430 rounds fired, as recorded in appendix.

U. S. Naval Experimental Battery, Annapolis, Md.
Report on test for endurance of Lowell cartridge shells. Sep 23, 1876.
Report made by Lt. Edward Very. Contains tabulation of results and summary.

U. S. Navy Yard, Washington, D. C.
Report of board on trial of Lowell battery gun, model of 1879. May 7, 1879.
Firing record appended to report.

U. S. Navy Yard, Washington, D. C.
Report on trial of Lowell Battery gun on Feb 16, 1876 at Navy Yard. Feb 28, 1876.
Prepared by Comdr. Picard, Inspector of Ordnance. Illustrated, by drawings.

Lübbe

U. S. Military Attaché, Berlin
Germany: large caliber machine gun. 8 Dec 1931. (Report No. 11,838)
Describes Lübbe 20 mm gun which inventor offers to sell in U. S. 7 photos in appendix.

McClean

Handbook of the McClean one-pounder automatic gun, Mark III, with instructions for its care. n. d.
Parts list and illustrations included with handbook.

Motor balloon guns; automobile vs. airship. (In *Scientific American*, Jan 15, 1910, p. 48)
Discusses mounting of machine guns on motor vehicles, including McClean-Lissak automatic gun mounted on Packard truck. Illustrated.

Naval Proving Ground, Indian Head, Md.
Proof tests of 37 mm gun, Russian type, manufactured by Poole Engineering and Machine Co. 19 Jun 1918 and 28 Jun 1918.
McClean cannon offered to U. S. after Russian defeat in WW I and cancellation of order. Tests proved unsatisfactory because of jamming.

U. S. Ordnance Board
Report of trials of McClean one-pounder automatic gun. 29 Sep 1904.
Preliminary tests in May 1903, followed by regular tests in Mar and Aug 1904. Results of trials not satisfactory. Action characterized by many breakages and interruptions. Rate of fire and accuracy poor.

U. S. Ordnance Board
Report of trials of remodeled McClean one-pounder automatic gun. 20 Oct 1905.
Weapon previously tested in Sep 1904. McLean gun Mark 2 is described and results of tests are given. Weapon failed in functioning of gas operated engine or piston rod.

McLean

McLean, James H.
Dr. J. H. McLean's peacemakers. St. Louis, 1880.
Boastful prospectus of wide range of inventions and theories of McLean and Coloncy. Illustrated.

Madsen

Dansk Industri Syndikat
The Madsen machine gun, model 1950. Copenhagen, 1950.
Brochure with photos, description and data on cal. .300 British model 1950 Madsen machine gun.

Dansk Industri Syndikat
The Madsen standard machine gun, model 1950. Trials at Mosede (near Copenhagen) on the 6th and 7th of Nov 1950. Copenhagen, 1950.
Results of tests before representatives of Great Britain, Dominion of Canada, India, and U. S. A. of cal. .30 (7.62 mm) Madsen model 1950. 36,720 rounds fired with one weapon. 27 different tests.

Dansk Industri Syndikat
La mitrailleuse Madsen pour l'armement des avions. n. d.
Manual on Madsen m. g. (In French)

Dansk Rekylriffel Syndikat, Ltd.
The Madsen recoil arms. Copenhagen, Denmark, n. d.
Photographs and descriptions of Madsen weapons.

Jessen, Halvor
Automatic standard arms of modern warfare. XI. Madsen arms during the World War 1939–45 and after 1945. Copenhagen, 1946.
Contains pictures of various Madsen weapons.

Jessen, Halvor
Automatic standard arms of modern warfare. XIII. Arming and organization of a modern infantry brigade in 1949. Copenhagen, 1950.
Includes firing results with various Madsen weapons, use of Madsen 20 mm cannon as a/a gun and data on Madsen weapons. Photos of weapons.

The Rexer automatic machine gun. (In *Scientific American,* Aug 19, 1905, p. 140)
Illustrations and description of Danish gun (Madsen).

U. S. Military Attaché, London
The Madsen automatic gun, cal. 20 mm. 17 Oct 1927.
(Report no. 9025)
Describes new Danish development of 20 mm automatic gun mounted as anti-tank and anti-aircraft weapon. Illustrated.

U. S. Military Attaché, London
Madsen equipment. 7 Mar 1929.
(Report no. 24501)
Lists development of weapons and nations using them.

U. S. Military Attaché, London
Purchase of the 23 mm Madsen aircraft cannon and ammunition. 9 Nov 1937.
Details of procurement of cannon are given. Originally represented as a finished development by contractor, but still requires modification.

U. S. Military Attaché, London
Visit to Danish Recoil Rifle Syndicate, Copenhagen, Denmark. 12 Oct 1926.
Description of shops, demonstrations of models made for various countries.

Whitehouse, A. G. J.
Cannon in the air. (In *Popular Aviation,* Mar 1939, p. 62)
Description of Madsen 23-mm cannon. Illustrated.

Mauser

Aberdeen Proving Ground
German 20 mm aircraft machine gun, Mauser MG 151 (FMAR–169) and several types of Mauser 20 mm ammunition: A.P.I. (FMAM–542); H.E.I. (FMAM–354); H.E.T. (FMAM–420); H.E. (FMAM–355); H.E. (FMAM–391; I. (FMAM–431). 21 Mar 1944.
(RC #2188)
Contains firing data.

Combined Intelligence Objectives Subcommittee
Visit to Mauser Werke A. G. Oberndorf am Neckar, and Mauser personnel at Lager Haiming, Otztal, near Innsbruck. 1945.
(CIOS target no. 2/24).
Interrogations of key personnel of Mauser firm at Oberndorf and other places, including group captured by American troops. (Harnisch, Fleck, von Lossnitzer, Linder, Schroth, and others.) Lists personnel and organization of firm. Appendix gives full particulars on main developments of recent years. (MG–213, electric cartridge ignition, paper case ammunition, barrel development and wear, MG–215, MK–214, measuring and testing apparatus.) Photos, drawings, diagrams.

Gt. Brit. Ministry of Aircraft Production
M.G. 151 German aircraft machine gun and mounting. n.d.
(R. T. P. translation no. S1484)
Detailed description and illustrations of 20 mm MG 151 aircraft cannon.

Butz, A.
Beschreibung, handhabung und bedienung des MG–34 als leichtes M. G., schwers M. G. und in der flugabwehr. Berlin, 1941.
(In German) Handbook on MG–34. Illustrated.

Medlin, M. F.
The German 7.92-mm machine gun, MG–34. (In *Army Ordnance,* Mar–Apr 1943, p. 324)
Description and instructions for use. Illustrated.

Smith, W. H. B.
Mauser rifles and pistols. Harrisburg, 1947.
Historical forward tells of part played by Charles Norris of Philadelphia in patenting 1st Mauser rifle in U. S., and other background of Mauser firm. Also describes Dreyse Needle gun, other Mauser weapons. Many illustrations.

U. S. Military Attaché, Cairo
20 mm A.A./A.T. gun Flak 38. 22 Mar 1943
(Report no. 50)
Description of captured German weapon, including action of gun. Also described is "Flakvisier 38", an electric sight-giving azimuth and elevation leads automatically.

U. S. Naval Powder Factory, Indian Head, Md.
Gun, machine, anti-aircraft, 20 mm Flak 38M1—German. 24 Apr 1945.
Photos and description of gun.

Maxim

Detail drawings and descriptions of the Maxim and Lewis rapid fire machine guns. (In *Scientific American,* Feb 6, 1915, p. 130–37)

Dienstbach, C.
Our enemies in the air. (In *Scientific American,* Feb 9, 1918, p. 133)
Shows Parabellum gun mounted in reconnaissance plane.

The German anti-tank machine gun (13 mm) 25 Aug 1921. (Service Report)
Discussion of secrecy surrounding this gun (T. u. F.) put into service in German army in spring of 1920. Contains data on ammunition.

Gt. Brit. Admiralty
Handbook of the 0.45-inch Maxim gun (G. G. chamber) or 0.303-inch Maxim gun. London, 1901.
Illustrated manual.

Gt. Brit. War Office
Handbook for the 0.45 Maxim m. h. chamber machine gun on parapet mounting. London, 1891.
Contains instructions and description. Illustrated.

Gt. Brit. War Office
Handbook for the .303" and .303" converted Maxim machine guns (magazine rifle chamber) London, 1911.
Diagrams.

The Hiram Maxim gun. (In *Scientific American Suppl.*, Oct 5, 1889, p. 1)
Illustration of firing demonstration in Austria.

Kabat, N.
Pol'zoranie otdacheyu r" ognestril'nom" oruzhyi. St. Petersburg, 1888.
Contains early pictures of Maxim guns. (In Russian)

The latest Maxim machine gun. (In *Scientific American Supplement*, Jul 7, 1888, p. 1)
Fired in competition with Gardner & Nordenfelt guns on continent. Supplied for trial to British government in March 1887. Drawings.

Mariotti, Carlo
Unser maschinengewehr. Bern, 1940.
Illustrated. (In German) Manual for use of Swiss soldiers on use of Maxim 7.45 machine gun.

Marsh, Roger
The first model Maxim automatic machine gun. Hudson, O., 1945. 12 p.
Illustrated description of Maxim's prototype.

Maxim, Hiram S.
Autobiography of a veteran inventor. (In *Scientific American*, Jun 24, 1914, p. 615)
Portrait. Brief sketch of life.

Maxim, Hiram S.
Fast firing with machine guns. (In *Scientific American Suppl.*, Apr 23, 1892, p. 13591–92)
Letter on how fast it is possible for a single-barreled automatic gun to fire and what sort of cartridges can be fired with the greatest rapidity.

Maxim, Hiram S.
My life. London, 1915. 322 p.
Personal story by inventor of the first automatic machine gun. Illustrations.

Maxim, Hiram
600 shots a minute. (In *Hearst's Magazine,* Jul 1913, p. 534–37)
The inventor describes his first machine gun and its trials; also his own early experiments with smokeless powder.

The Maxim automatic machine gun. n. d.
Contains description and illustrations of various caliber Maxim guns.

The Maxim automatic gun. (In *Scientific American Supplement*, Jul 16, 1887, p. 1)
Gun is illustrated mounted on steel carriage for service in the field.

The Maxim gun. (In *Scientific American Supplement,* May 7, 1887, p. 9450–51)
Describes modified version of first Maxim gun with simplification and refinement. Illustrations.

The Maxim gun. (In *Scientific American Suppl.*, Apr 16, 1898, p. 18582–83)
Describes and illustrates extra-light rifle caliber Maxim.

The Maxim machine gun. (In *Scientific American Suppl.*, Nov 8, 1884, p. 7367–68)
An account of the first showing of the Maxim gun with sketch of weapon.

The Maxim-Nordenfelt 1½ inch automatic gun. London, n. d.
Contains description and illustrations.

Springfield Armory
Proceedings of board of officers appointed to test Maxim automatic gun. Springfield, Jun 1899.
Maxim solid action gun, Mark II, cal. .303 given series of tests from 15 May through 31 May 1899. Gave good performance but no positive recommendation made by board.

U. S. Military Attaché, Riga
Comparative specifications of Russian and Finnish machine guns. 15 Oct 1927.
Both are Maxim water-cooled guns, model 1910, made in Tula Arms Factory, Russia.

U. S. Ordnance Dept.
All present available data on various types of German machine guns. Jul 1918.
Includes description of light Maxim 1908–15 and Parabellum machine guns.

U. S. Ordnance Dept.
Handbook of the Maxim automatic machine gun, cal. .30, model of 1904. Washington, 1917.
Illustrated.

U. S. Ordnance Dept.
Report of the Chief of Ordnance, 1896–97.
Appendix 22, trial of Maxim-Nordenfelt .303 caliber automatic machine gun. p. 239–48. Satisfactory performance given. Includes 10 plates.

U. S. Ordnance Dept.
Report of the Chief of Ordnance, 1899–1900.
Appendix 12 (p. 123–46) Report of board of officers on test of Maxim solid action gun and Vickers R. C. automatic machine gun. Test held starting 20 Nov 1899. (Vickers gun withdrawn before completion of trial.) Maxim performed well. Description and illustrations of guns are given.

U. S. Ordnance Dept.
Report of the Chief of Ordnance, 1903–04.
p. 153. Appendix XI. Test of 37-millimeter Vickers-Maxim automatic gun (pom-pom) Commenced 22 Jul 1902. Drawings and diagrams.

Zalinski, E. L.
The "Pom-pom", a new element in warfare. (In *Cassier's magazine,* Nov 1900, p. 133–36)
Describes use of this Maxim one-pounder in Africa and elsewhere. Illustrated.

Mendoza

Mexico. Army
Extracts from Mexican machine gun regulations. 1936.
Description of Mendoza light mg included.

U. S. Military Attaché, Mexico
Reports on Mendoza machine gun rifles. 1934–35.
Discussions of characteristics, adoption and production of this weapon in Mexico.

U. S. Ordnance Dept.
Memorandum on Mendoza machine gun. 10 Jan 1938.
Examination of weapon is described. Includes general data, sketches and photos.

MG 42

Johnson, Melvin M., Jr.
The final German machine gun, MG 42. (In *Army Ordnance,* May–Jun, 1946, p. 352)
Description and pictures.

Montigny

The French mitrailleuse, a full and complete description of its construction, service, etc. Washington, 1873.
Illustrated.

Nordenfelt

Gt. Brit. Admiralty
Handbook of the 0.45-inch 5-barrel Nordenfelt guns, Marks I and II. London, 1894.
Drawings.

Gt. Brit. Admiralty
Handbook of the 1″ 4-barrel Nordenfelt gun. London, 1889.
Contains illustrations and diagrams.

Mitrailleuse automatique modèle 1897 de la Société Nordenfelt (de Paris) (In *Revue d'artillerie,* Vol. 52, 1898, p. 105-ff)
(In French.) Description and illustration of weapon.

Nordenfelt, Thorsten
Letter to Capt. Chadwick, USN, 24 May 1884.
Lists suggestions for naval armament of machine guns, other than those of rifle caliber, by using same system of machine guns throughout—namely the Nordenfelt.

Nordenfelt, Thorsten
The Nordenfelt machine guns described in detail and compared with other systems: also their employment for naval and military purposes. Portsmouth, Eng., 1884.

The Nordenfelt machine guns. (In *Scientific American Suppl.,* Jul 25, 1885, p. 7962–63)
Range from 2¼-in. 6-pounder to single barrel rifle caliber gun firing 180 shots per minute. Illustrated.

Oerlikon

Aberdeen Proving Ground
Functional test of Japanese caseless gun, automatic, 40 mm, HO–301. 1947.
Gun given preliminary examination; then 56 rounds were fired, during which rate of fire, instrumental velocity, target dispersion, fuze function, and amount of breech and muzzle flash were observed. Aircraft gun which resembles Oerlikon a/a 20 mm guns. Photographs.

For free shell-guns. (In *Flight,* Apr. 14, 1938, p. 309)
An Oerlikon aircraft mounting with electrical drive. (FFS model) Illustrated.

Gt. Brit. War Office
Handbook of the gun, machine, Polsten, 20 mm Mk I. 6 May 1944.
Primarily an anti-aircraft weapon against low flying aircraft. Description and action are given. Similar in principle to 20 mm Oerlikon used by Royal Navy. Drawings and diagrams.

Modern shell guns. (In *Flight,* May 2, 1940, p. 406)
Describes the Oerlikon series for aircraft, anti-aircraft and infantry use. Drawings & technical data.

The Oerlikon cannon. (In *Flight,* Jul 22, 1937, p. 2)
Facts and data on this weapon.

"Oerlikon" engine gun type FFS/MK (In *Inter-Avia,* Nov 16, 1938, supplement to No. 594)
Data and description of weapon. Illustrated.

Oerlikon Tool & Arms Corp. of America
The Oerlikon 20 mm revolver gun 206 RK. Asheville, N. C., n. d.
(Technical Brochure no. 1393)
Description of high performance aircraft gun "featuring a high muzzle velocity and an exceptionally high rate of fire." Contains description, operation, parts list, etc. Diagrams, photos of weapon and components.

Oerlikon Tool & Arms Corp. of America
The Oerlikon 30 mm revolver gun 302 RK. Asheville, N. C., n. d.
(Technical Brochure no. 1362)
Technical data, principles of operation, installation, ammunition, description of components and service instructions are given. Photographs and diagrams.

Oerlikon Werkzeugmaschinenfabrik
The "Oerlikon" 20 mm automatic gun, type 5 TG. Zurich, n. d.
(Brochure no. 1039)
New weapon with rate of fire of 1000 r. p. m. and an initial velocity of 1130 m/sec, tripling performance of conventional 20 mm guns. Contains technical data, description, photos and diagrams.

Oerlikon Werkzeugmaschinenfabrik
The 20 mm aircraft armament "Oerlikon". Oerlikon, Switzerland, 1936.
Descriptions of Oerlikon guns, models F, L, S, with illustrations, types of mountings, sighting devices, ammunition. etc.

Société Francaise Hispano-Suiza
Notice technique du canon type 9. 1937.
(In French) Relates to mounting and upkeep of engine mounted 20-mm cannon. Illustrated.

U. S. Bureau of Ordnance
History of 20 mm A. A. gun and mount program. 7 Nov 1945.
Story of negotiations for and production of Oerlikon 20 mm a/a guns by Navy in WW II.

U. S. Bureau of Ordnance
20 mm A. A. gun. 20 mm machine gun mechanisms Marks 2 and 4 . . . Mar 1943.
(OP no. 911)
Describes construction, operation and maintenance of the 20 mm AA guns. (Oerlikon) Plates and diagrams.

U. S. Military Attaché, Berlin
"Semag" 2 cm machine gun. 14 Apr 1923.
Description, characteristics and photographs of Swiss-made gun, based on Becker cannon.

U. S. Military Attaché, London
Particulars of the 20 mm Sten gun. Oct 1941.
(Report no. 44898)
Tabulated comparison of data with those of 20 mm Oerlikon and Hispano-Suiza.

U. S. Naval Attaché, London
German 2 cm M. G.—F. F. 22 Apr 1943.
NA London 1574–43
Data on F. F. aircraft gun (Oerlikon) preferably used as fixed gun.

U. S. Naval Powder Factory, Indian Head, Md.
Gun, aircraft cannon, 20 mm, fixed, type 99, Mk I, with magazine—Japanese. 8 Nov 1945.
Preliminary descriptive report with photo. Jap version of Oerlikon cannon.

U. S. Naval Powder Factory, Indian Head, Md.
Gun, machine, cannon, aircraft, 20 mm, type 99, Mk II Mod IV—Japanese. 26 Nov 1945.
Description (brief) and photo. Oerlikon type.

Puteaux

Puteaux Arsenal
Note sur les canons automatiques de 37 mm. Sep 1922. (In French—some pages translated into English) Description and functioning of cannon mounted in Hispano-Suiza motor. Illustrations include detailed diagrams of guns.

U. S. Military Attaché, Rome
Special new French 37 full automatic guns. 8 Feb 1923.
Description of 2 new guns developed at Puteaux Arsenal, one to fire through propeller, the other free.

U. S. Ordnance Dept.
37 mm Puteaux automatic airplane motor gun. 22 Dec 1925.
General description and history of Puteaux gun, including canceled project to produce it in U. S.

U. S. Signal Corps
Cannons on airplanes. 25 Jan 1918.
Information on French experiments on developing Puteaux 37 mm semi-automatic cannon, Puteaux 37 mm automatic cannon, and Puteaux 75 mm airplane cannon.

Revelli

Puteaux Arsenal
Data on the Cannoncino automatico "Fiat" 25.4 mm. 24 Jun 1918. 14 p.
Also known as 25.4 semi-automatic Revelli, model 1917 cannon chambered for 1-inch ammunition. Contains drawing showing Scarff mounting for use in airplanes. Gives component parts and operation of cannon.

Revelli automatic machine gun. Villar Perosa, Italy, 1917.
Illustrated manual of weapon manufactured by Officine di Villar Perosa in Italy and Canadian General Electric Co., Toronto.

U. S. Military Attaché, Paris
Revelli automatic rifle. 11 Sep 1929.
(Report no. 15,424–W)
Translation of description of 1929 model of Revelli automatic rifle, published in *Revue d'artillerie.*

Rheinmetall

Aberdeen Proving Ground
Test of German 30 mm aircraft cannon MK 108A3 and companion ammunition (FMAR-462) (FMAM–HET 996, FMAM–HE 997 and FMAM–HEI 998) 1944.
(OR&DC#4693)
Description and results of tests. Tables and photos.

Aberdeen Proving Ground
29th partial report on test of machine guns and machine gun accessories and first partial report on the test of the Solothurn 2 cm machine gun model S5–106. 28 Oct 1933.
(Ordnance Program no. 5082)
Object of tests to check the functioning of the mechanism and to check the ballistic characteristics of this weapon. Tables and drawings.

Combined Intelligence Objectives Subcommittee
Development of weapons by Rheinmetall-Borsig. 31 May 1945.
(CIOS Blacklist item 2/26)
Contains: Organization; ballistics and ammunition for automatic weapons; 5.5 cm AA weapon 58; 15 mm aircraft gun HF 15; weapons SG–117—SG–119; armament of high speed fighter planes; 37 mm gun 341; 3 cm SG–116; 5.5 cm aircraft guns MK–112 and 114; 5 cm SG–500; 35 cm recoilless aircraft gun 104; misc. weapons; development of light AA carriages; aircraft armament installation; 5.5 cm automatic recoilless aircraft gun MK–115; development of light alloy steels for automatic weapons. Drawings, diagrams, graphs.

Combined Intelligence Objectives Subcommittee
Visit to Rheinmetall-Borsig A. G., Werk Unterluss. 1945.
(CIOS Target no. 2/47(4/9))
Target was examined, samples of weapons collected and staff members interrogated. Covers: Automatic weapon design and development; bombs and rockets; fuzes; controlled missiles; ballistic and other apparatus; organization of firm. Illustrations of MK 112, bombs and fuzes.

Germany. Luftwaffe
2 cm flak 30-waffe; beschreibung, wirkungsweise, aun behandeln. Berlin, 1937.
Illustrated manual of Flak 30. (In German)

The MG 131. (In *Flight*, Mar 18, 1943, p. 285)
Describes German 13-mm aircraft defensive weapon. Illustrated.

Ordnance Intelligence Section, USAFFE
German aircraft machine gun (MG 17). 13 Sep 1943.
(Report No. 26)
Description, operation, nomenclature and figures.

Rheinmetall-Borsig A. G.
Descripcion e indicaciones de servicio para la ametralladora de avion modelo ST 61. Berlin, 1936.
(In Spanish) See ONI Translation 610 for English. Illustrated.

Rheinmetall-Borsig A. G.
Description and action of the 2 cm automatic gun, Mark ST 5. Berlin, n. d.
Gives description, action and nomenclature of parts for A/A and A/T 20 mm gun. Drawings included.

Rheinmetall-Borsig A. G.
Description of gun cal. 20 mm ST 8, mounted on car, mode of acting and short prescription of service. Berlin, 1936.
Description of automatic firearm specially designed for mounting in cars. Photos.

Rheinmetall-Borsig A. G.
Description of ST 61 aircraft machine gun and directions for operation. 1936.
(ONI Translation 610)
Translated from Spanish by ONI.

Rheinmetall-Borsig A. G.
Einbaumappe MK 108. Apr 1944.
(In German) Contains data and installation diagrams for MK 108 cannon.

Short description of the 2 cm aircraft gun, Mark T 12–201, for use on aircraft mountings. 1937
Data, description, drawings and photos. Also included are descriptions and photos of gun ring mounting Mark T 13–111 and twin drum magazine Mark DT 20—T 12–201. Rheinmetall gun based on Ehrhardt design.

2 cm aircraft automatic gun MK ST 11. 1938.
Contains description, action, ballistic data, ammunition, drawings. Also a description of aircraft gun ring MK ST 14 for swivelling installation.

U. S. Military Attaché, Berlin
Aircraft armament and accessories seen at Fassberg—Bombardment gruppe. 1935.
(Report no. 14,384)
Describes aircraft gun, type 15, using 7.9 mm cartridge. Also flexible gun mount. Photos.

U. S. Military Attaché, Berlin
The machine rifle S.2 200 made by the Solothurn A. G. 11 Sep 1930.
(Report no. D–11,040)
Description and illustrations.

U. S. Military Attaché, Berlin
A visit to Unterluss. 4 Mar 1936. 36 p.
(Report no. 14,563)
Unterluss is proving ground of Rheinmetall-Borsig Co. Describes: 37 mm a/a gun; 20 mm machine gun S 5–100; 2 cm anti-tank gun (Tank Buchse), Mark S 18–100; 2 cm aircraft gun (revolving ring mount); MG 15 (aircraft), 7.9 mm. Description, operation, diagrams of MG 15 are included.

U. S. Military Attaché, Berlin
Waffenfabrik Solothurn A. G. 29 Apr 1929.
(Report no. 10,142)
Describes organization of new Swiss firm under controlling interest of Rheinmetall. Key personnel are listed.

U. S. Military Attaché, Bern
Experimental 20 mm antitank gun. 12 Jan 1940.
(Report no. 3536)
Description of Solothurn Swiss weapon, offered to U. S. for testing.

U. S. Naval Powder Factory, Indian Head, Md.
Gun, machine, aircraft, 30 mm MK 108A3—German. 7 Nov 1945.
Preliminary report with brief description, specifications and photo.

Waffenfabrik Solothurn A. G.
The machine rifle Rh. 29. 1929.
Description and illustration of light mg with 8.5 kg weight and 7.9 caliber.

Waffenfabrik Solothurn A. G.
The 20 mm machine gun S5–100. Solothurn, Switzerland, n. d.
Fired against ground and aerial targets. Weapon is described and illustrated.

Rolls-Royce

Handbook for the Rolls-Royce 40 mm type BD gun mounted on 20 mm type 3 SLa Oerlikon column mounting. 1940.
Contains arrangement drawing and photos of gun, also diagrams showing operation. Description of gun and its operation.

S. I. A.

S. I. A. machine gun. 21 Apr 1922.
(Service report)
Inclosure of descriptive pamphlet (in Italian) on S. I. A. gun prepared by Fiat Co. of Turin, Italy. Illustrated.

Schwarzlose

Instruktion über die einrichtung und verwendung der maschinengewehre. I. heft: Maschinengewehr (Schwarzlose) M. 7. Vienna, 1913.
(In German) Manual on M. 7 Schwarzlose gun. Illustrated.

Instruktion über die einrichtung und verwendung der maschinengewehre. I. heft (I): Maschinengewehr (Schwarzlose) M. 7/12. Vienna, 1913.
(In German) Illustrations; manual on M. 7/12 Schwarzlose.

Scotti

Brevetti-Scotti S. A.
Armement "Scotti" de 20 mm. Zurich-Oerlikon, n. d.
Description and illustrations of Scotti cannon. (In French)

Scotti, Alfredo
Les armes automatiques Scotti. [Title page missing] 1932.
(In French) Description and illustration of various Scotti weapons.

Shkas

Gt. Brit. C. I. S. A.
Russian machine gun, 20 mm Shkas aircraft machine gun. 1 Oct 1941.
(Report no. 14,281)
Description and data on subject gun.

Gt. Brit. C. I. S. A.
Russian machine gun, 7.62 mm Shkas. Description and particulars. 29 Sep 1941.
(Report no. 14,240)
Description and photo of weapon.

Russian small arms (aircraft machine guns) 15 Mar 1945.
(ETP TI Report no. 91A)
Includes brief description and photos of 7.61 mm Shkas.

U. S. CBI Enemy Equipment Intelligence Service
Russian 7.62 mm aircraft machine gun. 18 Oct 1944
(CBI Ordnance Technical Intelligence Report no. 49)
Contents: General data on 1939 Shkas aircraft gun, description of components, disassembly, and operation. Photos include views from different sides, markings, exploded views of various groups of components.

U. S. Military Attaché, Moscow
Report on Shkas machine gun. 9 Jun 1941.
(Report no. 1956)
Partial report on 7.62 aviation machine gun with sketchy data and 5 photos, including breakdown and markings.

USSR Red Army Air Force
7.62 mm aviatsionnyye pulemety SHKAS (7.62 mm aircraft machine guns SHKAS) 1941. 251 p.
(In Russian) Detailed description and instruction on installation of flexible, wing and synchronized guns, assembly, operation, etc. Many drawings.

Shvak

Mauser Werke
Description and results of investigation of the Russian airplane mg B. C. Shpitalnogo-S. W. Vladimirovo No. (.K. 75 of 20 mm caliber, 1941. Sep 41.
(ID no. 328430)
Translation of document describing Russian gun captured by the Germans. Weapon and ammunition are described. (Shvak)

Russian small arms (aircraft machine guns) 15 Mar 1945.
(ETO TI Report no. 91A)
Contains brief description and photos of 20 mm Shvak cannon.

Sistar

U. S. Military Attaché, Rome
Sistar machine guns. 30 Jan 1935.
(Report no. L. 14249)
Characteristics of 6.5 and 8 mm guns are given. Photos, diagrams and Mancini's British patent specifications on weapon are included. Also has samples of demountable links.

Skoda

Musgrave, Daniel D.
Skoda machine guns. (Manuscript)
Notebook with details, pictures of weapons.

Skoda, E., Pilsen
La mitrailleuse Skoda, mod. 1902, et son emploi. Pilsen, 1902. 41 p.
Illustrated brochure on products of firm. (In French)

Skoda Werke
Skoda Works, 1869–1919–1929.
Outlines history, development and principal products of firm. Illustrated.

Speechley, G. K. and others
Skoda Works, Pilsen, Czechoslovakia. 1945. 90 p.
(CIOS Target Nos. 2/27h, 18/93, 19/19, and 21/45)
Discussion of conventional artillery and ammunition made there, steel treatment, methods of manufacture. Brief description of 75 mm recoilless high velocity gun with revolving drum-type feed for aircraft. Many photos.

Vandenburgh

Vandenburgh, O.
A new system of artillery for projecting a group or cluster of shot. (In *Journal of the Royal United Service Institution*, vol. VI, 1863, p. 377)
Describes General Vandenburgh's invention. 265 barrels clustered together. Illustrated.

Vickers

Bostock, Sgt. Major
Machine gunner's handbook, including the Vickers light gun. London, 1914.

Gt. Brit. Air Gunnery Technical Board
Notes of meeting held 7/4/41. Apr 1941.
A review of the development in England of Vickers 15 mm aircraft gun program. Includes statement by Vickers representative, notes on 15 mm gun installation, comparative data on 15 and 20 mm guns, description of the Vickers-Armstrong 15 mm gun and data on its design.

Gt. Brit. War Office
Vickers GO machine gun, Mark I. Jul 1943.
(Military training pamphlet no. 35)
Describes handling, stripping and assembling, mechanism, immediate action, care and mounting. This is gas operated cal. .303 Vickers gun for twin mounting on PLM mounting in aircraft turrets. Exploded diagram.

Handbook of the Vickers machine gun, model of 1915, with pack outfits and accessories. Washington, 1917.
Illustrated manual.

The new Vickers light automatic rifle-caliber gun and its adjustable mounting. (In *Scientific American*, Feb 3, 1912, p. 109)
Illustrations of new mounting for greater mobility.

The new Vickers-Maxim automatic rifle-caliber gun. (In *Scientific American*, Aug 3, 1907, p. 83)
Described and illustrated.

.300 Vickers machine gun mechanism made easy. Aldershot, 1942. 36 p.
Written for British home guard to describe and illustrate Vickers guns with which they were armed.

U. S. AEF
Report on the 37 mm Coventry gun. 30 Apr 1918.
Reports firing trials of new model of gun to determine whether mechanism would function at all angles of elevation and depression.

U. S. Ordnance Dept.
Vickers aircraft machine gun, model of 1918; service handbook. Washington, 1920.
Illustrated manual.

U. S. Military Attaché, London
General characteristics of Vickers-Berthier light machine gun. 20 Jul 1934.
(Report no. 36020)
Includes data sheet.

U. S. Military Attaché, London
Vickers-Berthier machine rifle. 21 Apr 1928.
(G–2 report) (Report no. 21686)
Data on various competitions in Europe on this and other machine rifles.

Vickers, Sons and Maxim, Ltd.
Modern types of battleships, cruisers and ordnance as manufactured by the firm. London, n. d.
Includes mast top mounting for 37 mm auto. gun and naval mounting for auto. rifle cal. gun. Illustrated.

Vickers, Sons and Maxim, Ltd.: their works and manufactures. London, 1898.
Describes early products of firm. Illustrated. (Reprinted from *Engineering* magazine)

ZB

Aberdeen Proving Ground
Test of gun, light machine, BRNO-ZB cal. 7.92 mm. Czech. 28 Jul 1945.
Description and photo.

Ceskoslovenska Zbrojovka A. S.
BLG M. G. ZB 60. Brno, Czech., n. d.
Translation of manual for this weapon (15 mm) Advantages and tactical use are outlined. Gives types of ammunition used.

Ceskoslovenskia Zbrojovka A. S.
Light machine gun model ZB–26. Brno, 1934.
Translation of manual describing 7.92 mm ZB 26. Drawings and photographs.

Ceskoslovenska Zbrojovka
Light machine gun ZB–34. 1934.
Translation of manual with description, action, assembly, magazine, special equipment, and principal advantages. Photos of plant, weapon and components.

Ceskoslovenska Zbrojovka Brno
Machine gun ZB 50, model 32. 1934.
Brochure describes, and gives technical data and operating instructions for 7.86 mm Czech gun. Photographs.

Ceskoslovenska Zbrojovka A. S.
The ZB–80 pilot machine gun, cal. 7.92 mm. Brno, n. d.
Aircraft machine gun directly driven from the airplane engine through a mechanical transmission. Description, mounting, operation. Photographs.

Gt. Brit. War Office
Instructions for armourers, 1931. Supple. no. 4 Guns, machine, Besa, 7.92 mm, Mk I and Mk II; Guns, machine, Besa, 15 mm, Mk I and accessories. London, 1941.
Includes drawings and diagrams. Identical with ZB Model 37.

U. S. Military Attaché, Warsaw
Heavy machine gun ZB 53. 8 Apr 1938.
(Report no. 3112)
Brief description of weapon.

U. S. Military Attaché, Warsaw
Light machine gun ZB 30. 8 Apr 1938.
(Report no. 3113)
Furnishes brief descriptive data.

Appendix C

PATENT ABSTRACTS

This appendix contains a comprehensive collection of U. S. patents that are pertinent to the field of automatic weapons. The arrangement is by subject with the patents listed under each subject in chronological order. For each patent an abstract describing the principal features and claims of the invention is given. This abstract is phrased in the terminology of the patent; thus the summaries of some of the earlier patents may contain expressions that vary from current ordnance usage.

No effort has been made at complete analysis of the patents. Coverage of all the claims made by the inventors would make this appendix prohibitively long and would serve no useful purpose. An attempt has been made merely to select the central ideas as set forth in the patents.

Readers are cautioned that inventors are protected by patent regulations with respect to the ideas and claims described in these abstracts unless such protection has lapsed after the statutory period of 17 years for any particular patent. Any utilization of patents not in the public domain must be in accordance with outstanding rights affecting the invention.

Barrels and Related Mechanisms

Patent 198,366 — 18 Dec 1877
Farrington, DeWitt C. — Lowell, Mass.
Improvement in barrel-shifting mechanisms for machine guns.
Means for shifting barrels as they become heated; also means for supporting barrels whereby they will have the requisite longitudinal play, to compensate for any extension produced by high temperature, without disturbing their parallelism. Easily removable barrels.

Patent 300,515 — 17 Jun 1884
Schneider, Alois — San Francisco, Calif.
Rifling guns.
Rifling consists of channels or grooves by which rotary motion is imparted to ball, the first portions of which from the breech are nearly or quite parallel to axis of bore. Grooves then turn slightly to right before commencing the twist to the left. Latter is an increasing or gain twist to a point within an inch or two of muzzle or outer end, from which the twist is continued out with an even or regular turn.

Patent 632,094 — 29 Aug 1899
Browning, John M. — Ogden, Utah
Bolt-gun.
Improvement in bolt-guns in which bolt is located in bolt-housing formed in a rearward extension of barrel itself. Barrel may be readily removed from stock without use of tools for compact transportation. Barrel formed at its butt end with an integral receiver extension comprising a tubular bolt-housing formed with a longitudinal slot and a reach formed with a downwardly-opening longitudinal slot extending downward below axial center of barrel.

Patent 687,130 — 19 Nov 1901
Dawson, Arthur T. and Buckham, G. T. — London, Eng.
Automatic or other machine-gun.
Applicable to guns with sliding barrels and water jacket, as in Maxim 37-mm gun. Object to construct gun so that barrel and water jacket can be readily and simultaneously detached for convenience in transporting the gun. Projections on barrel fit into corresponding grooves in frame. Also grooves in jacket to correspond with ribs in breech casing.

Patent 918,380 — 13 Apr 1909
Schwarzlose, Andreas W. — Berlin, Ger.
Automatic firearm with forward-sliding barrel.
Increases weight of barrel and provides same with a chamber in which the usual spring is seated and that portion of the casing which usually surrounds the barrel and extends to muzzle end thereof is almost wholly dispensed with. Novel arrangement of usual abutting or breech wall against which barrel strikes, with respect to discharge end of magazine so as to avoid use of cartridge retaining mechanism.

Patent 988,996 — 11 Apr 1911
Frommer, Rudolf — Budapest, A-H
Automatic firearm.
Relates to automatic firearms with sliding barrels in which barrel can be fixed for use as a handloaded weapon and to facilitate cleaning of barrel. Fixing device consists in fixing barrel by means of a sleeve arranged on guide tube of the barrel, which sleeve is adapted to rotate and be secured in its operative positions.

Patent 989,432 — 11 Apr 1911
Schmeisser, Louis — Erfurt, Ger.
Automatic firearm.
An improvement in automatic firearms with stationary barrels. To provide a firearm of this class in which parts which must be dismounted for thorough cleaning can easily be mounted or dismounted by hand. Provides slidable or otherwise movable locking bar at upper part of firearm which enables the barrel to be easily secured or dismounted.

Patent 1,028,032 — 28 May 1912
Krag, Ole H. J. — Ullern, Norway
Automatic repeating firearm.
Improved repeating pistol (Patent 954,441—1910) that can be discharged as an automatic or operated as single

loader. Barrel has T-shaped ribs adapted to slide in T-shaped groove in slide mounted to move longitudinally on housing and to be released from engagement therewith when said slide is drawn rearward to a predetermined position. Means for normally locking barrel on housing. Improved safety features.

Patent 1,039,922 — 1 Oct 1912
Frommer, Rudolf — Budapest, A.-H.
Self-loading pistol of the kind having sliding barrels.
The two springs which return the barrel and the breech-block respectively into firing position are arranged above barrel concentrically to one another in such a manner that each of the two springs may have a length approximately equal to that of the weapon. Total length of the weapon can thus be made comparatively short, while springs can be made sufficiently long to fulfill their functions.

Patent 1,047,671 — 17 Dec 1912
Mauser, Paul — Oberndorf, Ger.
Recoil-loading pistol with fixed barrel.
Novel fastening device for barrel is provided in which barrel is held by a barrel holding device in the form of an insertable pin, after the removal of which the barrel can be readily detached from grip stock. New arrangement of trigger mechanism with sear provided above the magazine in upper part of grip stock and consisting of double-armed bell crank lever. Arrangement for locking breech slide in event of single loading.

Patent 1,217,974 — 6 Mar 1917
Mauser, Paul (deceased)
Firearm.
Relates to breech arrangement for firearms with return spring. Spring arranged in lid of breech casing so that it is removed together with lid when latter is taken off.

Patent 1,234,783 — 31 Jul 1917
Mauser, Paul (deceased)
Means for combining the barrel with the receiver in connection with firearms.
Renders barrel readily interchangeable. More easily possible to extract discharged shells without aid of a lubricant. Intermediate piece inserted between barrel proper and sleeve head of receiver. This piece contains cartridge chamber as well as locking abutment separately and extends into sleeve head on one hand and receives rear end of barrel on other.

Patent 1,242,068 — 2 Oct 1917
Stoddard, Vaughn — Chelsea, Iowa
Machine gun.
Embodies rotatable barrel having an annular series of rifle bores, an endless feed chain for conveying shells to and partially around with the barrel and means for moving the shells from the chain into said bores for firing and then withdrawing shells from said bores while shells are being carried around with barrel.

Patent 1,307,316 — 17 Jun 1919
O'Malley, John F. — Meriden, Conn.
Machine-gun.
Machine gun provided with a double reversible barrel which may be adjusted to permit one barrel to cool while the other barrel is in use; rapidity of fire may be regulated by adjustment of gears which connect operating member with loading and firing mechanism. Hammer operated by cartridge wheel and both are covered by a cap readily removable.

Patent 1,329,922 — 3 Feb 1920
O'Malley, John F. — Mount Vernon, N. Y.
Machine-gun.
Permits use of interchangeable gun-barrels, one of which is water-cooled, the second is double, reversible and air-cooled and third is a single air-cooled barrel. Provides perfect balance in rotating cartridge wheel and permits operating crank shaft from one side of gun instead of underneath.

Patent 1,363,262 — 28 Dec 1920
North, Thomas K. — Swaffham, Eng.
Rifle and machine-gun.
Provides for replacement of one barrel by another in gas-operated machine guns and rifles. By displacing locking device in form of transversely arranged pin rotatably mounted in body of gun.

Patent 1,468,262 — 18 Sep 1923
Dawson, Arthur T. and others — Westminster, Eng.
Automatic gun.
Maxim modification. Improved means for manually retracting barrel so as to simplify the loading operation.

Patent 1,588,887 — 15 Jun 1926
Haubroe, Werner C. L. — Copenhagen, Denmark
Machine gun with exchangeable barrel.
Shapes the bolt serving to hold the trigger plate and butt end in normal position in such a manner that it has to be turned only a half revolution to release swinging parts and same in opposite direction to lock parts in normal position. Simplifies removal of bolt and prevents danger of loss of bolt.

Patent 1,738,500 — 3 Dec 1929
Moore, Frederick T. — E. Hartford, Conn.
Barrel mounting for firearms.
Improvement on Browning machine gun (Patent 1,293,021—1919). Provides barrel mounting permitting barrel to be readily assembled with, or disassembled from, barrel extension to facilitate replacement of barrels in service.

Patent 1,758,486 — 13 May 1930
Frommer, Rudolf v. — Budapest, Hungary
Automatic firearm.
To provide an automatic arm having an air-cooled barrel sliding on a long way in the chamber of which the shell is loosened by a shock produced by a spring buffer against which the barrel strikes, the barrel of which can be changed in a few seconds under the most unfavorable conditions. All parts of weapon which would influence this quick change arranged to be easily removable from path of barrel.

Patent 1,789,308 — 20 Jan 1931
Hatcher, James L. — Winchester, Va.
Apparatus for rifling gun barrels.
Rifled by a cold work operation which will not only permit simultaneous formation of the rifling in a number of barrels but will serve to raise the elastic limit of the metal.

Patent 1,821,463 — 1 Sep 1931
Danthine, Karl — Bern, Switzerland
Machine gun.
Improvements in reciprocating barrels of machine guns such as Maxim. Barrel made in two pieces so that actual barrel with cartridge chamber consists of one part, this part being inserted into back portion or guide and interchangeably connected thereto. Simplifies replacement.

Patent 1,852,057 5 Apr 1932
Moore, Frederick T. and Pfeiffer, Christian
Hartford, Conn.
Spring mechanism for automatic firearms.
Improvement in Browning patents to provide a spring mechanism for restoring mechanism to its normal firing position after recoil. Reaction spring for reciprocating lock frame located at front of gun. Provides additional space within breech casing, guide tube for reaction spring to prevent buckling, and tension of spring is varied as result of barrel movement.

Patent 1,877,839 20 Sep 1932
Frommer, Rudolf v. Budapest, Hungary
Barrel spring for automatic firearms.
Improved construction of barrel spring in arms having straight pull breech and a barrel with long recoil movement. Buffer sleeve adapted to surround barrel spring and at same time guiding rod of barrel spring is provided with a flange on which said buffer spring bears.

Patent 1,980,399 13 Nov 1934
Green, Samuel G. Gray, Ga.
Gun barrel and barrel mounting. (Cl. 89–1)
Constructs barrel and its mounting so that the packing will be better protected against the heat of the barrel and the rifled muzzle end of the barrel will be available to the cooling medium in the jacket during reciprocation. Provides reserve water space in mounting in front of muzzle end of barrel.

Patent 1,987,939 15 Jan 1935
Lahti, Aimo J. Jyvaskyla, Finland
Machine gun. (Cl. 42–4)
Recoil-operated machine gun with much smaller number of parts. Possible, solely by changing the magazine support, to use both straight and cylindrical magazines and, if barrel is changed, to fire with cartridges of various calibers. Barrel and sliding device are rigidly connected and move a short distance to and fro.

Patent 1,991,302 12 Feb 1935
Frommer, Rudolf v. Budapest, Hungary
Automatic firearm with a movable barrel. (Cl. 42–4)
Fixes barrel automatically when opening the breech block manually by swingable handle, so that the breech block is opened on withdrawal of cartridge case out of chamber.

Patent 1,994,489 19 Mar 1935
Simpson, Clarence E. Springfield, Mass.
Machine gun. (Cl. 42–75)
In Browning guns, provision of externally accessible latch for holding barrel in position of adjustment, to permit more convenient and more rapid adjustment for head-space.

Patent 2,031,383 18 Feb 1936
Mendoza, Rafael Mexico City, Mex.
Machine gun bolt mechanism. (Cl. 89–3)
Improved means for releasably securing the gun barrel to the case or frame of a gun which will effectively prevent relative movements between said parts.

Patent 2,061,313 17 Nov 1936
Moore, Frederick T. W. Hartford, Conn.
Machine gun and attachment therefor. (Cl. 89–14)
Relates to air-cooled machine gun with readily detachable barrel. Attachment to rotate barrel to screw it into and out of engagement with barrel extension and also adapted to carry barrel when detached from gun.

Patent 2,093,706 21 Sep 1937
Browning, Marriner A. Ogden, Utah
Gas operated automatic firearm. (Cl. 89–2)
Relates to gas-operated firearm having piston tube normally connected with barrel and readily movable rearward to disengage barrel. Permits barrel to be disconnected from casing of gun.

Patent 2,110,165 8 Mar 1938
Moore, Frederick T. W. Hartford, Conn.
Machine gun. (Cl. 42–75)
To provide a machine gun of the reciprocating barrel type, wherein the barrel may be readily put in place or removed from front of gun without disturbing or disassembling any other essential part. Permits easy substitution for heated barrel. Has barrel guiding bearing on the guide which is readily detachable to permit forward removal of barrel.

Patent 2,223,004 26 Nov 1940
Holek, Vaclav Brunn, Czechoslovakia
Automatic firearm. (Cl. 42–4)
Firearm comprising a casing, a recoiling barrel, breech mechanism, an aperture in casing, an openable closure for aperture, and means connecting closure and barrel. Receiver has cover having a plunger arranged to cock barrel when lifted and closed.

Patent 2,326,139 10 Aug 1943
Green, Samuel G. Gray, Ga.
Gun barrel mounting. (Cl. 89–14)
Improved mounting for moving gun barrels, especially where muzzle end is provided with a recoil check and accelerator. Provides broaching action of such character that relatively large particles of carbon or other residue cannot form and cause ignition of the gas in the booster chamber.

Patent 2,345,596 4 Apr 1944
Green, Samuel G. Gray, Ga.
Barrel mounting. (Cl. 89–14)
Means for mounting muzzle and portion of barrel of an automatic gun so that travel of gases between barrel and blast tube rearwardly is positively precluded. Utilized flow of gases under high velocity from muzzle to withdraw gases accumulating rearwardly of muzzle between barrel and blast tube similar to manner in which an injector functions. Frequent dismounting for cleaning obviated.

Patent 2,345,833 4 Apr 1944
Schirokauer, Henry New York, N. Y.
Gun barrel lock. (Cl. 42–75)
Relates to mechanism for locking gun barrel in the gun frame, so that when in use barrel is more or less rigidly locked in place in frame to be more or less immovable and meet stress caused by firing of the gun. Locking member provided with a seat for engaging barrel, preferably an arc-shaped tapered engagement providing a large surface contact.

Patent 2,360,293 10 Oct 1944
Webb, George Hartford, Conn.
Barrel lock for automatic firearms. (Cl. 89–3)
Improved barrel lock for Browning machine gun. Readily releasable lock for preventing rotatable movement of firearm barrel or tube with respect to breech casing and barrel extension of firearm. Barrel and extension reciprocate as a unit during operation of gun but rotation of barrel is normally prevented by a detent moving bodily with barrel and extension. By this invention detent can be released to permit rotation of barrel.

Patent 2,364,487 5 Dec 1944
Swartz, William L. W. Hartford, Conn.
Firearm accessory. (Cl. 42-90)
Accessory for holding a barrel extension in its normal proper position within breech casing of an automatic firearm while barrel or tube is being attached to or detached from engagement with barrel extension. Applicable to Browning weapons.

Patent 2,406,089 20 Aug 1946
Martineau, Joseph A. E. Pendicton, Canada
Rotary barrel gun. (Cl. 89-1)
Provision of a gun that spins the bullet without rifling in the bore. Gun barrel is rotated by means of a turbine rotor attached to the barrel and driven by the gas liberated on explosion of the cartridge. Turbine built around magazine. Successive shots increase angular velocity of barrel and hence of spinning.

Patent 2,437,137 2 Mar 1948
Swebilius, Carl G. Hamden, Conn.
Gun-barrel lock. (Cl. 42-75)
Relates to quick-change mountings for barrels of small arms and machine guns. Provides barrel lock that will stand up under field service and long wear and usage.

Blowback and Blowforward

Patent 357,170 8 Feb 1887
Bjerkness, Carl J. Arkdale, Wis.
Repeating fire-arm.
To provide new repeating fire-arm, which is loaded automatically and throws firing pin back to its place by back action of the charge and also discharges cartridge-shell automatically. Consists of cylinder sliding in breech-block, of a firing pin sliding in cylinder and in a bushing on breech-block, and of a device for automatically loading and discharging cartridge shell.

Patent 581,296 27 Apr 1897
Mannlicher, Ferdinand von Vienna, A.-H.
Automatic firearm.
Relates to firearm in which barrel resting against rigid butt plate is thrown forward by action of projectile at firing of a shot and driven back against butt plate by spring. (Blowforward)

Patent 624,145 2 May 1899
Young, Franklin K. Boston, Mass.
Automatic firearm.
Improved gun capable of use at will either as an automatically loading and firing repeating gun or as one to deliver single shots at will of user. In combination with a movable breech-closing device, a movable plunger adapted to be actuated by a movable part of a cartridge in gun-chamber in rear of projectile, means for locking breech-closing device, and connections between such locking means and plunger whereby movement of latter causes closing device to be unlocked. Cartridge has igniting plunger rearwardly driven by explosion to cause automatic action of gun.

Patent 691,040 14 Jan 1902
Young, Franklin K. Boston, Mass.
Firearm.
Relates to automatically-reloading firearm, both small-arms and ordnance, in which operation of mechanism does not depend upon a movable barrel. (See Patent 624,145—1899.) Explosion of cartridge drives igniting plunger violently backward to actuate locking-block-opening mechanism to open and lock said block and prevent block from being unlocked until hammer is thrown forward.

Patent 712,730 4 Nov 1902
Schwarzlose, Andreas W. Suhl, Ger.
Recoil-operated firearm.
Firearm in which barrel as well as the breech-block are caused to execute a backward motion when powder charge of cartridge is exploded.

Patent 726,109 21 Apr 1903
Stow, Audley H. Hunter, W. Va.
Automatic firearm.
Improvements in automatic firearms in which rearward pressure of gases is utilized to make them automatic. Backward pressure of cartridge-shell when fired forces back breech block or bolt in substantially a right line. Breech block presses hammer back to cocked position and also presses back return-lever alongside hammer. Spring acts on lever to force breech block forward to closed position and partially rotate cylinder (if revolver) or feed cartridge (if magazine gun).

Patent 998,867 25 Jul 1911
Young, Franklin K. Winthrop, Mass.
Firearm.
Relates to automatic self-loading firearms in which barrel is fixed and immovable. Object to provide breech mechanism automatically operated by cartridges in common use, and not dependent for reloading on recoiling barrel or gas-operated piston or lever or on rearwardly moving plug or piston within base or head of cartridge case or on rearwardly movable primer. Utilizes elongation of case or shell after explosion of powder charge, and also recession or rearward motion of cartridge case or shell upon explosion of powder charge to operate breech mechanism.

Patent 1,195,307 22 Aug 1916
Wheatley, Charles S. Needham Heights, Mass.
Automatic-reloading rifle.
Improved rifle of this type of approximately same weight as such rifles without the improvements; eliminates use of sliding barrels, "blowback" breeches, recoil springs and inertia weights; loading and ejecting means operated by forward force of exploding powder after bullet has left firearm, and to include in same device used for operating loading and ejecting mechanism means for silencing the report of the arm to an appreciable extent.

Patent 1,297,240 11 Mar 1919
Pritchett, William H. Cartersville, Ga.
Automatic machine-gun.
Improved machine gun fired either automatically or single shot, in which there is no positive lock to reciprocating breech bolt when in the firing position; but mass of breech bolt and parts carried thereby is such that, together with compressive force of the main spring sufficient support is furnished to base of cartridge case to enable gun to be fired and projectile to clear muzzle before breech bolt has moved an appreciable distance to rear. Rearward movement of breech bolt taken care of by compressing main, or return spring, and arrested by pneumatic dashpot arrangement.

Patent 1,429,370 19 Sep 1922
Putnam, Burleigh Pasadena, Calif.
Machine gun.
Uses reciprocating barrel which is blown or pulled forward by explosion of cartridge and by the use of cartridges which

are mounted in sets of 10 or more in a clip in which they are fired. Provides an oiling device by means of which shells are thoroughly lubricated just before they are fired. Magazine mounts a plurality of clips. Retarder for slowing down barrel. New form of air cooling devices.

Patent 1,472,126 30 Oct 1923
Kewish, John T. New York, N. Y.
Machine gun.
Improved machine gun of type adapted to be carried on and fired from shoulder of user. Power actuating the automatic parts is derived from the primer of the cartridge but with means to prevent primer from coming completely out of cartridge when fired. Means for securely locking cartridge in barrel of gun. Movable actuator piece through movement of which gun is automatically loaded and unloaded. Spring-actuated movable breech mechanism so that rearward movement of mechanism stores energy to reload and fire gun.

Patent 1,696,537 25 Dec 1928
Kewish, John T. New York, N. Y.
Automatic firearm.
Simplified construction for firearms in which power for actuating automatic parts is derived from the primer of the cartridge. Means for removably attaching barrel to forward end of receiver and means associated therewith to lubricate the cartridges while the same are being inserted within barrel. Means to prevent primer from coming completely out of cartridge when fired. Improved trigger mechanism.

Patent 1,827,037 13 Oct 1931
Pedersen, John D. Springfield, Mass.
Firearm.
Provides automatic action for a gun having a rotary and reciprocatory bolt, with power storing mechanism and firing mechanism containable in a receiver of normal dimensions. Power obtained from backward pressure of fired cartridge against face of the bolt, the barrel being fixed to the receiver. Provision made for initial delay of opening of bolt by force in inerita.

Patent 1,851,696 29 Mar 1932
Ekdahl, Carl E. New Haven, Conn.
Firearm.
Blowback firearm in which extractors, firing pins and other moving parts especially at forward end of breech bolt have been eliminated and can be fired indefinitely without cleaning. Novel trigger mechanism. Arrangement for supporting cartridge case during ejection. Improved safety.

Patent 2,286,133 9 Jun 1942
Williams, David M. Godwin, N. C.
Firearm. (Cl. 42-3)
Improvement on Patent 2,144,951 (1939) for firearm in which firing of shell initiates movements to operate gun into position to fire again. Provides breech opening mechanism for autoloading which does not function by mass or momentum. Driver converted into a member having merely the function of transmitting motion which it derives from actuator to an action opening spring. Driver acts to energize or store power in a spring which in turn acts on breech mechanism.

Patent 2,290,156 21 Jul 1942
Brewer, Nicholas L. E. Longmeadow, Mass.
Firearm. (Cl. 42-3)
Improved form of blowback or automatic gun, particularly to provide new ways for venting the gun so that venting allows for dispersal of gas blast. Force of blast is effective to prevent deposit of waste materials on action of gun. Provides opening on left-hand side of gun consisting of series of vertical slots so that gases are directed to rear at angle of less than about 45 degrees with axis of gun.

Patent 2,401,616 4 Jun 1946
Clarke, Howard R. Newton Highlands, Mass.
Firearm. (Cl. 42-3)
Relates to automatic or semi-automatic firearms in which piston-like action of primer of a fired cartridge is utilized to unlock bolt. Receiver slidably supports a bolt to reciprocate out of and into a closed position to extract, eject and reload. Tappet is positioned positively relative to receiver and independent of bolt shell.

Breech and Bolt Mechanisms

Patent 14,819 6 May 1856
Lindner, Edward New York City
Improvement in breech-loading guns.
An arrangement by which, through the firing off of the gun, the breech will be made to open itself, allowing air to enter the barrel and clean same of unconsumed powder and condensed gas. Performed either by action of the cartridge against a lever protruding into the barrel or by expansive power of the powder. Also contains method for lubrication of breech mechanism.

Patent 78,603 2 Jun 1868
Norris, Samuel (Phila.), Mauser, Wm. and Mauser, Paul
Improvement in breech-loading fire-arms.
Relates: (1) to breech-loading mechanism whose breech is closed by cylindrical block fitted to slide endwise in a chamber at rear of barrel, with improved mainspring and devices used in connection with trigger for holding and releasing spring, and also elastic extractor attached to breechblock; (2) modifications in needle-guns ("Chassepot") to adapt weapons to firing of metallic cartridges, by substitution of firing pin for needle.

Patent 115,483 30 May 1871
Joslyn, Benjamin F. New York, N. Y.
Improvement in revolving fire-arms.
Improvements to prevent binding of cylinder due to swelling of exploded cases, to prevent escape of gases between cylinder and barrel, to enable exploded cases to be readily ejected from cylinder, and to produce firearm of economical construction. Uses movable or sliding breech-piece adapted to recess in frame at rear of barrel or at rear of uppermost chamber of cylinder on line with barrel. This has effect of moving cylinder forward and holding against barrel.

Patent 207,056 13 Aug 1878
Mesle, Franz J. Brooklyn, N. Y.
Improvement in breech-loading fire-arms.
Breech-piece or shoe formed with bores of different diameters constituting receiving-bed for cartridge and retaining shoe for rear of bolt, in combination with bolt consisting of a forward and rear portion corresponding in their diameters respectively with bores of breech piece in which they slide.
Enables construction of rifle of smallest bore without reducing size of rear portion of breech-bolt containing firing pin and spring.

Patent 323,997 11 Aug 1885
Allender, Henry Detroit, Mich.
Machine-gun.
Relates to guns with rotating but longitudinally immovable breech-block and rotating longitudinally moving

barrels. Improvements in breech and barrel mechanism, cartridge-feeding mechanism and means for transferring cartridges from feed-cases to rotating breech. Combination with barrel-inclosing case of a ring-cam inclosed by and attached to said case, series of rotating barrels and rotating breech block having a flange-holding recess for a cartridge head in line with each barrel. Barrels move to the rear over cartridges.

Patent 357,518 — 8 Feb 1887
Burgess, Andrew — Owego, N. Y.
Magazine firearm.
Relates to breech loading and magazine arms, especially double magazine-guns; consists of arrangement of various devices to operate breech mechanism, whether attached to a single or double gun or whether operating singly, doubly or simultaneously, and devices to cock hammers independent of breech-operating mechanism.

Patent 366,560 — 12 Jul 1887
Burgess, Andrew — Owego, N. Y.
Magazine fire-arm.
Consists of means for operating breech and lock and the magazine and cartridge feeder. Reciprocating breech is moved and locked by a brace pivoted in the bolt; operating projection of brace is engaged by or connected to a sliding guard, by which it is operated. Cartridge feeder pivoted to frame and turning down at side thereof, having grooves to receive and guide cartridges by their flanges in combination with a magazine box or casing secured to the side of the breech-frame to receive and cover cartridges.

Patent 372,191 — 25 Oct 1887
Allender, Henry — Detroit, Mich.
Machine-gun.
Machine-gun, the main priciple of which is the use of semi-chambers whereby the reciprocating motion necessary to insert a fresh cartridge and extract the shell is entirely dispensed with. Has two rotary shafts, each carrying on its periphery series of semi-chambers adapted to register with each other; wheel on one of shafts carrying number of circular projections corresponding to semi-chambers therein, and having in each projection a firing pin opposite center of chamber; wheel on other shaft having depressions adapted to mesh with said projections, etc.

Patent 431,668 — 8 Jul 1890
Mauser, Paul — Oberndorf, Ger.
Bolt-stop with cartridge-shell ejector for breech-loading guns.
In a breech-loading bolt gun, the combination, with the breech-case and bolt, the latter constructed with a recoil projection at its front part entering a socket in front part of breech-case when bolt is locked, of a bolt-stop consisting of an arm pivoted to exterior of breech-case, having stop-tooth entering the latter and standing in the path of said recoil projection, and a spring for holding said arm against breech-case.

Patent 439,248 — 28 Oct 1890
Maxim, Hiram S. — London, Eng.
Machine gun.
Substitution of hydraulic apparatus whereby proper movement of breech block is insured without at any time imparting a high velocity to said block and also to insure closing of breech without jar or shock. At termination of recoil or backward movement of barrel, breech-block will be unlocked therefrom and will continue backward movement by force applied to said block by barrel in its return movement either by hydraulic or other means. Other improvements on Maxim gun.

Patent 441,673 — 2 Dec 1890
Krnka, Silvester and Karl — Michle, A.-H.
Straight-pull breech-loading gun.
Relates to gun in which breech bolt is adapted to be reciprocated endwise for opening and closing breech and combined with magazine underneath bolt feeding cartridges through slot in receiver. Consists in improvements to strengthen breechbolt by double locking lugs, to simplify means for guiding cartridges from magazine to chamber, to provide automatic spring-flap closer to receiver, to enable magazines to be filled with cartridges while either connected to or separated from gun.

Patent 472,795 — 12 Apr 1892
Mannlicher, Ferdinand — Vienna, A.-H.
Repeating fire-arm.
Object to render breech bolt action generally used in repeating fire-arms capable of effectually resisting most powerful charges, while making same shorter and lighter. Combination with sliding breech-bolt of guide ribs, radially disposed on lower side of sliding part and receiver, having interior grooves which permit ribs to slide, and with recesses to receive locking studs.

Patent 478,222 — 5 Jul 1892
Burgess, Andrew — Owego, N. Y.
Magazine firearm.
To produce double-barrel magazine gun having peculiar breech system; to improve breech system, so that one set of bolt-operating mechanisms is required for double bolt; to lock one of bolts by connections from other bolt; to connect firing devices, so one hammer may fire own cartridge and, if desirable, actuate mechanism to fire other cartridge.

Patent 574,189 — 29 Dec 1896
Carr, Howard — San Francisco, Calif.
Recoil-operated firearm.
Relates to firearms employing longitudinally-movable barrel actuated by recoil, and comprises improved breech movement for weapon (rifle or shotgun). Barrel and breech-bolt connected by pair of links pivoted together and actuated to withdraw breech-bolt and open breech and to return bolt to normal position.

Patent 613,195 — 25 Oct 1898
Driggs, Louis L., NYC, and Tasker, V. C., Wash., D. C.
Rapid fire gun.
Improved mechanism for opening and closing breech, improved firing mechanism for firing cartridge, improved extractor for removing and ejecting empty case. In breech-loading rapid-fire guns.

Patent 643,119 — 13 Feb 1900
Garland, Frank M. — New Haven, Conn.
Automatic machine-gun mechanism.
Improvement in mechanism in Patent 643,118 to simplify and perfect action of mechanism which holds the parts, so as to accomplish the backward movement of the breech-block while the barrel is drawn forward. Relates to arrangement, location and action of catches that engage and hold pivot block of breech-block levers as it moves backward with breech-block and barrel so that levers oscillate and draw back breech-block as barrel moves forward.

Patent 661,897 13 Nov 1900
Toll, Herman H. Clarinda, Iowa
Machine-gun.

Combination of a barrel and a bolt adapted to slide telescopically thereon, to contain a cartridge and load same into barrel as bolt moves forward, bolt having opening in one side through which cartridge is fed thereto, and another opening, in advance of former, covered by barrel as bolt moves forward and uncovered by barrel as bolt recedes, through which latter opening shell is ejected. A number of guns may be combined in a single arm for field or naval service.

Patent 708,794 9 Sep 1902
Browning, John M. Ogden, Utah
Automatic firearm.

Magazine firearm in which breech block not only is adapted to move on the frame to and from the barrel to be engaged by reaction-spring and be positively limited in its movements on frame, but shall be readily removable from frame and disengaged from spring without use of tools. Also positive means for indicating when supply of cartridges is exhausted and renewing supply without operating breech mechanism.

Patent 710,411 7 Oct 1902
Bergmann, Theodor Gaggenau, Ger.
Firearm.

Improvement in brakes for automatic firearms without stiff bolts to prevent breech bolt or cylinder from being pushed back forcibly in event of a heavy charge. Obtained by a breech-bolt or cylinder which is enlarged during discharge of the weapon by exercising friction on sides of the casing. Uses wedge.

Patent 764,513 5 Jul 1904
Young, Franklin K. Boston, Mass.
Firearm.

Improvements in breech mechanisms in firearms in which initial movement of breech mechanism after firing is rearward movement of firing pin actuated by the explosion before movement of the bolt. Provides means for automatically locking bolt before cartridge is exploded and automatically unlocking it after explosion. Also guide and support for bolt when it is thrown back and means for automatic return to firing position.

Patent 796,307 1 Aug 1905
Fay, Charles P. and Mossberg, Oscar F.
Chicopee Falls, Mass.
Breech-loading firearm.

To provide breech-closing mechanism in which when bolt is moved forward to close breech the hammer will be momentarily arrested toward end of breech-closing movement of bolt, then allowed to advance after bolt has been locked, whereby when end of bolt comes in contact with cartridge, end of firing pin will be retracted thus preventing possible premature explosion. Bolt locked non-rotatably in receiver by cocking movement of hammer.

Patent 799,884 19 Sep 1905
Odkolek, Adolf von Vienna, A.-H.
Automatic firearm.

Relates to gas-actuated breech loading guns. Simplification of breech mechanism to strengthen gun and increase efficiency.

Patent 800,103 19 Sep 1905
Hellfritzsch, Louis Berlin, Ger.
Automatic small-arm.

Relates to automatic recoil-operated breech-loading firearm having sliding barrel. During rearward movement of barrel only the breech-bolt, which is provided with straight locking-nipples, performs a partial revolution within the barrel enlargement, thus disengaging the nipples, while independent movement of breech-bolt effects release of nipples from grooves of barrel enlargement, whereby the breech closure is unlocked. Also coupling arrangement to provide for a single loading.

Patent 802,582 24 Oct 1905
Muller, Bernhard Winterthur, Switz.
Automatic firearm.

Automatic firearm with sliding barrel and locked breech, the breech-block carrier being arranged to slide on the barrel and with a trigger perfectly independent of the hammer. Bolting device consists of an upper bolt carried by barrel itself and of a lower bolt lodged in the frame, which latter bolt when the barrel has slid forward keeps the upper bolt raised behind a projecting part of the breech-block carrier with a view to locking the latter with the barrel. Upper bolt falls simultaneously with backward sliding of barrel in consequence of a recess in lower bolt.

Patent 823,004 12 Jun 1906
Taylor, Cecil H. Philadelphia, Pa.
Automatic gun.

In a gun, a movable breech-block having a plurality of breech-faces, means for reciprocating same and means for rotating same in one direction to bring said breech faces successively in line with barrel, said means comprising a cam-groove and a stud engaging therein.

Patent 836,554 20 Nov 1906
Bennett, Thomas G. New Haven, Conn.
Firearm.

Improvement in guns having "balanced" breech blocks, made so as to move back under thrust of recoil and operate breech mechanisms, a balance being established between thrust of recoil and inertia of the mass of the block and power of block-closing spring and power required to open breech mechanism. Breech block remains at rest when gun is fired.

Patent 889,279 2 Jun 1908
Warnant, Jean Liege, Belgium
Pistol.

Improvements in firearms, either automatic or break-down. Combination with one portion comprising breech casing, breech bolt and slide therefor, of another portion comprising barrel and breech bolt rod mounted thereon and connected to the slide, one of said portions being mounted to break relative to the other.

Patent 909,233 12 Jan 1909
Schmeisser, Louis Erfurt, Germany
Breech mechanism for self-loading firearms.

Breech mechanism designed for firearms for which a stronger charge of powder is used, e. g., automatic rifles and guns; also for quick-firing guns provided with recoil barrels in which lock is opened by recoil of explosion. Combination of breech casing, breech bolt therein, and locking lever with buffer having an inclined face opposed to rear end of lever to tilt same, and removable closure to breech casing, said closure carrying the buffer.

Patent 909,849 — 12 Jan 1909
Dawson, Arthur T. and Buckham, George T.
Westminster, Eng.
Automatic gun.
Improvement in Maxim-type guns to enable feed block and breech mechanism to be readily accessible independent of each other. Cover plates of both are pivoted to same axle in such a manner that either piece can be reached without uncovering other.

Patent 935,237 — 28 Sep 1909
Savage, Arthur J. — Chicopee Falls, Mass.
Firearm.
Automatically re-loading fire arms. Combination in a firing arm of a barrel, a frame, a longitudinally and vertically movable recoil operated breech block, an inertia piece connected to breech block and serving to operate the latter vertically.

Patent 954,543 — 12 Apr 1910
Ross, Charles L. — Balnagowan Castle, Scotland
Breech-closing mechanism for automatic firearms.
Relates to repeating firearms operated by recoil, particularly pistols in which undischarged cartridges are contained in a magazine within grip or handle. A barrel and a breech bolt mounted for sliding movement and a toggle formed of links pivotally connected to barrel and bolt members respectively and connected with each other to fold together backwardly from said pivotal connections when in firing position.

Patent 956,430 — 26 Apr 1910
Schmeisser, Louis — Suhl, Ger.
Automatic firearm.
Firearm automatically loaded by recoil and provided with tilted barrel, and characterized essentially in that breech bolt, which is introduced into the receiver from the front, is raised with and on being raised can be removed from, the receiver which is rigidly connected to barrel.

Patent 991,398 — 2 May 1911
Walther, Carl — Zella, Ger.
Automatic firearm with stationary barrel.
To provide a firearm in which breech block is guided at its front end by a sleeve secured around the barrel and at its rear by means on the stock, whereby when it is desired to remove the breech block, sleeve is removed and breech block then conveniently removed. Detent intended to hold breech block open to remove sleeve may also be used for holding breech block open for inserting a single cartridge in lieu of utilizing magazine.

Patent 993,175 — 23 May 1911
Knotgen, Mathias — Cologne, Ger.
Automatic firearm with stationary barrel.
Breech block pushed back by gases formed by combustion of the charge and driven into position ready for shooting. Essential feature of invention lies in a spring which at the beginning opposes resistance to return movement of breech block but when block is moved back to some extent, is released, thus assisting further return movement of block and tensioning of spring. Permits opposing to return movement an appreciable resistance while avoiding any danger of block not being completely moved back.

Patent 1,002,764 — 5 Sep 1911
Schmeisser, Louis — Erfurt, Ger.
Breech-operating mechanism for automatic firearms.
Relates to device for connection and disconnection of return spring and breech block in automatic firearms with stationary barrels and recoiling breech blocks. A member which carries both rear and front sights is pivoted to breech block and a projection on this member engages with a corresponding projection on a sleeve of the return spring to connect said breech block and spring.

Patent 1,008,552 — 14 Nov 1911
Mauser, Paul — Oberndorf, Ger.
Small-arm.
Modification of Patent 943,949 referring to recoil loader with fixed barrel and locking levers actuated by a sliding cam plate. Invention facilitates withdrawal of breech block during single loading without necessity for retaining cam plate in its unlocking position. Spring catch is provided in connection with sliding cam plate. It engages with cam plate and holds it fast until breech is opened and has again been closed, whereupon after catch has been moved back, cam plate springs back into its locking position.

Patent 1,018,914 — 27 Feb 1912
Krnka, Karl — Hirtenberg, A.-H.
Automatic firearm.
Relates to improved breech block, enabling a firearm of this character to be made with a relatively short and self-contained breech casing. Consists in an improved breech block, comprising a sliding and rotary locking breech bolt sleeve, a breech bolt and a breech bolt plug for effecting initial unlocking movement and then effecting complete unlocking movement and opening sleeve thru gas pressure produced in gun barrel. Also utilizes an accumulator to store and utilize energy to close and lock sleeve and cock firing pin under tension.

Patent 1,020,596 — 19 Mar 1912
Brauning, Karl A. — Herstal, Belgium
Automatic firearm with fixed barrel and breech action.
Breech action controlled by a lock rotating in a movable breech bolt, the combination of a firing pin with a rotating lock centered by cylindrical part of the firing pin, means by which firing pin is displaced backward. Means by which rotating lock is acted upon by firing pin and a sear pivoted to firing pin.

Patent 1,021,130 — 26 Mar 1912
Brown, Richard J. W. — London, Eng.
Breech mechanism for automatic recoil-operated guns.
Barrel receiver slidable in stationary part of the firearm and in which breech block slides, breech block and receiver being connected by downwardly breaking toggle levers, at times held against downward movement by ribs on stationary part but at the proper time moved downwardly by a tumbler rocked by the movement of the receiver. Catches for holding receiver in rearward position to insure safe and positive reloading.

Patent 1,021,381 — 26 Mar 1912
Sjogren, Carl A. T. — Stockholm, Sweden
Firearm.
Relates to firearm in which breech bolt is operated entirely automatic and consists in combination with a breech bolt movable to swing about its front end when mechanism is to be opened, of a weight movable under the action of the recoil and acting to swing said breech bolt out of engagement with the abutment, when firing takes place.

Patent 1,034,750 — 6 Aug 1912
Whittier, Walter H. — Grand Rapids, Mich.
Automatic firearm.
Automatic gun, comprising a reciprocal barrel extension, a breech bolt, a bayonet lock to connect bolt and extension, re-

ciprocal carrier in which breech bolt is both rotative and longitudinally movable, means for rotating breech bolt when same moves longitudinally within carrier to engage and disengage bayonet lock, latch on carrier to engage and hold breech bolt when same is in unlocking position and means for disengaging latch when breech and carrier are forward

Patent 1,042,363 — 22 Oct 1912
McClean, Samuel N. — Cleveland, Ohio
Breech-loading and discharge-actuated firearm.
Discharge-actuated machine gun having a breech bolt and operating part engaging with a helical drum feed for consecutively and positively retaining and controlling the feeding and firing of the cartridges. Breech mechanism and feeding, firing and ejecting mechanism operated and controlled by a single operating slide; devices for utilizing powder gas; interlocking form of mechanism removable by hand without tools; novel cartridge magazine and magazine feeding mechanism.

Patent 1,043,670 — 5 Nov 1912
Chronis, Aris D. — Dusseldorf, Ger.
Breech-block mechanism for firearms or guns.
Relates to firearms wherein breech-blocks are unlocked by recoil of the whole weapon. A movable device moves backward during the recoil of the gun at first with the gun and when the latter has come to rest continues to move alone and thereby unlocks the breech block. In hand firearms recoil occurs as a matter of course and is taken up by shoulder of operator. In guns with stationary carriages provision must be made for allowing the movement.

Patent 1,073,452 — 16 Sep 1913
White, Joseph C. — Chelsea, Mass.
Firearm.
Automatic firearm comprising a breech closer, a member to retard the opening of the breech closer and rotatable to strike the breech closer to aid in opening the latter, after the pressure of the gases in the barrel has fallen to the desired point. Barrel rigidly attached to frame; delayed extraction of empty shell to await partial abatement of gas pressure.

Patent 1,073,908 — 23 Sep 1913
Kiraly, Paul von and Lovasz, Josef — Budapest, A.-H.
Automatic breech-loading firearm.
Improvement in breech mechanism of automatic firearms so that it will be adapted to afford a relatively great inertia yet having a comparatively low weight and small compass. Combination of 2-armed lever as a connective member for parts of breech block, arms being of different length.

Patent 1,075,431 — 14 Oct 1913
McClure, Adolphus C. — Keithville, La.
Automatic repeating firearm.
Provides breech block projecting and locking means disposed within receiver of the firearm for automatic release, due to the recoil from explosion of a cartridge within breech of barrel and effect thereof upon breech block. Manual controlling means for retracting breech block to eject an unused shell or for introducing 1st loaded shell into breech. Means for rendering elevator mechanism inactive during manual retraction and projection of breech block.

Patent 1,077,166 — 28 Oct 1913
Schwarzlose, Andreas W. — Charlottenburg, Ger.
Breech mechanism.
Front member of the knuckle is extended up to rear end of the barrel so that at the moment of firing the back thrust of the cartridge head is not received by breech block but directly by front member of the knuckle joint and is transmitted to the rear member.

Patent 1,077,760 — 4 Nov 1913
Schmeisser, Louis — Erfurt, Ger.
Automatic firearm.
Has rectilinearly moving breech mechanism opened through recoil of fire arm by movable butt cap. Tenon of the connecting device between butt cap and breech block engages a depression provided with an incline of breech block to automatically unlock breech block and move it backward, while breech block carries an oscillating spring controlled locking lever which causes breech block to swing into locking position.

Patent 1,096,679 — 12 May 1914
Chronis, Aris D. — Larissa, Greece
Breech mechanism for automatic firearms.
Improvement in Patent 1,043,670 (1912) to reduce to minimum effort required for unlocking the block. Unlocking effected by recoil of whole weapon. The mass of the displaceable member can be considerably reduced and unlocking effected in weapons in which recoil is not sufficient to bring about automatic action. Locking is positive and not due to friction which would cause an immediate shifting of cartridge case on firing due to gas pressure.

Patent 1,109,910 — 8 Sep 1914
Eastwick, James — Fyning Wood, Eng.
Automatic small arm.
Small arm of type in which opening of breech is effected by the forward lurch, on discharge, of a weight which is capable of moving a short distance relative to the rest of the breech mechanism. Combines stock, barrel, a raceway fast therewith, recoil spring, breech bolt, a weight, a spring between bolt and weight, and means actuated by this spring for unlocking the bolt.

Patent 1,114,150 — 20 Oct 1914
Knotgen, Mathias — Cologne, Ger.
Automatic firearm.
Improvement on Patents 993,175 and 1,055,759, in which breech blocks are moved to and fro for removal of an empty cartridge and insertion of fresh one. New arrangement of levers and springs for effecting said movement, permitting use of tensile spring and better distribution of rebound.

Patent 1,131,360 — 9 Mar 1915
Fyrberg, Andrew — Worcester, Mass.
Automatic hand-firearm.
Improvement in firearm described in Patent 1,105,416 (1914). Breech block readily disconnected from recoil spring device to allow moving breech block rearwardly by hand to position 1st cartridge in magazine. Complete withdrawal of breech block and firing pin can be had for repairs or other purposes. Barrel quickly and securely fastened in position on frame.

Patent 1,144,285 — 22 Jun 1915
Becker, Reinhold — Krefeld, Ger.
Automatic firearm.
Relates to automatic firearms in which breech piece is not locked in its forward position but is released from its rear position and projected forwardly on actuating trigger. Cartridge chamber is provided with an extension adapted to receive a plunger on end of breech piece when latter moves forward. Ignition is adapted to take place before breech piece reaches its foremost position. Piece continues forward dur-

ing firing of shot, thus insuring gas-tight closure of rear end of barrel and reduces the recoil, which is then only sufficient to return piece to its rear position.

Patent 1,159,059 — 2 Nov 1915
Mauser, Paul — Oberndorf, Ger.
Automatic firearm.
Breech mechanism comprising a rotary breech member provided with locking lugs, and consisting mainly in the combination of the rotary member with a locking member which in closed position engages one of locking lugs, thereby locking breech member against rotation and which on firing is automatically released or moved from its locking position whereby breech member is free to rotate and to open breech.

Patent 1,165,621 — 28 Dec 1915
Nelson, Charles A. — Utica, N. Y.
Firearm.
Relates to automatic recoil-operated guns. Means for controlling opening of the breech upon explosion of the charge with a view to prevent dangerous release at the breech of the powder gases. Provides cartridge chamber of gun with means for setting up resistance to backward movement of the shell and the consequent expansion of the shell.

Patent 1,166,913 — 4 Jan 1916
Krnka, Karl — Hirtenberg, A.-H.
Automatic firearm.
Improvement on Patent 1,018,914 (1912) on breech mechanism for automatic firearms in which head of rigidly locked breech bolt is able to move short distance back and cartridge case is able to move back for a limited short distance. Provides necessary space for rearward movement of bolt head at another point of breech mechanism, thereby attaining advantageous ratio of transmission of motion, although less strain on cartridge case occurs.

Patent 1,169,249 — 25 Jan 1916
Frommer, Rudolf — Budapest, A.-H.
Automatic firearm.
Improvement in automatic arms having sliding barrels and breech blocks of bolt type, whereby such arms can be readily converted into hand-loaders. Retaining device by which breech block is temporarily held in its retracted position during return movement of barrel to initial position can be rendered inoperative when used as hand-loader.

Patent 1,180,784 — 25 Apr 1916
Mauser, Paul — Oberndorf, Ger.
Rotatable breech-bolt for automatic firearms.
Improved breech bolt wherein locking part does not lock the breech bolt directly but through the medium of a pawl inserted between locking part and the breech bolt, such pawl in its inner position controlling the movement of the bolt nipples and being positively rocked inwardly and outwardly by locking part in its longitudinal movement.

Patent 1,184,065 — 23 May 1916
Borchardt, Hugo — Charlottenburg, Ger.
Breech mechanism for automatic firearms.
Provides breech mechanism allowing its automatic operation even when blank cartridges are used. Decreases work to be effected by gas pressure when shooting blanks by displacing or altering the breech members. For instance, in arm having toggle breech, inserting between toggle joint and breech casing a lifting block which bears upon the wall of the casing so as to lift or partly break the joint.

Patent 1,196,759 — 5 Sep 1916
Borchardt, Hugo — Charlottenburg, Ger.
Device for retaining the breech-block of automatic firearms in the rearward position when the magazine is empty.
Breech closure is held by a spring engaging device and is therefore resiliently supported so that interengaging faces of locking member and of breech block are secured from injury due to shock.

Patent 1,227,668 — 29 May 1917
Reising, Eugene G. — Hartford, Conn.
Firearm.
Hand firearm having breech-bolt actuating lever, lever detent, mounts for said lever and detent arranged to cause detent to exert its greatest resistance to the movement of the lever when latter is in its closed position and separate member to return detent to its position of rest.

Patent 1,262,181 — 9 Apr 1918
Dawson, Arthur T., and Buckham, George T.
Westminster, Eng.
Automatic gun.
Relates to guns in which barrel recoils and breech mechanism comprises a reciprocating lock provided with a vertically moving cartridge carrier. Object to construct and arrange breech mechanism so that a comparatively long recoil of the barrel can be obtained for purpose of diminishing shock on gun trunnions when gun is fired. Crank is angularly displaced about its axis to initially bend the toggle levers.

Patent 1,286,884 — 3 Dec 1918
Revelli, Abiel B. — Turin, Italy
Machine-gun.
Improvement in machine guns having one or more barrels for lighter weight and greater rapidity of firing. Comprises a casing, a reciprocatory breech block within casing, with means on breech block to engage a longitudinal slot and helical notch in casing, a plunger on breech block with means on plunger to engage helical notch of breech block and means to reciprocated breech block and plunger relative to the casing.

Patent 1,323,025 — 25 Nov 1919
Darne, Regis and Pierre — St. Etienne, France
Automatic firearm or machine-gun.
Relates to gas-operated machine guns. Comprises inclined planes for controlling oscillation movements of breech block, these planes being arranged near the top and at the rear part of the firing pin support and acting on corresponding inclined planes arranged opposite them on lower side of breech block. Cartridges drawn out and elevated from belt by means of 3 elevators pivotally mounted on firing pin support.

Patent 1,327,897 — 13 Jan 1920
Baldwin, Arthur S. — Baltimore, Md.
Gun.
Improved means for operating breech mechanism through the force of the gases expelled at the muzzle after shell has left latter. Avoids use of cylinders or inclosed pistons and blows directly into atmosphere all unburnt powders with gases. Expelled gases directed against a movable abutment mechanically connected to breech mechanism.

Patent 1,340,891 — 25 May 1920
Graham, Oliver B. — Cleveland, Ohio
Breech closure.
Relates to breech closure of type covered in Patent 1,340,943. Moves the locking member of the breech closure

mechanism into locking position quickly, smoothly and positively, to move it both to and from firing chamber with breech block, to actuate breech block and locking member by common means, and to attain other results in subject mechanism.

Patent 1,340,943 25 May 1920
Eickhoff, Theodore H., and Payne, Oscar V.
Cleveland, Ohio
Breech-closure.
Improved closure comprising 3 principal elements: breech block in form of reciprocatory bolt, a locking member and a stop or abutment. Coordinated so that breech block is locked in advanced positions at relatively high breech pressures, but unlocked and retracted in response to reduced breech pressure. Lock moves longitudinally with and transverse to block. Action independent of magnitude of breech pressure.

Patent 1,344,499 22 Jun 1920
Gabbett-Fairfax, Hugh W. London, Eng.
Automatic firearm.
Relates to automatic machine guns in which breech mechanism is operated by compressed air or compressible fluid. Utilizes energy developed on firing gun to compress air and store it in a receiver attached to gun mounting or to gun, from which container air or fluid is taken to operate gun. Energy required to compress air or fluid obtained either by recoil movement of barrel or by a sliding or rotary muzzle cap, or both.

Patent 1,344,911 29 Jun 1920
Lewis, Isaac N. London, Eng.
Breech-action for firearm.
Improved action by which breech may be opened and closed rapidly with minimum of jar and wear on parts. Locking and unlocking operations effected by a relatively light and small locking piece capable of rotation relative to main portion of breech block.

Patent 1,347,756 27 Jul 1920
Payne, Oscar V. Cleveland, Ohio
Gun.
Relates to automatic guns having reciprocatory breech closure arranged to rotate into locked position at forward end of its stroke. Improvements designed to overcome difficulties causing excessive wear and breakage. Blends reciprocatory and rotary movements of breech closure; interlocking abutments on closure and receiver; means for automatically closing slots formed in receiver for projecting parts of breech mechanism.

Patent 1,357,857 2 Nov 1920
Gabbett-Fairfax, Hugh W. London, Eng.
Automatic firearm.
Relates to recoil-operated machine guns and small arms in which bolt and barrel are unlocked during or at end of recoil when barrel returns to forward position of rest while bolt remains stationary or completes recoil. Invention provides bolt capable of a limited rotation and having a radial arm controlled and operated by a reciprocating cam plate. Also 2 independent spring controlled drums connected by chains to breech sleeve and cam plate respectively for returning recoiling parts.

Patent 1,359,635 23 Nov 1920
Thompson, John T. Newport, Ky.
Gun.
Provides breech closure adapted for use in all types of guns in which a reciprocating bolt is positively locked by a non-reciprocating member and in which breech closure has no other motion in either locking or unlocking than its reciprocation in opening and closing chamber. Comprises bolt reciprocating relatively to gun breech and non-reciprocating locking ring encircling bolt together with interlocking means upon bolt and ring.

Patent 1,391,496 20 Sep 1921
Pedersen, John D. Jackson, Wyo.
Firearm.
Modification of breechblock mechanism in Patent 1,348,-733 (1920), autoloading pistol operated by power slide actuated by gas pressure. Improved slide-and-block mechanism in which breechblock is movable with slide and is movable rearwardly prior to rearward movement of slide. Transmits rearward movement to slide after which breechblock is retarded in its rearward movement while slide continues to move. Breechblock engaged with frame of pistol.

Patent 1,397,698 22 Nov 1921
Payne, Oscar V. Cleveland, Ohio
Gun.
Improved construction and disposition of breech lock in guns having breech lock provided with oblique locking surfaces so that breech is closed during high breech pressure but automatically unlocked by pressure after it has decreased to a relatively low value. Increased strength and durability of lock, uniform and unfailing action of breech closure, increased effective bearing surfaces of lock, etc.

Patent 1,406,546 14 Feb 1922
Eickhoff, Theodore H. Cleveland, Ohio
Breech closure for guns.
Relates to breech closures in which high breech pressures are transmitted through abutting surfaces of limited area. Initial locking made more certain at time of high pressure; released as pressure lowers. Invention provides breech closure having 2 abutment members so load is distributed over practically entire area of opposing faces to reduce breakage and wear.

Patent 1,410,270 21 Mar 1922
Pedersen, John D. Jackson, Wyo.
Firearm.
Improvement in breechblock mechanism set forth in Patent 1,348,733 (1920). Improved slide-and-block mechanism in which breechblock transmits rearward movement to slide and is retarded relatively to slide during an early part of rearward stroke of slide and during shell-extracting period, without requiring breech block to have compound movement relative to the slide.

Patent 1,410,524 21 Mar 1922
Asbury, Dorsey F. Washington, D. C.
Breech closure.
Provide means independent of elasticity and resiliency for utilizing motion imparted to breech closure by discharge of gun to open and close same, thereby eliminating use of spring elements of any kind as a positive actuating medium in operation of automatically opening and closing gun breech.

Patent 1,425,808 15 Aug 1922
Thompson, John T. Newport, Ky.
Breech mechanism for guns.
Mechanism affording smoothness of action during rapid fire and permitting extremely rapid fire. Comprises a lug and mechanism for moving lug behind an abutment on breech closure to restrain latter when it is in position to close firing chamber and removing lug after firing to permit rearward movement of the closure. Lug utilized on its entering movement for driving the firing pin to discharge cartridge.

Patent 1,425,809 15 Aug 1922
Thompson, John T. Newport, Ky.
Breech-closure mechanism.

Relates to breech mechanisms for automatic guns operating automatically in response to the breech pressure acting through the breech closure. Employs in combination with bolt a lock which instead of reciprocating back and forth along same path between locked and unlocked positions moves along an orbital or continuing or closed path, movement of lock being substantially continuous, pausing only when in locking position. Movement of lock rendered synchronous with that of closure, preferably by means of a spring.

Patent 1,425,810 15 Aug 1922
Thompson, John T. Newport, Ky.
Automatic gun.

Relates to breech closure mechanism whereby restraining means operates in synchronism with the closure, continuous with the closure movement and in a path continuing in the same sense into and out of restraining position.

Patent 1,426,851 22 Aug 1922
Fokker, Anthony H. G. Amsterdam, Holland
Breech lock for machine guns.

Improvement in the means of holding the breech block firmly in position while shot is fired, by means of independent locking members which transmit the pressure acting on breech block when shot is fired, directly to frame of gun instead of to crank mechanism which reciprocates the breech block.

Patent 1,433,945 31 Oct 1922
Eickhoff, Theodore H. Cleveland, Ohio
Gun mechanism.

Relates to breech closures for guns. Automatic gun which cannot be fired until bolt is closed and locked, and functions automatically in response to breech pressure acting through the bolt, thereby obviating all auxiliary mechanism such as gas-operated, recoil-operated and other mechanism. Improved buffer, fire control mechanism, bolt stop, magazine attachment, etc.

Patent 1,456,811 29 May 1923
Marga, Uldarique A. Dieghem, Belgium
Automatic firearm.

Relates to firearms of kind in which movable breech is bolted to barrel during a certain time after percussion of cartridge and thus carries barrel with it in its recoil movement. Insures that unbolting of movable breech of barrel will take place at proper instant. Effects on recoil a partial rotation of barrel in order to disengage barrel from breech block, when latter has completed a portion only of recoil movement.

Patent 1,497,096 10 Jun 1924
Eriksen, Johan Christiania, Norway
Machine gun.

Improved breech mechanism for machine guns in which loading and firing mechanism is actuated by reciprocating piston whose backward stroke is caused by action of powder gases. Rear end of recoil piston has connecting rod turnably attached to it; other end of rod turnably connected to disc-shaped eccentric which is connected to rear end of rod carrying the firing mechanism.

Patent 1,502,676 29 Jul 1924
Kewish, John T. New York, N. Y.
Automatic rifle.

Provides simple breech mechanism for cartridge-using firearms, adapted to be operated with primer, regular movement of barrel or both combined as desired. Convertible to single shot or rapid fire. Simplified trigger mechanism and elimination of trigger guard.

Patent 1,518,498 9 Dec 1924
Furrer, Adolf Berne, Switz.
Automatic firearm.

An articulated breech mechanism actuated by recoil comprising a breech bolt frame movable in stationary guides of stock and breech bolt proper movable in frame which bolt closes rear end of barrel. Comprises a pivoted link moving bolt in bolt frame, which link is pivotally connected to supporting link in rear which rotates on a pin in stock of weapon.

Patent 1,520,671 23 Dec 1924
Rosier, Henry Lowell, Mass.
Automatic firearm.

Sliding breech block carrying a firing pin, a locking device, a hammer and trigger mechanism including a member normally lying in contact with hammer and with locking device and operable to release the hammer from said device, hammer adapted when released to throw said member out of contact with locking device.

Patent 1,550,759 25 Aug 1925
Swebilius, Carl G. New Haven, Conn.
Automatic firearm.

Utilizes gas pressure within barrel immediately after firing to lock breech mechanism in closed position until gas pressure has diminished sufficiently to allow gun to be safely unbreeched. Provides a lever one end of which cooperates with breech locking mechanism to maintain latter in locking position. Opposite end subjected to the gas pressure within barrel to maintain locking mechanism in operative position until pressure diminishes.

Patent 1,568,005 29 Dec 1925
Sutter, Charles Suresnes, France
Accelerating device for automatic firearms.

Comprises spring which stores up the energy imparted thereto by the firing mechanism at the end of its rearward stroke, said spring, which is called the accelerating spring, then gives back this energy at commencement of forward stroke of firing mechanism, at same time causing an acceleration of the movement of the latter. Pivoting lever interposed between actuating mechanism and accelerating spring.

Patent 1,613,205 4 Jan 1927
Soncini, Cesare and Castelli, Vittorio Brescia, Italy
Automatic firearm with recoiling barrel.

Breech bolt accomplishes a rectilinear movement only while a supplementary member effecting at suitable moments the locking of the breech bolt with the barrel accomplishes rotary movements controlled by breech bolt and by effect of screw shaped surfaces controlling the movement thereof.

Patent 1,625,994 26 Apr 1927
Gorton, Walter T. Springfield, Mass.
Machine gun.

Improvements on Browning gun for mounting in pairs in aircraft. Means for alternate feeding of a cartridge belt, stripping of links from cartridge, stopping cartridge and belt, extracting and ejecting. Adapting of barrel extension and bolt for the functioning of the extractor and ejector during alternate assembly and operation.

Patent 1,637,235 — 26 Jul 1927
Norman, George — Birmingham, Eng.
Automatic firearm.
Relates to automatic guns in which recoiling breech bolt compresses a spring in which energy is stored. Provides means whereby the return spring can be held or locked when compressed in breech bolt, in order to facilitate assembling and stripping of the parts of the gun. Internal lugs are provided on end cap and adapted to engage with lugs on outer end of bolt when latter is drawn to its outward position.

Patent 1,648,833 — 8 Nov 1927
Vincon, Gustavo — Turin, Italy
Breech-closing mechanism for automatic firearms.
Provides two retaining shoes on head portion of breech block engaging with corresponding shoulders provided in a member secured to the cradle. Permits rotation of breech block towards its open position owing to the reaction resulting thereon when firing.

Patent 1,744,162 — 21 Jan 1930
Hatcher, James L. — U. S. Army
Gun.
Means for locking and unlocking breech closure of a gun barrel. Intended for guns wherein a high pressure is developed. Barrel is held against longitudinal displacement while permitting rotary movement thereof, and actively to oppose unlocking action of breech bolt by reason of having unlocking rotary movement of the barrel in the direction of the rifling of the barrel.

Patent 1,746,471 — 11 Feb 1930
Herlach, Fritz and Rakula, Theodor — Dusseldorf, Ger.
Automatic firearm.
Relates to automatic firearm having sliding barrel and longitudinally moving locked breech, opened during recoil to eject empty cartridge and supply new one. Required recoil acceleration is imparted by an accelerating mechanism that operates elastically. A spring acts on breech piece after barrel and breech piece have been unlocked from one another during common recoil. Mechanism can be adapted to conditions of any firearm by suitable determination of spring's power and relaxing stroke.

Patent 1,755,034 — 15 Apr 1930
Stange, Louis — Sommerda, Ger.
Automatic firearm.
Hollow stock constitutes rear guiding member of recoiling breech piece. Stock connected so that it can be easily disconnected from the other parts of the casing containing trigger, breech sleeve and barrel. After removal, casing can be opened at rear end and parts are readily accessible.

Patent 1,759,277 — 20 May 1930
Revelli, Bethel A. — Turin, Italy
Automatic firearm.
Breech closure is obtained, as in small automatic pistons, by means of the weight of the breech block combined with the action of a spring pressing it forward, thus keeping the breech block of a moderate weight and size. Percussion effected in advance of the complete closure of the breech block so that the latter is still moving forward to close breech at moment of discharge whereby pressure of exploded charge is admitted to a space in chamber surrounding neck of cartridge to balance internal pressure thereon.

Patent 1,799,284 — 7 Apr 1931
Coupland, Richard C. — Norfolk, Va.
Operating mechanism for machine guns.
To replace rigid bolt operating slide in machine guns with a flexible operating mechanism which will function in a more satisfactory manner and provide greater freedom of installation for both the proximate and the remote guns mounted in aircraft.

Patent 1,801,070 — 14 Apr 1931
Browning, John M. — Ogden, Utah
Breech mechanism for firearms.
Provides single pivoted lock link or bolt which directly engages the breech bolt to normally hold it in firing position. Upon recoil lock bolt is automatically moved out of obstructive relationship with the breech bolt and a connecting means is provided between breech bolt and lock bolt for transmitting motion from former to latter.

Patent 1,801,179 — 14 Apr 1931
Stange, Louis — Sommerda, Ger.
Automatic firearm.
Relates to apparatus in automatic firearms in which breech mechanism moves axially with barrel and in which a rearward acceleration is imparted to breech piece after it has been unlocked from barrel. Acceleration relative to barrel is imparted to unlocked breech piece by one or more members rotatable about bore of barrel, by the parts of the weapon which are moved on firing.

Patent 1,809,222 — 9 Jun 1931
Soncini, Cesare — Brescia, Italy
Automatic firearm having a recoiling barrel and an amplifying push lever.
Improved weapon characterized by the following: accelerator lever and bolt are formed and arranged so that the one operates upon the other without the intermediary of any spring and without contact between the two being broken at any time when weapon is in use. Lever drives and controls movements of breech and bolt directly and all other operating parts indirectly.

Patent 1,825,904 — 6 Oct 1931
Heinemann, Karl — Dusseldorf, Ger.
Automatic firearm.
Provides movable latch which, in its inner position, forms an abutment for the end of the spring pressing on the breech, preventing its outward pressure and relieving breech from same, so that latter can be removed easily and without danger. Applied to automatic gun with toggle link closure. Automatically thrown into latching position when gun is opened.

Patent 1,845,242 — 16 Feb 1932
Coupland, Richard C. — U. S. Army
Bolt operating mechanism for machine guns.
Mechanism consists of a slide retracted by means of a flexible cable and having an individual return spring. Facilitates initial retraction of slide when gun barrel is locked to bolt. Used in aircraft where bolt handle is inaccessible to gunner.

Patent 1,858,498 — 17 May 1932
Hatcher, James L. — U. S. Army
Bolt operating mechanism for machine guns.
Auxiliary operating mechanism when gun is mounted, as in aircraft, so handle is inaccessible to gunner. Rigid slide bar type having pivoted handle arranged to act as lever in

raising bar from its latch-plate and in initially retracting bar when barrel is locked to bolt. Bar also has fixed handle.

Patent 1,897,710 14 Feb 1933
Pelo, Carl Tavastehus, Finland
Light machine gun.

Positive operation of breech block with respect to movement of barrel sleeve together with barrel is effected by a two-part angle link constructed as a rack drive, which forms the connection between the breech and the slide.

Patent 1,906,800 2 May 1933
Marek, Anton Vienna, Austria
Automatic firearm.

Relates to automatic arms with sliding barrel of type in which accelerated backward movement is imparted to breech mechanism by means of an impelling device after disengagement of breech from barrel. Invention obviates occurrence of shocks and jolts by providing impelling device with controlling and actuating means adapted to impart to breech mechanism a backward movement in relation to the barrel.

Patent 2,015,908 1 Oct 1935
Rakula, Theodor and Herlach, Fritz Solothurn, Switz.
Automatic firearm.

Means operative in dependence on forward movement of breech block relatively to barrel suitable for interlocking lugs on breech block and barrel to automatically couple these two parts with each other in order to ensure subsequent rotation to complete the interlocking. Barrel and breech block remain together until locking lugs engage with each other and cannot be separated prematurely, for instance by recoil. Prevents barrel from flying forward relative to breech block. Coupling device also is catch for barrel in its rear position.

Patent 2,031,305 18 Feb 1936
End, Gotthard and Gaetzi, Jacob Schaffhausen, Switz.
Automatic firearm. (Cl. 42-3)

Relates to automatic gas operated firearms having stationary barrel and locked breech bolt. "Open breech closure" mechanism normally held at its rear position and only by actuation of trigger does it close and simultaneously fire the cartridge, which it introduces on its closing movement from magazine to chamber. Never a cartridge in chamber except at moment of ignition. Prevents "cook offs." Form of construction divides closing movement of breech closure mechanism into 2 phases of which only the latter is used for actual firing of cartridge.

Patent 2,035,303 24 Mar 1936
Delacre, Henri Boulogne, France
Automatic quick firing arm. (Cl. 42 4)

Whole of movable breech piece and of barrel, suitably locked together, is mounted in a slideway, so as to permit the recoil when a shot is fired. At end of recoil, breech piece is unlocked from barrel and temporarily maintained in this position by a catch. Feeding organ containing fresh cartridge is so arranged to be released by return movement of barrel and bring cartridge opposite chamber. Device for slowing rate of fire consisting of cylinder in which a piston moves by compression or suction, thus braking return stroke of barrel or breech piece.

Patent 2,037,647 14 Apr 1936
White, Joseph C. Wakefield, Mass.
Gun. (Cl. 42-3)

Improved recoil-operated breech mechanism for self-loading guns. Toggle joint or crank structure comprising 3 main elements which are readily assembled or dismounted with respect to receiver, as a unit.

Patent 2,050,538 11 Aug 1936
Moore, Frederick T. E. Hartford, Conn.
Automatic firearm. (Cl. 89-27)

Improvement on Browning machine gun (Patent 1,293,-021—1919). Breech bolt, instead of being at its forward position at the end of firing, is held in its rearward position and construction of gun is such that cartridge is thus maintained in a rearward position and prevented from entering chamber of heated barrel. Bolt released when firing resumed. Prevents explosion of cartridge in heated barrel.

Patent 2,052,287 25 Aug 1936
End, Gotthard Schaffhausen, Switz.
Automatic firearm. (Cl. 42-3)

Increased initial velocity and increased range and accuracy necessitate a long barrel. Breech action permitting use of a locked breech closing piece, while retaining simplicity of inertia breech closure. Large pivoted magazine moved into position at right angles to barrel when in use, swinging back to position parallel to barrel.

Patent 2,067,322 12 Jan 1937
Herlach, Fritz and Rakula, Theodor Berlin, Ger.
Automatic gun. (Cl. 89-3)

In large caliber machine guns, use of removable housing wall members for purpose of inspection or changing parts in barrel and breech system is not possible. Invention provides, in automatic guns having a sliding barrel, a longitudinally movable breech and separate running out device for each, a single movable cover-like part of the housing, permitting the bringing of barrel and breech system out of cooperation of running-out mechanism. Also includes propelling member for accelerating backward movement of breech block, control device for bolting barrel and breech together, and barrel securing member.

Patent 2,078,155 20 Apr 1937
Pelo, Carl Helsingfors, Finland
Automatic rifle. (Cl. 42-4)

Relates to automatic rifles for high explosive cartridges and combines brief recoil movement of barrel and breech block with reliable locking of breech block to barrel. Invention removes drawbacks of weight, reliability and simplicity by locating catches in the breech block and guiding same with guide grooves provided in rifle frame or a part connected thereto.

Patent 2,094,156 28 Sep 1937
Johnson, Melvin M., Jr. Brookline, Mass.
Firearm. (Cl. 42-4)

To provide automatic breech mechanism which has sufficient strength to function indefinitely with high-power ammunition, to facilitate the feed of cartridges to firing chamber, to improve locking and unlocking action of bolt, etc. Relates to semi-automatic type of firearms having bolt slidably mounted and locked to a reciprocating barrel.

Patent 2,101,957 14 Dec 1937
Sanders, Thomas F. London, Eng.
Recoil loading firearm. (Cl. 42-4)

Means for locking and unlocking the breech bolt at the appropriate times. A locking member is pivoted on breech casing and makes contact by a lateral surface with an abutment on a part that does not at first participate in the recoil. Latter may be an inertia member capable of sliding longitudinally in relation to breech casing or may be a support on which gun is mounted to recoil against resilient means.

Patent 2,104,033 4 Jan 1938
Green, Samuel G. Gray, Ga.
Bolt operating mechanism for machine guns. (Cl. 89–27)
Facilitates manual retraction of breech bolt and to this end bolt handle is arranged to have an initial lever action. Handle also arranged so that it is not retracted by breech bolt during firing of gun.

Patent 2,181,131 28 Nov 1939
Johnson, Melvin M., Jr. Brookline, Mass.
Breech mechanism. (Cl. 42–25)
Combination of a bolt, an extractor extending along the side and overhanging the forward end of the bolt, an operating handle for manually moving bolt, and a plunger extending through both handle and extractor and thence into a recess in the bolt for interlocking parts together.

Patent 2,199,871 7 May 1940
Birkigt, Marc Bois-Colombes, France
Automatic firearm. (Cl. 42–3)
Relates to guns with breech structure constituted of 2 elements movable axially with respect to each other, one constituting breech block proper and other carrying firing pin. Interposes between the two elements an elastic means for urging the firing pin carrier toward the front of the firearm, with respect to the breech block proper.

Patent 2,199,872 7 May 1940
Birkigt, Marc Bois-Colombes, France
Automatic firearm. (Cl. 42–3)
Relates to gun in which movable breech structure is adapted to recoil after firing of each shot against the action of a counter spring. Avoids drawback of violent shock on disengagement of breech block from breech casing and re-engagement of firing pin carrier with breech block. Firing pin carrier and pawl carried by breech block have corresponding projections adapted to cooperate together to avoid excessive shocks.

Patent 2,202,201 28 May 1940
Henning, Hermann Berlin, Ger.
Automatic gun. (Cl. 42–4)
Relates to automatic gun with sliding barrel and locked breech. Comprises a latch between barrel and breech bolt, a slide provided with a spring to hold the latch in position releasing breech bolt and releasable against action of spring by forward movement of breech relative to barrel, and a resilient member associated with bolt and latch extending period of contact between breech bolt and latch.

Patent 2,251,304 5 Aug 1941
Summerbell, William Watervliet, N. Y.
Breech closure for guns. (Cl. 89–2)
To provide a breech block especially adaptable as a breech closure of the blow-back type in which a novel cartridge tray is retained in place through the instrumentality of a firing pin, and in which firing pin is retained and controlled in both cocking and firing by means of a lever without aid of springs.

Patent 2,267,501 23 Dec 1941
Holek, Vaclav Brunn, Czechoslovakia
Automatic firearm. (Cl. 42–3)
Relates to automatic firearms comprising a breech block the movements of which are controlled by a breech-block carrier. Device arranged between block and carrier in which there is stored up during recoil movement energy which on the locking movement of the breech block during forward movement of carrier is released to effect accelerated movement of carrier in relation to locked breech block. Prevents breakage of cartridges.

Patent 2,290,778 21 Jul 1942
Swebilius, Carl G. Hamden, Conn.
Bolt action firearm. (Cl. 42–17)
Improved construction and arrangement of parts whereby breech bolt and associated parts are retained in place in the structure.

Patent 2,296,242 22 Sep 1942
Brewer, Nicholas L. E. Longmeadow, Mass.
Firearm. (Cl. 42–3)
Improved mechanism in repeating guns. Relates to rear end of action of gun, including rearward part of breech bolt, hammer slidingly mounted in receiver to rear of bolt and assembly with said hammer of a hammer spring and breech bolt spring concentrically mounted about a guide rod.

Patent 2,297,693 6 Oct 1942
Dicke, Allen A. Montclair, N. J.
Autoloading firearm. (Cl. 42–3)
Assures that breech closing mechanism will remain fully closed until gas pressure has dropped to a certain predetermined value. Supporting collar is directly connected with breech block for longitudinal movement therewith.

Patent 2,308,257 12 Jan 1943
Williams, David M. New Haven, Conn.
Automatic firearm construction. (Cl. 42–3)
Improvement in construction of parts (including a breech-closing spring) whereby breech bolt of an automatic firearm is returned toward its breech-closing position following automatic retirement of bolt as an incident to discharge of gun. Breech closing means may be disassembled from firearm for inspection, cleaning, etc.

Patent 2,308,283 12 Jan 1943
Humeston, Frederick L. New Haven, Conn.
Repeating firearm. (Cl. 42–16)
Improvements in firearms employing reciprocating action-slide for actuating a movable breech bolt. Gas-operated system for actuating action slide without cramping action and with freedom for being conveniently released for dismounting.

Patent 2,320,348 1 Jun 1943
Clarkson, Ralph E. Hamden, Conn.
Firearm. (Cl. 42–3)
Arrangement of parts whereby breech bolt and associated parts are returned to normal positions after having been operated by discharge of firearm. Bolt return spring may be of sufficient length to function uniformly and be accommodated within buttstock of firearm without undue lengthening of stock.

Patent 2,321,592 15 Jun 1943
Green, Samuel G., Gray, Ga., and Hopkins, Edward W., Enfield, Conn.
Back plate and driving spring for machine guns. (Cl. 89–2)
Improved back plate structure for Browning gun permitting employment of a bolt return or driving spring of greater length. Increases source of energy for driving cartridge belt feed advancing mechanism of gun.

Patent 2,337,273 21 Dec 1943
Robinson, Thomas R., Jr. New Haven, Conn.
Locking-bolt actuating means for machine guns. (Cl. 89–3)
Superior actuating means that will withstand strains caused by rapidity of operation. Mounted for slight pivotal movement to resist shocks imposed on it.

Patent 2,350,821 6 Jun 1944
Revelli, Gino Rome, Italy
Bolt closer for automatic guns. (Cl. 42–4)
Means permitting retraction of breech block at a relatively low pressure thereby reducing friction, wear of parts and strain. Pawl provided with downwardly extending part designed to engage arm of bell crank lever only when lever has completed a predetermined angular movement.

Patent 2,351,976 20 Jun 1944
Koucky, Josef Brunn, Bohemia
Automatic firearm. (Cl. 42 3)
Relates to automatic arms having breech block actuated and controlled by breech block carrier. Recuperator spring arranged in connection with breech mechanism to actuate movements of striking member of firing pin and to actuate during forward movement the breech block carrier until locking position of breech block is reached.

Patent 2,352,193 27 Jun 1944
Gorton, Walter T. Springfield, Mass.
Automatic firearm. (Cl. 42–4)
Improved bolt operating mechanism for firearm having recoiling barrel. Utilizes recoil and "blowback" forces consecutively to obtain unlocking and opening of bolt. Bolt has locking member to engage stop on a fixed member attached to barrel.

Patent 2,356,595 22 Aug 1944
Koucky, Josef Prague, Bohemia
Breech device for firearms. (Cl. 42–16)
Breech device for firearms in which projectiles of a greater force of percussion are used. Characterized by a breech block forming a body having flat sides and tiltable around longitudinal axis of firearm and provided with locking lugs which engage in notches in casing of firearm. More favorable straining by the pressure of the gases produced in firing the cartridges is obtained.

Patent 2,357,047 29 Aug 1944
Horan, Timothy F. New Haven, Conn.
Automatic firearm. (Cl. 42–3)
Relates to guns in which bolt is moved rearwardly by firing reaction and returned to forward position by spring action. Retards temporarily return of bolt to breech closing position until cartridge lifter has had sufficient time to operate and lift fresh cartridge into position. Effected by a detent connected to trigger.

Patent 2,365,307 19 Dec 1944
Swebilius, Carl G. Hamden, Conn.
Self-loading repeating firearm. (Cl. 42–16)
Embodies a reciprocating breech bolt and manually operable slide for manually retiring the said breech bolt. Member acts to restrain bolt from turning movement relative to firearm structure. Operating slide does not partake of automatic rearward movement of breech bolt.

Patent 2,372,339 27 Mar 1945
Roemer, William C. New Haven, Conn.
Self-loading firearm. (Cl. 42–3)
Superior means for effecting actuation of breech bolt as a result of discharge of a cartridge. Means for guiding action slide during operation. Provision for accurate guiding of connecting means between piston and breech bolt.

Patent 2,373,761 17 Apr 1945
Humeston, Frederick L. Hamden, Conn.
Breech-closing means for self-loading firearms. (Cl. 42–3)
Improved breech-closing spring-means for moving breech bolt into its breech closing position following retirement of breech bolt after discharge of cartridge.

Patent 2,383,487 28 Aug 1945
Johnson, Melvin M., Jr. Brookline, Mass.
Automatic gun. (Cl. 42–3)
To provide fire-control mechanism which can be quickly and easily shifted from locked position to either automatic or semi-automatic condition and permits breech closure to remain in closed position after each semi-automatic shot. Retains breech closure in retracted position after automatic firing.

Patent 2,397,963 9 Apr 1946
Harvey, Earle M. Springfield, Mass.
Automatic firearm. (Cl. 42–3)
Improved form of primer-operated gun. Improved bolt construction which is light in weight, has minimum number of parts, readily assembled or disassembled.

Patent 2,425,749 19 Aug 1947
Lochhead, John L. Springfield, Mass.
Bolt lock for machine guns. (Cl. 89–188)
Improvement in bolt locks for Browning type machine guns. Provides breech lock for positive timing and locking of recoiling members of gun. Minimizes impaired function and stoppage resulting from lack of correct headspace.

Patent 2,466,577 5 Apr 1949
Corte, Alfred Glendale, Calif.
Bolt mechanism for guns. (Cl. 89–159)
Machine gun or cannon mechanism embodying a practical and effective breech block and breech bolt assembly. Provides barrel extension and multi-bolt combination. Empty cases reinserted in cartridge belt to prevent disintegration of belt. In order to successively withdraw a round from belt, fire it and replace in belt, a plurality of bolts is required for cooperating with single breech block, with round extracting means associated with bolts.

Patent 2,476,232 12 Jul 1949
Williams, David M. New Haven, Conn.
Inertia operated bolt lock. (Cl. 89–182)
Improved automatic firearm embodying a fixed barrel, a breechblock and a chamber-unit, latter being movable rearwardly with respect to said barrel on discharge of said firearm to initiate rearward excursion of breechblock. Forces of recoil are minimized by utilizing a chamber unit which moves only a very small fraction of total distance moved by breechblock. Resilient means independent of recoil spring for returning unit from its rearward position to normal.

Patent 2,484,694 11 Oct 1949
Dicke, Allen A. Upper Montclair, N. J.
Two-part breech closing mechanism for repeating firearms. (Cl. 42–18)
Improved rotary bolt firearm construction most of the parts of which may be utilized in repeating guns whether

repeating operation is effected by lever action, a sliding fore-end or "straight pull". Breech is closed by means of a bolt having one or more locking lugs preferably near its front end, which bolt is helically connected to a bolt carrier, slidably mounted in a receiver. Extractor carried on bolt. Impact firing mechanism extending above topmost cartridge in magazine.

Patent 2,501,069 — 21 Mar 1950
Maillard, Bernard — Geneva, Switzerland
Gas piston operated breechblock lock. (Cl. 89–191)
Relates to automatic firearms including breechblock slidable in a breech casing and cooperating with a gas-operated system to insure temporary locking of breechblock with respect to breech casing. This system utilizes transmission systems constituted by at least 2 independent push pieces disposed end to end and freely slidable with respect to breech casing whereby rebounding oscillations are quickly damped.

Patent 2,512,027 — 20 Jun 1950
Lippert, Hanns and Muhlemann, Ernst — Zurich, Switz.
Automatic firearm breech bolt lock. (Cl. 89–188)
Gas operated firearm including a split block body permitting displacement of the various parts in relation to each other, front part including rotatably mounted locking bolt sliding through its milled ends in a guiding groove of the breech casing terminating in a round hole and carrying gear teeth in engagement with a gear rack rigidly connected with the lock actuator carrying hammer, the control taking place through the movements of block and lock actuator in relation to each other.

Patent 2,515,315 — 18 Jul 1950
Saive, Dieudonné J. — Wandre, Belgium
Tilt locking breech block for automatic firearms. (Cl. 89–184)
Relates to firearms having fixed barrels and in which breech block is opened by a slide acted upon by the explosion gases. Right-angled lever provided in breech block housing, the 2 arms of which are unequal. Long arm is positioned along slide and has its end in shape of a cam coming in contact with a cam of the slide. End of other arm bears on front surface of breech block. From beginning of recoil slide acts on breech block through medium of lever and extractor exerts strong action slowly applied to cartridge.

Patent 2,529,391 — 7 Nov 1950
Hedges, Ellsworth C. — W. Hartford, Conn.
Bolt mechanism for machine guns. (Cl. 89–33)
Bolt mechanism for Browning type machine guns wherein cam block is held against vertical movement otherwise than by the extractor stud or by any other removable element engaging the stem or pintle of the cam block. Cam block or switch may be removed without removing extractor.

Buffing

Patent 1,298,911 — 1 Apr 1919
Dibovsky, Victor V. — Kingsway, London, Eng.
Machine-gun.
In an automatic gun of kind that has its main crank between the sides of the gun casing (Vickers) a construction of spring buffer is employed, which comprises a base and a sliding head movable in relation to base and which intercepts main crank near that end of its path toward which it is impelled by recoiling lock. Cushions resiliently companion webs of crank to reduce shock received during finish of recoil and accelerate return movement.

Patent 1,298,912 — 1 Apr 1919
Dibovsky, Victor V. — London, Eng.
Buffering device for machine guns.
Buffering device for use in high speed machine gun to counteract disadvantages arising because of degree of shock imposed on gun mechanism and liability to jam when rate of fire is increased by increasing rate of reciprocation of breech block and other parts. Spring and fusee provided at end of crank shaft so that leverage of fusee increases as crank moves toward end of path toward which it is impelled by recoiling lock.

Patent 1,338,649 — 27 Apr 1920
Gabbett-Fairfax, Hugh W. — London, Eng.
Automatic or semi-automatic firearm.
Interposes, between gases and mechanism for operating breech-action, a cushion of air which undergoes successive compression and expansion after each shot is fired, chamber containing air cushion being arranged so it has no communication with barrel nor with any chamber directly connected with it. Protects breech-closing mechanism from shock.

Patent 1,456,626 — 29 May 1923
Dawson, Arthur T. and Buckham, G. T.
Westminster, Eng.
Machine gun.
Relates to machine guns of Vickers automatic type, having relatively short recoil and high rate of fire. To absorb surplus energy at end of rearward movement of parts in such a manner as to obviate this disadvantage without reducing or materially reducing high rate of fire. Crank comes against a fixed stop-piece at end of movement of crank during recoil.

Patent 1,499,846 — 1 Jul 1924
Tansley, George H. and Pfeiffer, Christian
Hartford, Conn.
Automatic machine gun.
Relates to guns in which adjustable buffer rests against rear wall of breech casing and in which said wall comprises a plate transversely removable from casing. Provides easily accessible means for adjusting buffer without opening casing, together with means for indicating amount of such adjustment on outside of casing. Means may be automatically disengaged from engagement with buffer.

Patent 1,548,708 — 4 Aug 1925
Browning, John M. — Ogden, Utah
Recoil buffer for automatic guns.
Improved buffer for cushioning blow of recoiling members at end of recoil. Horizontally moving buffer block projects forward through opening in chamber of rear plate. Recoiling breech block strikes front face of buffer block and drives it rearward. Rear portion of block is held against downward movement by bottom of chamber in rear plate, thus forcing transversely sliding block to compress elastic discs and cushion blow of breech block.

Patent 1,561,713 — 17 Nov 1925
Gorton, Walter T. — U. S. Army
Buffer mechanism for machine guns.
Mechanism which receives the impact of recoil at a central point and dispels or absorbs the shock by oppositely disposed cushioning members, which may be variably maintained in constant relation. Also novel buffer plug and buffer cam maintained in rigid assembly which permits free camming action and prevents binding and tilting of cams.

Patent 1,565,756 — 15 Dec 1925
Rockwell, Hugh M. — Bristol, Conn.
Automatic gun.
Improvement in "heavy Browning" machine gun mounted in aircraft. Provides novel buffer carrier which is small and compact and reduces length of gun. Means whereby breech bolt may be retained in its rear position. Release of bolt allows same to return to firing position.

Patent 1,834,021 — 1 Dec 1931
Destree, Joseph — Brussels, Belgium
Firearm.
Movement of recoil is damped by the gases taken from the barrel at a distance from the breech at least equal to a number of times the length of the cartridge. Shock absorbing gases act on a member connected mechanically to breech, said gases tending to displace this member in reverse direction to recoil of breech.

Patent 1,960,913 — 29 May 1934
Marek, Anton — Vienna, Austria
Self loading firearm. (Cl. 42–4)
Relates to arms comprising a travelling breech the movement of which into the locking and unlocking positions is governed by actuating or controlling means. Provides a shock absorbing device which influences the unlocking and locking movements of breech. Consists of guiding means which guide breech positively during its controlled movement.

Patent 2,116,141 — 3 May 1938
Browning, Marriner A. — Ogden, Utah
Gas operated automatic firearm. (Cl. 89–2)
A buffer is provided which is engageable by the operating slide for cushioning the movement of the latter to normal position. Also the piston tube is arranged to vibrate longitudinally so as to assist in preventing deposits in the cylinder.

Patent 2,364,103 — 5 Dec 1944
Simpson, Clarence E. — Springfield, Mass.
Recoil mechanism. (Cl. 42–4)
Improved shock absorbing mechanism adapted for mounting under barrel. Includes a breech operating rod within its assemblage. Produces hydraulic energy absorption in 2 directions wherein amount and rate of energy absorption for either direction may be independently and conveniently changed. Permits shoulder firing of firearms of cal. .60 or larger.

Patent 2,395,211 — 19 Feb 1946
Bell, Davitt S. and Wikander, Oscar R. — Pittsburgh, Pa.
Automatic gun. (Cl. 89–44)
Improvement on Patent 2,370,835 (1945) for gun having energy absorbing spring having coacting friction surfaces for absorbing recoil energy of gun. Employs substantially frictionless spring and an energy absorbing spring so constructed as to limit total recoil to not over a predetermined amount.

Cartridges

Patent 39,405 — 4 Aug 1863
Joslyn, Benjamin F. — Stonington, Conn.
Improvement in revolving fire-arms.
Deals with revolving fire-arms in which metallic cartridges are used. Consists of device for preventing spent cartridges from interfering with rotation of cylinder; device for operating cylinder through movement of hammer; device serving double purpose of center pin for front of cylinder and instrument for removing spent cartridges from chambers of cylinders.

Patent 44,363 — 20 Sep 1864
Wood, S. W. — Cornwall, N. Y.
Improvement in revolving fire-arms.
In use of metallic case cartridges, loaded in cylinder chambers from front end, rear ends being permanently closed, except for apertures to give access to face of hammer. Chambers are somewhat conical or flaring, with greatest diameter at front. Cartridges have corresponding taper form. Enables easy extraction when once started from 1st position.

Patent 115,911 — 13 Jun 1871
van Choate, Silvanus F. — Boston, Mass.
Improvement in breech-loading fire-arms.
Adaptation of needle gun or Chassepot gun to use of metallic cased cartridge instead of paper or cloth cartridge. Cartridge case started by rotary movement of bolt, then withdrawn from barrel by the sliding movement of the same. Notch or score in breech bolt, together with ejector, used to seize and eject case.

Patent 923,431 — 29 Jun 1909
Luger, Georg — Charlottenburg, Ger.
Cartridge having multipart projectiles.
Improved construction of respective bullets in cartridge having a plurality of bullets which take separate flights because of variation in size and weight. Invention improves construction to insure their separate trajectories and to provide means for insuring prompt separation of the bullets without creating a retarding force.

Patent 1,081,983 — 23 Dec 1913
Pedersen, John D. — Jackson, Wyo.
Cartridge.
To effect completion of head of cartridge shell for enabling this head to sustain maximum gas-pressure, by utilizing gas pressure itself to form or finish head into its final shape and to do this subsequently to the firing of the primer. Without mobility between tube of shell or any part thereof and the extractor rim.

Patent 1,856,022 — 26 Apr 1932
Blacker, Lathan V. S. — London, Eng.
Machine gun and small arm.
Comprises a breech-block adapted to fit externally over the barrel. Cylindrical case adapted for sliding fit over rear end of barrel. Twin barrels each provided with externally fitted breech block. Loading effected through slot in breech block. Ignition of charge effected by pneumatic means. Cartridges have completely consumable charge (e. g., cordite). Cartridges connected together by interconnecting webs of same material as charge.

Patent 2,099,993 — 23 Nov 1937
Tauschek, Gustav — New York, N. Y.
Firearm. (Cl. 42–4)
Enables series of shots to be fired with the aid of a plurality of projectiles arranged in a novel relation to each other. Shell closed at one end and open at other with a plurality of bullets arranged in tandem fashion within such shell and with a charge of powder or the like between each 2 neighboring projectiles.

Patent 2,391,865 14 Feb 1942
Chandler, Edward F. Brooklyn, N. Y.
Self-propelled projectile.
Projectile having a tapered internal bore in the after section containing a combustion chamber and reaction jets projecting rearward from the combustion chamber. Ignited gases are forced against the base of the charge to keep the walls expanded and seal the gases in the bore.

Patent 2,514,422 11 Jul 1950
Simpson, Clarence E. Springfield, Mass.
Cartridge. (Cl. 102–44)
Improved cartridge for firearm of type wherein an element of the cartridge actuates a piston or tappet member which in turn effect operation of breech mechanism of the firearm. Particularly for cal. .60 projectiles. Breech mechanisms of arms actuated by set back of the cartridge primer. Piston-like inserts mounted on base of cartridge independent of primer.

Charging and Cocking

Patent 231,652 31 Aug 1880
Coloney, Myron St. Louis, Mo.
Magazine-gun.
Provides breech-loading as well as magazine fire-arms with recoil spring and follower, firing pin and trigger, so combined that piece will be cocked automatically by explosion of the charge. Trigger adapted to catch pin automatically and instantaneously whether released by finger or not.

Patent 327,914 6 Oct 1885
Anson, William Small Heath, Eng.
Breech-loading fire-arm.
Relates to hammerless guns, by which cocking is effected by the dropping of the barrels for charging. Invention dispenses with use of fore-end as a means of cocking and to cock gun by means of a solid block or pillar, referred to as "cocking-block". Block is placed on barrel, relieving fore-end iron of strain in act of cocking.

Patent 884,065 7 Apr 1908
Brauning, Karl A. Zaandam, Netherlands
Hand-firearm.
Improvement in recoil-operated automatic firearms. Combines, with a bolt, a stationary rail and a spring-actuated firing-pin in the bolt, a cocking lever pivoted in bolt and actuated by engagement with the rail when the bolt is retracted, said lever engaging firing pin to move it into cocked position and independent means passing through firing pin to hold firing pin in cocked position and simultaneously actuated by cocking lever.

Patent 1,059,680 22 Apr 1913
Menteyne, Paul M. and Degaille, Pierre A.
Paris, France
Automatic firearm.
Improvements in automatic firearms. A piece called "repetition arrester" which permits automatic charging of cartridges contained in the magazine or prevents such charging, according to its position. Mechanism in combination with "arrester" to warn firer when magazine is void of cartridges by maintaining open breech when last cartridge has been fired.

Patent 1,178,468 4 Apr 1916
Hartigan, Thomas F. Ghent, N. Y.
Firearm.
Relates to firearms in which cartridge is automatically placed in firing position and shell automatically ejected. Can be cocked without movement of breechbolt and without direct movement of hammer by manual operation when needed by reason of misfire or hangfire. Safety devices; improved magazine. A circulation of air is provided around barrel support and carrier to obtain uniform expansion and contraction of parts.

Patent 1,447,861 6 Mar 1923
Johnston, James S. Utica, N. Y.
Cocking mechanism for automatic machine guns.
Manual means adjacent the trigger for cocking the gun, whereby the hand of the operator will not be shifted from one part of gun to another in this operation.

Patent 1,471,348 23 Oct 1923
Paulus, Charles L. Dayton, Ohio
Charging device for machine guns.
Mechanism especially adapted for use in connection with the cal. .30 Browning machine gun adapting it to be charged by the use of the left hand of the gunner. Necessary when gun is flexibly mounted in an airplane. Charging stud of bolt of gun is free to move backward and forward entirely unhampered.

Patent 1,504,717 12 Aug 1924
Russell, Herbert O., Detroit, Mich., and Paulus, Charles L., Dayton, Ohio
Automatic cocking attachment for machine guns.
Provides for automatically re-cocking the gun upon failure to fire and when therefore there is no recoil action. Does not hamper forward movement of bolt which is accomplished only by bolt actuating spring. Allows gun to fire ammunition which would otherwise be worthless due to fact that the machine gun upon taking a single dead shell would stop its fire.

Patent 1,528,950 10 Mar 1925
Russell, Herbert O., Detroit, Mich., and Eyler, Lawrence J., Dayton, Ohio
Cocking handle for aerial guns.
Handle that is easily adjustable for the purpose of changing the gun from a right hand to a left hand cocking gun. Retracts bolt rearwardly on Browning aircraft machine gun.

Patent 1,821,385 1 Sep 1931
Holek, Emanuel Brunn, Czechoslovakia
Charging device for firearms.
Gas-pressure operated charging device of relatively small weight and adapted for portable firearms. Piston rod in cylinder of charging device constructed at its rear end so that it forms carrier for breech and also closing organ for aperture for ejection of empty cases and for supplying fresh cartridges to arm.

Patent 1,907,342 2 May 1933
Capell, William H. Hampton, Va.
Aircraft machine gun installation.
Device for loading or charging a pair of machine guns from a common source of supply. Central cartridge reservoir and means for conveying cartridges from reservoir to said guns, said means being operated by loading mechanism of the guns. Conveyor belt leads from hopper to each gun.

Patent 2,056,577 6 Oct 1936
Kehne, Karl Dusseldorf, Ger.
Cocking device for automatic firearms having a sliding barrel and a bolted breech. (Cl. 42–4)
To facilitate loading of large-bore guns having sliding barrel and bolted breech, invention provides a cocking device having a transmission device which assists the hand pull of the common return of the barrel and breech to point of unbolting. Lever then moves the unbolted breech alone further back, while continuing the movement in a straight line.

Patent 2,133,661 18 Oct 1938
Engel, Georg, Berlin, and Winter, Alfred, Dusseldorf, Ger.
Automatic firearm (Cl. 89–27)
Cocking mechanism for returning sliding parts of firearms against influence of recuperator devices which store recoil energy and release to move parts again forward is designed as a ratchet mechanism adapted to return moving parts in a series of steplike movements over entire recoil path into the cocked position. Multiplies manual force exerted by gunner.

Patent 2,180,751 21 Nov 1939
Wagner, Paul G. Los Angeles, Calif.
Machine gun starter and recharger. (Cl. 89–1)
Adapted for aircraft use for Browning-type guns. Electrically operated starter and recharger where several banks of guns are put under control of a single trigger-switch. Recharger comes into action instantaneously if a stoppage occurs. If successive cartridges are defective, device continues in operation until a live cartridge reaches the chamber. Automatically acting switch which opens firing circuit in event recharger starts into reloading operation.

Patent 2,202,232 28 May 1940
Rossmanith, Wolfgang Solothurn, Switz.
Cocking mechanism for automatic firearms. (Cl. 89–27)
Comprises an open ended chain which is guided in grooves in the gun body. Single sprocket wheel is required. Means at one end of chain adapted for engagement with a portion of the breech mechanism for cocking same.

Patent 2,340,705 1 Feb 1944
Slate, Thomas B. Washington, D. C.
Automatic machine gun charger. (Cl. 89–1)
Electrically controlled charger replaces the trigger solenoid. Carbon dioxide gas utilized to charge gun. Contains an automatic cut-off device to open the charging circuit after the charger has operated the gun for a predetermined number of times. This cut-off device is manually controlled. Contains a means for recharging automatically on failure to fire.

Patent 2,355,179 8 Aug 1944
Pontius, George W., III South Bend, Ind.
Automatic gun selector. (Cl. 89–1)
Selector mechanism for charging one or several guns with a common charging control. Incorporates a means for indicating which gun has jammed and will charge only the gun or mechanism which is inoperative.

Patent 2,356,981 29 Aug 1944
Drescher, John F. and Hirstensteiner, Walter E. Inglewood, Calif.
Hydraulic gun charger. (Cl. 89–1)
Gun charger, hydraulically operated, for multi-gun operation. Can also be used as a safety device.

Patent 2,386,801 16 Oct 1945
Johnson, Clifford E., Medway, and Elliott, Carleton R., Dayton, Ohio
Gun cocking device. (Cl. 89–1)
Simple charging or cocking unit which is interchangeable for association with different guns. Moves gun bolt to initial charged condition in engagement with its sear, preparatory to firing automatically. Comprises movable plunger adapted to engage and move gun bolt to charging position. Adaptable for use with guns placed in different positions in aircraft. Actuating means includes cable and pulley.

Patent 2,389,943 27 Nov 1945
Wall, Alexander C. Indianapolis, Ind.
Gun charger. (Cl. 89–1)
Mechanism for automatically recharging or reloading a machine gun in the event that it fails to fire. Provided with a counting device for disabling the device after its operation a predetermined number of times to reload gun. Device is reset after a defective cartridge is replaced, assuring operation until ammunition is exhausted.

Patent 2,397,507 2 Apr 1946
Roberts, Fred T., Jr. Los Angeles, Calif.
Remote-control gun charger. (Cl. 254–185)
Charger that may be remotely controlled so that charger may be mounted in any available space in wings, turret or fuselage and be operated by button convenient to pilot or gunner. Mechanism returns to normal position after setting operation is performed. Operating shaft may be continually rotated in one direction by means of electric motor.

Patent 2,408,624 1 Oct 1946
Goepfrich, George A. South Bend, Ind.
Gun charger. (Cl. 89–1)
Automatic charging device for automatic guns of type where reloading operation is effected by expansion of exploded gases in barrel and behind projectile. Electrical circuit for effecting manual charging of guns to make them ready for automatic operation and automatic charging of guns whenever necessary once automatic operation has begun. Employs fluid supplied by fluid pressure system of the aircraft. Provides automatic cut out means if one or more guns jam.

Patent 2,409,623 22 Oct 1946
Grant, Harry C., Jr. New York, N. Y.
Gun charger. (Cl. 89–1)
Gun charger for Browning type automatic machine guns adapted to be mounted on either side of a machine gun. Adjustable to compensate for variance in the stroke of the guns. Adapted to be operated by a high pressure fluid medium and apply sufficient force to initiate the movement of the bolt or charging mechanism. Improved detecting mechanism.

Patent 2,410,767 5 Nov 1946
Wisman, Franklin O. and Rohn, William C. South Bend, Ind.
Automatic machine gun charger. (Cl. 89–1)
Device for effecting re-loading operation of machine gun upon failure to operate. Employs usual fluid pressure system incorporated with aircraft. Readily adaptable for use with different kinds of automatic guns. Charging system for one or a plurality of guns. Automatic cutout system.

Patent 2,411,877 3 Dec 1946
Heizer, Edward J. W. Caldwell, N. J.
Gun charger. (Cl. 89–1)
Charger for recharging and recocking machine guns, automatic cannon, etc. Light and compact; minimum number of parts.

Patent 2,411,934 3 Dec 1946
Naugler, Walter E. Beverly, Mass.
Gun charging mechanism. (Cl. 89–1)
Produces in machine gun the recoil movement of the breech bolt if this does not result from gun discharge. Combines with gun having a breech bolt movable in recoil and counter-recoil, a motor, a movable charging member, as a reciprocatory rack acting upon breech bolt to produce movement in direction of recoil and means for connecting motor to member to cause charging movement of bolt.

Patent 2,413,104 24 Dec 1946
Goepfrich, George A. South Bend, Ind.
Gun charging mechanism. (Cl. 89–1)
Mechanism of hydraulic type for charging machine guns and small cannon of 37 mm type. Employs a telescoping piston arrangement which allows foreshortening of overall length of cylinder with respect to total stroke of piston arrangement. May be operated from a distant point for charging a gun.

Patent 2,431,079 18 Nov 1947
Richey, David M. Devon, Conn.
Gun charger installation. (Cl. 74–501)
To prevent shipping of charging cable in aircraft upon its release. Provides charger handle assembly that will pull cable in a straight line and prevent it from whipping as it snaps back.

Patent 2,458,028 4 Jan 1949
Rataiczak, Francis I. Dayton, Ohio
Operating mechanism for machine guns. (Cl. 89–1)
To provide low cost machine gun capable of firing high powered cal. .60 ammunition. Parts adapted for mass production. Improved hand cocking mechanism which makes it possible to hold bolt in any desired position.

Patent 2,535,156 26 Dec 1950
Pastore, Michael W., Hartford, and Rothwell, John C., Bolton, Conn.
Semiautomatic firearm with trigger operated cocking mechanism. (Cl. 89–196)
Mechanism operable by trigger for moving bolt rearward independently of the reaction spring to cock the firing mechanism, bolt then being movable forward by spring separate from reaction spring to effect loading. Mechanism not only moves bolt rearward but also releases it so it is moved forward by separate spring independent of mechanism.

Converters

Patent 739,732 22 Sep 1903
Sjogren, Carl A. T. Stockholm, Sweden
Automatic gun.
Provides in gun one or more movable weights, heavy bodies, pistons or the like, which on account of their inertia do not partake of recoil of gun, but move forward relative to the latter. This movement is accomplished by suitable mechanical connections between the weights and one or more of mechanisms in gun used to effect a certain function whereby gun can be made partly, semi or fully automatic. Weights are movable in longitudinal direction of gun and slide by its movement in suitable guides. Energy is stored up in springs to effect working of gun mechanisms.

Patent 852,253 30 Apr 1907
Benet, Laurence V. and Mercié, Henri A. Paris, France
Semi-automatic gun.
Improvement in semi-automatic guns to provide means for operating gun either semi-automatically (recoil) or wholly by hand, or to open it only semi-automatically and close by hand. Means for causing extractor to act as an automatic stop for breech mechanism until fresh case is inserted.

Patent 952,896 22 Mar 1910
Frommer, Rudolf Budapest, A.-H.
Firearms for hand and automatic loading.
Conversion from hand loader to automatic loader and vice versa takes place with greatest certainty; safety devices prevent conversion from only taking place partially. Position of handle indicates condition of the weapon. When automatic handle does not project out of weapon.

Patent 954,654 12 Apr 1910
Smith, Morris F. Philadelphia, Pa.
Firearm.
To render magazine automatic firearms easily convertible to hand loading and magazine reserve shooting and to facilitate hand loading by interrupting automatic operation after each shot with breech open ready to receive a cartridge dropped in by hand and then permitting completion of cycle of automatic operation by releasing breech closure.

Patent 954,797 12 Apr 1910
Hammond, Grant Hartford, Conn.
Automatic gun.
Conversion of gun employing longitudinally reciprocating breech-bolt adaptable for either single or magazine feeding into automatic gun wherein gas force is used to retract bolt, cock firing bolt and place trigger mechanism so that gun may be successively fired by trigger pull.

Patent 954,798 12 Apr 1910
Hammond, Grant Hartford, Conn.
Automatic gun.
Relates to attachment to Springfield rifle or other U. S. service gun, whereby with little alteration gun may be converted into an automatic gun, when desired. Automatic gun having bolt mechanism including a reciprocating breech bolt and means for imparting a rotary movement thereto; a mechanism operated forwardly by the gases of discharge; said bolt mechanism being normally uncoupled from gas operated mechanism, also means for storing energy of exploded charge and for coupling bolt mechanism with means for storing energy to permit automatic operation.

Patent 954,799 12 Apr 1910
Hammond, Grant Hartford, Conn.
Automatic gun.
Mechanism capable of attachment to existing types of magazine guns whereby gun may be converted to an automatic gun, when desired. May be instantly thrown into or out of connection with gun-action for conversion from single-firing to automatic or semi-automatic.

Patent 1,377,629 10 May 1921
Rosebush, Waldo E. Spokane, Wash.
Composite automatic firearm.
Improved composite automatic hand firearm that can be readily changed for use in target practice or for service by

the use of comparatively inexpensive interchangeable parts to accommodate the various cartridges of the hand firearm type of various calibers length and power. May be either hammerless or hammer. Interchangeable assembly of barrels, receivers, breech blocks and magazines in sets, using same frame and actuating mechanism.

Patent 2,139,691 — 13 Dec 1938
Michal, Charles J., Jr. — Hinsdale, Ill.
Machine gun. (Cl. 42–69)
Device for converting other firearms into machine guns. Utilizes motion of recoiling parts of a firearm acting against the natural resiliency of the trigger-finger of person firing arm, to automatically release safety mechanism of firearm and to discharge same in regular sequence.

Patent 2,452,617 — 2 Nov 1948
Wechsler, Joseph W. — New York, N. Y.
Gas operated shoulder weapon. (Cl. 89–140)
Improvements in M1 rifle. Mechanism to convert it to full automatic.

Cooling

Patent 231,607 — 24 Aug 1880
Parkhurst, Edward G. — Hartford, Conn.
Machine gun.
Device for keeping barrels of machine guns cool while firing. Uses water chamber without openings below water line surrounding barrels and adapted to hold water in direct contact with them. Barrels remain at about the temperature of the boiling water.

Patent 513,995 — 6 Feb 1894
Garland, Frank M. — New Haven, Conn.
Machine gun.
Relates to battery gun Object is construction so that it will not become hot under rapid explosion of cartridges. Inner casing contains liquids; outer casing vented for drawing in currents of air.

Patent 621,085 — 14 Mar 1899
Hookham, George — Birmingham, Eng.
Automatic gun.
Object to cool barrel without use of water. Combination of heat radiating ribs or surfaces attached to barrel and a mechanical air draft induced by each discharge of gun. Nozzle extends beyond barrel.

Patent 716,976 — 30 Dec 1902
Alfson, Andrew — Chicago, Ill.
Rifle.
Means for keeping magazine as well as loading and firing mechanism at a very low temperature during rapid successive discharges, to keep rifle from getting heated during long and continuous use. Provides outer chamber having suitable opening therein communicating directly with atmosphere and magazine consisting of a pair of perforated disks having cartridge chambers rigidly secured to said magazine, latter being revoluble on spindle or axis.

Patent 920,832 — 4 May 1909
Dawson, Arthur T. and Buckham, George T., London, Eng.
Automatic gun.
To lighten gun, water jacket made of thin steel tubing suitably strengthened by corrugating its surface, arranged lengthwise of the jacket and extending to within a short distance of its ends. Also increases area of jacket's surface exposed to atmosphere.

Patent 1,004,666 — 3 Oct 1911
Lewis, Isaac N. — Fortress Monroe, Va.
Air-cooled automatic firearm.
Object is to produce more effective cooling of firearms by air than now produced by water and to dispense with excessive weight of water chamber and water. Use of close-fitting jacket of high heat conductivity, such as aluminum. Rapid dissipation of heat by use of radiating longitudinal ribs or fins.

Patent 1,017,373 — 13 Feb 1912
Berthier, Andre — Paris, France
Cooling device for firearms.
Consists of a water jacket surrounding barrel to which water is supplied through a hole situated in rear part of casing and discharged through another hole in muzzle end thereof. Flexible tube carries away the steam generated in casing.

Patent 1,216,939 — 20 Feb 1917
Brotherston, Alexander M. — Moncton, N.B., Can.
Method of and apparatus for cooling gun barrels.
Means for cooling barrels of machine and quick-fire guns. Provides reservoir surrounding barrel and provided with a sump portion which will always be the lowest point of the reservoir at all angles of elevation within the range of the gun. A pump draws the cooling liquid from reservoir through a radiator and forcing it in a spray over entire length of barrel.

Patent 1,227,897 — 29 May 1917
Dunwoody, Henry H. C. — Washington, D. C.
Automatic gun.
Means for cooling barrels of rapid fire guns. A casing surrounding the gun barrel with means to admit air at one end of casing and means to create a partial vacuum at other end of casing. A plurality of disk like members provided with staggered openings for passage of said air located between casing and barrel.

Patent 1,290,853 — 7 Jan 1919
Sturgeon, John C. — Erie, Pa.
Firearm-barrel-cooling mechanism.
Air cooling mechanism. Secures to barrel longitudinal radiating strips of highly conductive metal preferably longitudinally corrugated, so as to present maximum radiating surface to action of air passing thereover. Extend from periphery of barrel outward and are inclosed by a metal shell open at its rear end and extending beyond end of barrel at its front end. Conical deflecting disks secured within shell covering radiators.

Patent 1,294,349 — 11 Feb 1919
Silloway, Frederick D. — Springfield, Ill.
Steam escape fixture for machine gun water jackets.
Means by which ports of steam tube in a machine gun jacket may be automatically controlled, so that lowermost of said ports will be closed and the uppermost opened simultaneously upon change of position of machine gun with respect to water level within the jacket.

Patent 1,294,892 — 18 Feb 1919
Fox, Ansley H. and Rice, Walter J. — Philadelphia, Pa.
Gas-operated automatic machine gun.
Simplified and strengthened construction. Improved air-cooling means for cooling barrel; readily operable while upside down or in any position. Reciprocating slide provided with upright spaced extensions, a breech bolt, and a firing

pin having a flattened portion near its rear end adapted to be fitted between extensions, firing pin carrying means for rotating and reciprocating bolt.

Patent 1,296,193 — 4 Mar 1919
Johnston, Millard L. — Utica, N. Y.
Cooler for firearms.
A casing, a barrel and ports in said barrel alining with ports in casing, whereby to permit a draft of air both before and after the charge to chill the barrel of the firearm.

Patent 1,333,498 — 9 Mar 1920
Lang, Charles W. — Philadelphia, Pa.
Rapid fire gun.
Improved rifle caliber rapid fire gun adapted to be operated semi-automatically or with full automatic fire at will. Gun mounted with increased stability against vertical deflection resulting from firing. Ready assembly of barrel with receiver, utilizing air flue tube to lock barrel against unscrewing relatively to receiver. Efficient cooling air flue around barrel, subjected to blasting effect of powder gases escaping from muzzle end.

Patent 1,351,017 — 31 Aug 1920
Blackmore, Charles C. — Dayton, Ohio
Automatic gun.
Novel arrangement of twin guns, or two duplicate gun mechanisms, in such a manner as that the reacting force of discharge of one of the guns may be utilized to load and fire the other gun. Improved means for air cooling guns whereby a current of air is forced into each barrel and through it each time barrel is fired.

Patent 1,379,339 — 24 May 1921
Haskell, George D. — Concord, Mass.
Machine-gun.
Improved means for air-cooling machine guns. Casing surrounding barrel and extended forwardly beyond the muzzle, air ports entering said casing near its opposite end, whereby firing of gun will cause a current of air to enter casing and flow along barrel.

Patent 1,406,404 — 14 Feb 1922
McCrudden, John C. R. — Hurstville, N. S. W., Australia
Machine gun.
Improved means for inducing a draft of air over the barrel of gun for cooling it and means for masking the explosion flash and muffling the explosion report. Comprises finned radiator fixed on gun barrel, tubular casing enclosing radiator and extending forwardly thereof, air admission apertures in rear part of casing; conical tube concentrically disposed in said casing.

Patent 1,434,812 — 7 Nov 1922
Fowler, Elbert — U. S. Army
Machine-gun casing.
Machine gun in which breech casing and water jacket are axially aligned and in one integral piece. Novel arrangement of barrel with relation to water jacket whereby no portion of barrel exposed to the cooling medium when gun is in horizontal plane will be exposed by said medium when gun is tilted so as to incline upward. Means for locking rear end plate of gun. Other improvements.

Patent 1,527,585 — 24 Feb 1925
Hamilton, Laurens M., Paris, France, and others.
Means for cooling machine guns.
Casing surrounding barrel of gun and having openings at its front and rear ends, a rotary fan within said casing and mounted on barrel and over an aperture in the wall thereof rearward of the muzzle, and means for causing the compressed gases resulting from the explosions of the charges during fire to rotate said fan, thus producing a current of cooling air through casing.

Patent 1,549,051 — 11 Aug 1925
Schreiber, Bedrich — Prague, Czechoslovakia
Light machine gun.
No provision made for water cooling. Consists in an arrangement which enables the hot barrel to be readily exchanged by 4 manipulations and without changing position of gun.

Patent 1,551,617 — 1 Sep 1925
Pohlmann, Christian — Augsburg, Ger.
Machine or rapid-fire gun or the like.
Permits rapid and prolonged firing as with water-cooled guns or rifles by novel air-cooling device with plurality of successively placed and properly designed gas or air ejector nozzles. Strong suction created at barrel outlet at moment the lock is opened thus producing cooling-air currents in barrel. Increased reloading of gun as fast as firing is permitted by improved air cooling.

Patent 1,556,225 — 6 Oct 1925
Kung, Albert — Zurich, Switzerland
Automatic gun
Cooling arrangement. Adapted to cause a continuous renewal of the layer of air surrounding barrel and thereby a more intense cooling action. Recoil spring is arranged as a pump cylinder of a double acting pump the piston of which is formed by a closing ring fixed to barrel so that a renewal of cooling air is effected with every shot.

Patent 1,631,190 — 7 Jun 1927
Bull, William R. — Springfield, Mass.
Method of and apparatus for cooling gun barrels.
Provides pumping apparatus conveniently operable at a distance for circulating water through the jacket of the gun, the steam being condensed on return to the container enclosing the pumping apparatus.

Patent 1,963,086 — 19 Jun 1934
Green, Samuel G. — Gray, Ga.
Water jacket for machine guns. (Cl. 89–1)
Provides circulating system in the cooling jacket that may also serve as a steam escape system when the circulation of the cooling fluid is not employed. Outlet or return line of cooling fluid conveniently positioned in proximity to axis of elevation of gun.

Patent 2,026,528 — 7 Jan 1936
Green, Samuel G. — Gray, Ga.
Packed joint for guns. (Cl. 89–1)
Mounting whereby a shaft, rod or barrel will be in direct contact with a cooling medium over all or practically all of its length and packing material of the fluid seal will be spaced from the barrel by a portion of the cooling medium and by a metal sleeve.

Patent 2,077,415 — 20 Apr 1937
House, William E. — Auburndale, Fla.
Gun. (Cl. 89–2)
Modification of Browning machine gun so that barrel may be held stationary to facilitate air cooling thereof. Breech block and barrel extension permitted to perform usual recoiling movements. Front part of barrel extension separated from remainder of extension and secured to receiver and gas operated piston and rod attached to barrel extension. Piston has same amplitude of recoil as originally had by barrel.

Patent 2,112,144 — 22 Mar 1938
Coupland, Richard C. — Norfolk, Va.
Means for cooling gun barrels. (Cl. 89–14)
Provide air-cooled jacket for gun barrels which will be effective in conducting heat from the barrel and which may in part be conveniently extended to the rear end of the barrel.

Patent 2,129,648 — 13 Sep 1938
Catron, Russell M. — San Diego, Calif.
Rifle. (Cl. 42–4)
Improved semi-automatic rifle, adaptable with slight modification to completely automatic. Sights positioned at side. Air jacket for cooling purposes. Rifle casing extends past the end of the barrel to provide reaction for drawing fresh air through barrel after discharge.

Patent 2,140,809 — 20 Dec 1938
Moore, Frederick T. — W. Hartford, Conn.
Machine gun. (Cl. 89–14)
Improved construction of packing for machine guns with water cooled reciprocating barrels to prevent leakage of coolant between barrel and jacket. Improves cooling of weapon.

Patent 2,205,426 — 25 Jun 1940
Lochhead, John L. — Springfield, Mass.
Machine gun. (Cl. 89–14)
Means for cooling barrel of gun. Provides pumping apparatus which is operated by a portion of the gases of the propellant charge and which circulates the cooling fluid. Especially arranged to conduct the cooling fluid to breech of gun barrel.

Patent 2,337,840 — 28 Dec 1943
Scott-Paine, Hubert and Jaggard, Robert W. — Hythe, Eng.
Air-cooled gun. (Cl. 89–14)
Means for controlling the flow of air through cooling jacket which is automatically actuated in accordance with temperature of a part of the gun which becomes heated when it is fired. Provides an air inlet valve between a source of compressed air and the chamber between barrel and jacket, being thermostatically controlled.

Patent 2,363,563 — 28 Nov 1944
Vinson, Neal L. — Mill Valley, Calif.
Air-cooled gun barrel. (Cl. 89–14.1)
Improved air-cooling device for automatic weapons attaining an increased flow of air. Usual jacket cylinder separated from barrel by a considerable distance and provided with a plurality of air ports.

Patent 2,416,768 — 4 Mar 1947
Monner, Ray J. — Denver, Colo.
Machine gun cooling means. (Cl. 89–1)
Means for preventing transfer of heat from firing chamber to barrel; which will extinguish or inhibit bore combustion in gun after each firing. Uses compressed carbon dioxide into chamber after each firing.

Patent 2,427,374 — 16 Sep 1947
Walker, Brooks — Piedmont, Calif.
Air-cooled gun. (Cl. 89–14.1)
Provides cooling means for automatic arms. Stream or streams of fluid cooling agent are intermittently injected into breech end of bore of barrel during that portion of the period of automatic fire in which bore is unblocked by recoil mechanism and while bore is free of cartridge case, injections resulting from a valving action caused by recoil mechanism and in which supply of cooling agent may be controlled by movement of trigger or other moving parts of arm. Compressed air preferred agent.

Patent 2,428,359 — 7 Oct 1947
Permentier, Paul R. de — Casablanca, Morocco
Thermostatically controlled firearm cooling system. (Cl. 89–14.1)
Cools weapons in aircraft by utilizing air which is inevitably directed against the aircraft in flight. Forces air both directly around barrel and against various other parts of mechanism of weapon.

Ejection and Extraction

Patent 42,688 — 10 May 1864
Reynolds, Henry — Springfield, Mass.
Improvement in revolving fire-arms.
Relates to revolving firearms for use of fixed ammunition or other metallic cartridges; object is to provide for expulsion of discharged shells of such cartridges. Sliding pin, bolt, or piston enters cylinder chambers for expelling shells in forward direction.

Patent 53,955 — 17 Apr 1866
Crowell, George G. — Lime Rock, Conn.
Improvement in revolving fire-arms.
Applied to removal of cartridges introduced from the front. Based on removing shell by motion of the hammer. Can be so constructed as to remove the cartridge which is directly opposite to that which is being fired, or either of the other cartridges except that directly in line with barrel and in position to be fired.

Patent 99,505 — 1 Feb 1870
White, Rollin — Lowell, Mass.
Improvement in revolving fire-arms.
Object is to provide convenient means of ejecting exploded cartridge-shells, guiding cartridges to places and securing them in their chambers in cylinder. Uses ejector with coiled spring inclosed in it, acting as piston or rammer.

Patent 103,013 — 17 May 1870
Calver, George W. H. — Burlington, N. J.
Improvement in revolving fire-arms.
To furnish improved cartridge-ejector designed for attachment to all kinds of revolving or cylinder small arms. Uses sliding block the forward end of which is provided with a claw which draws shell out to rear.

Patent 133,732 — 10 Dec 1872
Wells, Charles S. — New Haven, Conn.
Improvement in cartridge-ejectors for revolving firearms.
Use of slide provided with hook in combination with oscillating lever and hammer or striker. Extractor and oscillating lever arranged to eject shell by blow from hammer in the act of firing. Use of starter and ejector for loosening cartridges by positive force and then ejected by sudden and rapid movement.

Patent 178,824 — 13 Jun 1876
Wood, Stephen W. — Cornwall, N. Y.
Improvement in cartridge-ejectors for revolving fire-arms.
Automatic ejector, adapted to be operated by the rotation of the cylinder independently of the firing mechanism.

Patent 179,084 20 Jun 1876
White, Rollin Lowell, Mass.
Improvement in cartridge-ejectors for revolvers.
Swivels or pivots ejector in front of cylinder in such a way that operation of ejector shall revolve the cylinder, so as to bring one chamber at a time in line with discharge barrel.

Patent 184,145 7 Nov 1876
Cochran, John W. New York, N. Y.
Improvement in revolving fire-arms.
Combinations of revolving cylinder with 2 or more extractors for withdrawal of 2 or more cartridges to be withdrawn from chambers simultaneously.

Patent 186,470 23 Jan 1877
Gardner, Henry L. Springfield, Mass.
Improvement in revolving fire-arms.
To eject empty shells automatically by discharging arm and without ejecting a loaded cartridge. Cylinder or barrel having 2 or more chambers, connected by small hole or orifice, made in such a manner that the gas generated by explosion of cartridge in one chamber will pass through said hole into next chamber and force out its shell if cartridge has been exploded. Enters chamber at point in rear of conical part of projectile.

Patent 171,506 28 Dec 1875
Cole, Otis F. Norwich, Conn.
Improvement in extracting shells from revolving fire-arms.
Automatically throws out empty shell from one chamber by firing off another one of the chambers in cylinder of a revolver. Small portion of gas generated by burning of powder is conveyed into muzzle end of chamber containing empty shell to be thrown out.

Patent 196,491 23 Oct 1877
Smith, Dexter Springfield, Mass.
Improvement in revolving fire-arms.
Ejector stem extending through, or nearly through, cylinder at its forward end, in connection with a bolt, spring and latch, arranged to be operated by projections in the joint where barrel is hinged to the frame. Starts shells from chambers of cylinder by slow or positive movement, then eject entirely from chambers by quick movement.

Patent 202,351 16 Apr 1878
Joslyn, Benjamin F. Worcester, Mass.
Improvement in revolving fire-arms.
Relates to mechanism for operating extractor of revolving firearm; consists of extractor stem extending through cylinder and arranged to revolve therewith and into a socket beneath the barrel, with a spiral groove and an annular groove made on inner end of stem, and a pin projecting into socket and also into said grooves to operate extractor.

Patent 202,915 23 Apr 1878
Ybarra, Luis Madrid, Spain
Improvement in revolving fire-arms.
Special chamber for receiving from rear end of revolver-barrel a portion of gas resulting from explosion of cartridge in cylinder and conveying it to one of discharged chambers to expel empty cartridge. Also device for controlling gas pressure in said chamber and device for expelling cartridge or shell when it is not desirable to discharge weapon. Recess in revolver stock for guiding cartridge into cylinder and for receiving empty shells as they are expelled.

Patent 204,334 28 May 1878
Joslyn, Benjamin F. Springfield, Mass.
Improvement in revolving fire-arms.
Sliding rod operating in socket attached to frame or upper part of barrel, and moving in a line parallel to axis of barrel, said rod being provided with wedge-shaped projection on outer end, adapted to pass between flange of shell and end of cylinder when rod is brought into position for that purpose as cylinder revolves. Automatically extracts shells from chambers by rotation of cylinder.

Patent 204,336 28 May 1878
Joslyn, Benjamin F. Worcester, Mass.
Improvement in extractors for revolving fire-arms.
Ejects shells from revolver chambers automatically as cartridges are exploded by operation of discharging arm. Consists of lever pivoted above cylinder, having at one end a wedge-shaped projection to pass in between flanges of shells and rear end of cylinder as the latter is revolved, and adapted at other end to be struck by piece secured to upper end of hammer.

Patent 223,101 30 Dec 1879
Bell, William H. Baltimore, Md.
Improvement in revolving fire-arms.
Device for automatically ejecting empty shells from breech loaded cylinders. Ejects each shell an instant of time prior to discharge of succeeding one through medium of mainspring operating hammer. Consists of retractor adapted to take hold of rim of shell and operated by mainspring through medium of hammer during descent of the same.

Patent 270,599 16 Jan 1883
Mauser, Paul Oberndorf, Ger.
Magazine fire-arm.
Relates to "Mauser" gun closed by cylindrical breech-piece. Provides means for extracting and expelling empty shells and for setting and releasing cartridge carrier.

Patent 271,091 23 Jan 1883
Marlin, John M. New Haven, Conn.
Ejector for magazine-guns.
To overcome difficulties in use of magazine guns in which breech-piece is reciprocating bolt in axial line with the barrel—namely, misplacement of cartridge as it comes from magazine to carrier. Uses combination of breech-piece, spring extractor-hook, cradle seated in breech-piece under extractor with projections from cradle to strike during rear movement of breech-piece to tip cradle and raise extractor hook.

Patent 301,181 1 Jul 1884
Trabue, William Louisville, Ky.
Revolving fire-arm.
Relates to special construction and arrangement of ejector-rod and operating-lever, by means of which former is permitted to freely rotate with cylinder; also means for positively locking rear end of cylinder in proper alignment with barrel at or before discharge. Forward end of ejector rod connected with rear end of link by which it is connected to operating lever so that rod is free to rotate; bolt adapted to be operated positively by pull on trigger, and moved thereby upwardly across curved groove to lock therein projection on rear end of cylinder.

Patent 398,064 19 Feb 1889
Mauser, Paul Oberndorf, Ger.
Cartridge-ejector for breech-loading fire-arms.
Relates to firearms having longitudinally sliding bolt. Improved construction of cartridge-ejector for such guns

(single-loaders, temporary detachable magazines, or repeaters). Ejector consists of bar to slide longitudinally in groove in breech-case and having ledge entering said recess, an ejector pin fixed to ledge and sliding in a hole in bolt-head, a spring in recess pressing backwardly against ledge, and a stop for limiting rearward movement of ejector.

Patent 427,587 — 13 May 1890
Mauser, Paul — Oberndorf, Ger.
Ring cartridge-extractor.
Improved extractor applicable to breech-loading bolt-guns whether bolt has separate head or not and whether it is formed with recoil or locking projections at front end or elsewhere. Extractor is steel ring cut open at one side, fitted around reduced end of bolt and attached thereto and having a claw for engaging the shell.

Patent 431,669 — 8 Jul 1890
Mauser, Paul — Oberndorf, Ger.
Shell-extractor for bolt-guns.
Combination, with a bolt having a recoil projection at its front end and formed with a radial recess in said projection, of a shell-extractor consisting of a block mounted in said recess and movable radially therein, provided with a claw on its front side and a spring for pressing it inwardly.

Patent 431,670 — 8 Jul 1890
Mauser, Paul — Oberndorf, Ger.
Shell extractor for bolt-guns.
Applies to bolt which has no separate bolt-head. Combination of bolt having longitudinal groove extending back from front end and rear portion of which is laterally undercut, with an extractor consisting of a plate formed thick at its rear portion, having a claw at its front end, whereby extractor is applied by sliding it longitudinally backward into the groove until its shoulder springs into engagement with that on the bolt, and when applied the extractor lies within the groove.

Patent 446,807 — 17 Feb 1891
Armit, Robert H. — London, Eng.
Machine gun.
Relates to guns used with cartridges wherein powder is inclosed or contained in wrapped or solid-drawn metallic cases or envelopes. Claims combination with a gun barrel of a false chamber, or bushing, provided with an intermittent or divided screw and with notches and recesses for reception of a key. This is utilized to remove crushed or parts of empty cases.

Patent 467,180 — 19 Jan 1892
Mauser, Paul — Oberndorf, Ger.
Shell-extractor for bolt-guns.
New extractor for breech-loading bolt guns, the bolts of which are furnished with recoil or locking projections on their front end without separate locking heads. Extractor located in horizontal groove in breech-case of gun, being held thereby from rotation relatively to cartridge while bolt goes through quarter-revolution for purpose of locking or unlocking same.

Patent 477,671 — 28 Jun 1892
Mauser, Paul — Oberndorf, Ger.
Shell-extractor for bolt-guns.
Relates to extractors, such as in Patent 467,180 (1892). Improved connection between ring and extractor in guns of this class. Ring engaging bolt constructed with laterally projecting shoulders while extractor has similar shoulders adapted to engage shoulders on ring by longitudinal movement of extractor relatively to ring, said shoulders being adapted when parts are in correct relative position to lock extractor and ring together.

Patent 488,316 — 20 Dec 1892
Keller, Moses A. — Batavia, N. Y.
Automatic shell-ejector for breech-loading guns.
Improvements in ejectors by which main springs of the locks are employed for power to actuate the mechanism. Automatic ejector working independent of cocking action of the locks so that latter will always cock before shells are knocked out. Full power of main springs of locks operate on ejector mechanism to force shell out.

Patent 495,137 — 11 Apr 1893
Krnka, Karel — Prague, A.-H.
Extractor and ejector for bolt-guns.
Improved extractor and ejector capable of movement laterally of the head, former under spring tension, the latter under action of the cam surface against projection of ejector cylinder, when bolt is retracted.

Patent 632,090 — 29 Aug 1899
Bennett, Thomas G. — New Haven, Conn.
Bolt-gun.
Improvement in gun in which bolt is located in a bolt-housing formed in a rearward extension of barrel. (Browning's Patent 632,094.) Consists in longitudinally and vertically movable combined extractor, sear and trigger. Friction stop coacts with bolt and combined extractor and sear for frictionally holding bolt in its closed and locked position.

Patent 669,520 — 12 Mar 1901
Fyrberg, Andrew — Worcester, Mass.
Firearm.
To provide an ejector capable of dislodging a shell from barrel of a gun, however tightly it may fit or be held therein; to afford means for completely removing shell after it has been started. Spring-actuated shouldered ejector proper provided with a hook operating in lug of barrel, shoulder on frame pivot being adapted to engage shoulder on ejector to move latter initially; and a spring-actuated dog pivoted in lug to assist in actuating ejector.

Patent 695,485 — 18 Mar 1902
Passage, Hiram H. — Plymouth, Mich.
Firearm.
Means for automatically extracting shell after cartridge has been exploded by force of recoil, whereby breech bolt at breech of barrel is retracted sufficiently to allow shell to be expelled by pressure of the exploded charge within the barrel.

Patent 747,675 — 22 Dec 1903
Bennett, Thomas G. — New Haven, Conn.
Extractor for firearms.
Improved extractor to prevent extractor from being displaced or disarranged in firing gun in case of escape of gas under high pressure at time of firing, due to bursting of cartridge head. Swinging non-pivotal extractor, spring-actuated plunger therefor and plunger stop for limiting movement of plunger after extractor is in place.

Patent 783,561 — 28 Feb 1905
White, Franklin P. — Shallotte, N. C.
Shell-ejecting mechanism for firearms.
Provides novel ejector for breech-loading guns. Provides shell-holder which will firmly hold shell during firing, and

thus prevent rupture of shell, whether paper or metal, so it may be refilled. Shell received in supporting sleeve movable in and out of breech end of barrel.

Patent 830,226 — 4 Sep 1906
Hall, Adelbert E. — West Bay City, Mich.
Recoil-operated firearm.
Devices for automatic ejection and loading of shells. Also means for governing speed of recoil of discharged shell and speed with which new shell is pushed into place.

Patent 869,967 — 5 Nov 1907
Fyrberg, Andrew — Hopkinton, Mass.
Breech-loading gun.
Improved independent ejecting mechanism for each barrel of double-barrel breech-loading gun of break-down type. Ejecting mechanism combined with firing mechanism so it will not operate until after particular barrel has been discharged. Provides safety to prevent discharge except when safety is moved to firing position, and having third position to permit lowering of hammers without discharge of gun.

Patent 987,672 — 21 Mar 1911
Consentino, Thomas — Houston, Tex.
Firearm.
To provide an automatic firearm composed of few parts which will eject the empty shell and replace a cartridge in position for firing automatically. Provision against accidental discharge. Detachable magazine containing large number of cartridges within a small compass.

Patent 992,854 — 23 May 1911
Cobb, Lyman H. — Fitchburg, Mass.
Automatic firearm.
Relates to automatic firearms provided with magazines for cartridges and in which ejection and reloading is automatically operated by explosion of the charge. Invention simplifies construction, reduces cost, increases efficiency and safety and avoids liability of breakage or derangement of parts. Has frame and handle in single integral piece, barrel and sleeve mounted on said barrel and integral therewith, with rear end of barrel and sleeve inclosed in said frame.

Patent 1,009,464 — 21 Nov 1911
Borchardt, Hugo — Charlottenburg, Ger.
Cartridge-ejecting device for firearms.
Ejector permits ejection of a cartridge to take place at a variable distance from the end of the barrel and also permits regulating the ejection operation so that it is quicker or slower. Comprises ejector lever pivotally mounted on front end of breech block and a stop on the casing operating said ejector lever to act on base of cartridge, said lever being adapted to slide over said stop.

Patent 1,025,733 — 7 May 1912
Borchardt, Hugo — Charlottenburg, Ger.
Small-arm.
Relates to recoil-operated small arm in which there is a delayed and preferably yielding or elastic action of breech bolt in its operation of extracting cartridge-case. Breech block movable into and out of engagement with breech thereof, and a cartridge extractor mounted on a part of breech bolt capable of allowing main portion of breech bolt a limited movement independent thereof in its movement away from breech of gun. Spring arranged between this part and body of bolt.

Patent 1,035,210 — 13 Aug 1912
Mauser, Paul — Oberndorf, Ger.
Ejector device for automatic firearms.
Consists of ejector rod longitudinally slidable on the breech closure and a resilient ejector lever acting with a yielding tappet on the ejector rod. Tappet is pivoted as a separate pawl on spring controlled ejector lever and after ejection it is rocked outward by ejector rod acting on a nose on this pawl and ejector lever is simultaneously pressed down.

Patent 1,041,410 — 15 Oct 1912
Benét, Laurence V. and Mercié, Henri A. — Paris, France
Cartridge-case extractor.
Improved apparatus for positively extracting empty case after firing and for ejecting same laterally. Adapted for use in breech-loading small arms or machine guns, in which breech block has rectilinear movement in receiver.

Patent 1,108,356 — 25 Aug 1914
Frommer, Rudolf V. — Budapest, A.-H.
Resilient ejector for firearms.
Ejector is retained in its recess by its operative spring and easily fitted into or removed from firearm.

Patent 1,114,463 — 20 Oct 1914
Gebauer, Paul — Berlin, Ger.
Automatic gun.
Improved mechanism for ejecting empty cartridge case in automatic guns. Mechanism so constructed that case is safely ejected even when firearm is directed upward. Removes danger that first unfired cartridge located within ejecting tube is fired.

Patent 1,169,248 — 25 Jan 1916
Frommer, Rudolf — Budapest, A.-H.
Ejector for firearms.
Regulates ejecting force by arranging ejector hook in such a manner that it can give way against the action of a spring, as it is struck by an empty cartridge, so that by use of a correspondingly strong spring, force of the blow is controlled so shell is ejected with only the necessary force.

Patent 1,170,014 — 1 Feb 1916
Stamm, Hans — St. Gallen, Switzerland
Cartridge-case extractor for firearms.
Improved method of mounting extractor in straight pull breech actions of rifles wherein breech action consists of a rotatable breech bolt and a bolt actuating sleeve mounted to slide on said bolt. Extractor is mounted in breech bolt actuating sleeve so that it is fixed relatively to breech bolt so that it will move longitudinally with bolt and be guided along the sleeve in the sliding movement of the latter.

Patent 1,293,776 — 11 Feb 1919
Hillman, Leroy T. — Watertown, Mass.
Firearm.
Relates to automatic firearms of type in which rearward movement or elongation of cartridge case resulting from explosion of charge automatically operates a self-loading breech mechanism. Provides means for retarding rearward movement of bolt head at about the time of maximum pressure, so bolt head will offer sufficient resistance to the resulting sudden rearward movement of the end of the cartridge case to prevent latter from rupturing.

Patent 1,309,337 8 Jul 1919
Reising, Eugene G. E. Hartford, Conn.
Extractor for firearms.
Improved extractor comparatively free from injury in movements of breech-bolt and readily placed in position in breech-bolt or removed therefrom.

Patent 1,309,338 8 Jul 1919
Reising, Eugene G. E. Hartford, Conn.
Ejector for firearms.
Improved ejector carried by breech bolt and moving longitudinally thereof and operative by being pressed against a cam in a groove in bolt.

Patent 1,317,587 30 Sep 1919
Mercié, Henri A. St. Denis, France
Extractor for automatic and other firearms.
Improvement on Patent 1,041,410 (1912), having no rigid connection with breech block on which it is freely mounted and held in place by a coiled spring. Improvement to relieve strain and fatigue on spring by making extractor very short and arranged in the very axis of the breech block.

Patent 1,317,988 7 Oct 1919
Pedersen, John D. Jackson, Wyo.
Magazine-firearm.
Improvement on magazine arm having "bottom ejection" of cartridge shells from a receiver chamber otherwise closed. Improved organization of a reciprocable breech action combined with a carrier and ejector whereby usual loading firing and extracting operations may be reliably performed and shells may be positively discharged by bottom ejection regardless of position of the arm.

Patent 1,372,336 22 Mar 1921
Browning, John M. Ogden, Utah
Firearm.
Adapted to firearms using 22 caliber rim-fire greased cartridges. Improved extracting means; adjustable extractor to suit cartridge.

Patent 1,418,862 6 Jun 1922
Ball, George H. New Haven, Conn.
Firearm.
Improvement in gun of type patented by Swebilius (1,146,536—1915) in which ejector is pivoted at its rear end in a groove in one wall of receiver and its forward end pressed toward center of receiver by means of a spring. Invention houses ejecting mechanism within a groove in wall of receiver when not in operation. To prevent breaking off or catching on cleaning cloth.

Patent 1,451,443 10 Apr 1923
Fowler, Elbert Baltimore, Md.
Machine gun.
Improvement in recoil operated machine guns such as Vickers and Browning. Same means used for extracting cartridge from feed belt and cocking firing pin. Cartridge extractor movable on an instant pivot whereby front end of extractor moves downward in substantially a straight line. Extractor mounted on breech bolt. Construction of ejector obviating use of springs. Improved breech-bolt locking member. Other improvements.

Patent 1,494,186 13 May 1924
Pomeroy, Edward S. Springfield, Mass.
Firearm ejector.
Effects ejection of both loaded cartridges and empty cases reliably and uniformly. Eliminates difficulty of cases falling from extractor before being ejected. Ejector confined wholly within interior of receiver.

Patent 1,507,900 9 Sep 1924
Frommer, Rudolf v. Budapest, Hungary
Cartridge extractor for firearms.
One part of extractor is an inelastic hook which works in the manner of a two-armed lever and serves to extract the cartridges; the other part is a flat spring which is provided to operate the extracting hook and at same time to keep it in position in its groove. Adaptable to even the smallest size of firearms.

Patent 1,518,602 9 Dec 1924
Pedersen, John D. Jackson, Wyo.
Automatic pistol.
Ejector for weapons of type in which slide is moved forwardly off the frame when disassembling the arm, so constructed that it will be unnecessary to cut a slot into rear end of slide to provide a clearance for ejector when disassembling arm, thereby preventing gases, particles of powder or broken primers from blowing back into face of shooter. Movable ejector automatically moved out of obstructing position when slide is removed from frame.

Patent 1,533,967 14 Apr 1925
Browning, John M. Ogden, Utah
Automatic rifle.
Improvement on Patent 1,293,022 (1919) on BAR. Provides manually operated means for covering or uncovering the ejection-opening, such as a lever for at will raising or lowering the cover-plate for said opening, combined with a safety device to prevent firing of rifle by positively locking the action-slide.

Patent 1,533,968 14 Apr 1925
Browning, John M. Ogden, Utah
Automatic rifle.
Improvement on BAR (Patent 1,293,022—1919). Manually operated device for at will covering and uncovering the ejection-opening, combined with a safety device which positively prevents firing of rifle while said ejection opening is covered.

Patent 1,656,845 17 Jan 1928
Sutter, Charles Suresnes, France
Combined loader ejector and safety mechanism for automatic firearms.
Improvement in mechanism permitting stoppage of machine gun after cartridges have been used up. Not only stops firearm after cartridges are gone but also automatically ejects loader, so that firer will realize, if gun stops and loader is not ejected, that there are still cartridges in gun and will bring breech block back to full cocked position before further handling.

Patent 1,682,704 28 Aug 1928
Loomis, Crawford C. Ilion, N. Y.
Firearm.
Improved firing and cartridge case ejecting mechanism for firearms firing relatively short and light cartridge cases. Ejector mechanism functions positively regardless of rapidity or slowness with which action of gun is opened and breech block retracted. Comprises a single member functioning as firing pin and ejector.

Patent 1,796,757 17 Mar 1931
Little, William L. El Dorado, Ark.
Shell extractor.
Simple means whereby shell will be successfully ejected even though somewhat longer than that for which gun was designed.

Patent 1,828,330 — 20 Oct 1931
Loomis, Crawford C. — Ilion, N. Y.
Firearm.
Improvements in extractor and ejector mechanisms in magazine firearms wherein a movable breech block is used to load, extract and eject cartridges. Effects forceful and controlled ejection when action is manipulated slowly and with ordinary speed and at high speed. Provide breech block with an extractor claw sufficiently yieldable to accommodate shell rims of varying thickness. Improved ejector mechanism.

Patent 1,889,099 — 29 Nov 1932
Loomis, Crawford C. — Ilion, N. Y.
Firearm.
Improved form of extractor capable of both vertical and longitudinal movement. Extractor retained in its shell rim engaging position both vertically and horizontally by means of a single spring.

Patent 2,089,671 — 10 Aug 1937
Stecke, Edward — Warsaw, Poland
Automatic firearm. (Cl. 42–3).
Object to provide an automatic gun having a stationary barrel, no gas chamber and a breech block which is locked during the firing. Eliminates need to lubricate cartridge cases. Slidable member is provided and connected with breech block so that very small return rearward movement of locked breech block produces a comparatively considerable displacement of said movable member. Mechanism actuated by pressure existing in chamber before bullet leaves barrel.

Patent 2,101,236 — 7 Dec 1937
Burton, Frank F. — Mt. Carmel, Conn.
Cartridge-ejecting mechanism for firearms. (Cl. 42–25)
Effectively ejects shells varying in length and/or in diameter, shape, etc., of their heads or rims. In arms having breech bolts which reciprocate longitudinally of the arm.

Patent 2,146,743 — 14 Feb 1939
Johnson, Melvin M., Jr. — Brookline, Mass.
Firearm. (Cl. 42–4)
Means for applying to bolt at beginning of each extraction a sharp blow to the rear, thereby to start the sliding movement of shell in chamber. In breech mechanism is included a kicker which recoils relatively to the bolt during initial stage of recoil to produce blow. Applicable to firearms of reciprocating barrel type in which bolt has locking lugs seated against abutments on barrel.

Patent 2,198,610 — 30 Apr 1940
Garand, John C. — Springfield, Mass.
Extractor for firearms. (Cl. 42–25)
Extractor well housed in bolt thereby rendering structure more compact and less liable to injury. No attenuated spring members as part of extractor proper.

Patent 2,204,289 — 11 Jun 1940
Williams, David M. — Godwin, N. C.
Extractor mechanism for firearms. (Cl. 42–25)
Firearm having a pair of extractors both of which have a positive hook engagement with rim of cartridge. Means for disengaging one of extractors from cartridge rim in order to allow ejection thereof by ejector.

Patent 2,345,077 — 28 Mar 1944
Swebilius, Carl G. — Hamden, Conn.
Cartridge ejecting means for firearms. (Cl. 42–25)
Improved ejector firmly supported in firearm-structure so as to preclude its derangement.

Patent 2,347,559 — 25 Apr 1944
Higson, Percy R. — Sidcup, Eng.
Automatic gun. (Cl. 89–3)
Relates to automatic guns of long recoil operated type. Concerned with ejection of empty cases whilst breech block remains stationary, thereby permitting use of smallest possible opening in the gun for the ejection of the cases.

Patent 2,350,477 — 6 Jun 1944
Rowley, Arthur A. — Hamden, Conn.
Extractor-and-ejector assembly for firearms. (Cl. 42–25)
Improvements in extractor-ejector assemblies which include a movable breech-bolt. Ejector serves to prevent unintentional detachment of extractor from bolt. Extractor and ejector serve to retain each other in place in a movable breech bolt.

Patent 2,404,325 — 16 Jul 1946
Swebilius, Carl G. — Hamden, Conn.
Extractor-switch mechanism for machine guns. (Cl. 89–33)
Adapted for use with Browning-type machine guns. Superior extractor switch capable of satisfactorily functioning in a machine gun when latter is operated at speeds in excess of 1,000 shots per minute.

Patent 2,411,979 — 3 Dec 1946
Rataiczak, Francis I. — Dayton, Ohio
Ordnance. (Cl. 42–25)
Rugged shell ejecting mechanism capable of ejecting empty shells from a high speed machine gun without damaging rims of the shells. Mounted within bolt head. Can be used in existing guns without making major changes in gun construction.

Patent 2,412,663 — 17 Dec 1946
Williams, David M. — New Haven, Conn.
Cartridge extracting mechanism for firearms. (Cl. 42–25)
Extractor positively locked or held in engagement with cartridge, when breech bolt is in its breech closing position, thereby avoiding inadvertent retirement of extractor in the event a faulty case should burst and thus permit emission of hot high-pressure gases.

Patent 2,421,249 — 27 May 1947
Delsole, Joseph H. — New Haven, Conn.
Extractor-and-breech-bolt assembly for firearms. (Cl. 42–25)
Improved assembly which includes a movable breech bolt and a cartridge extractor carried by and movable relative to breech bolt. Firmly held in relation to bolt despite high displacing stresses.

Patent 2,436,937 — 2 Mar 1948
Rataiczak, Francis I. — Dayton, Ohio
Shell ejecting mechanism for machine guns. (Cl. 42–25)
Mechanism ejecting shells from high speed machine gun without damaging or breaking away fragments of the rims of the shells. Improvement of Patent 2,411,979 (1946); improved arrangement for supporting mechanism relative to rest of gun parts.

Patent 2,460,862 — 8 Feb 1949
Weiss, Albert — Zurich, Switz.
Ejector for firearms. (Cl. 42–25)
Breech casing provided with a crosspiece extending immediately behind cartridge chamber transversely to ejecting direction and shell released from engagement by claw is supported at front end by cross piece until breech block has carried shell directly against ejector. Overcomes tendency of extracted shell to drop out of claw.

Patent 2,462,889 1 Mar 1949
Neidhardt, Graham B. Albion, Ind.
Cartridge case extractor. (Cl. 42–25)
Extractor made rigid with the bolt either by being made integral therewith or rigidly attached thereto and provided with a lip having a "positive" angle. When round straightens out as it is chambered, rim is cammed down the inclined lip of extractor until base of cartridge is flush with face of bolt, thus closing the space between bolt and cartridge when bolt is locked in firing position.

Patent 2,465,553 29 Mar 1949
Robinson, Thomas R., Jr. New Haven, Conn.
Cartridge extractor construction for firearms. (Cl. 42–25)
Improved extractor construction including 2 opposed yielding arms in which relationship of said arms is maintained with surety. Utilizes clamping band to stabilize arms.

Patent 2,466,578 5 Apr 1949
Corte, Alfred Tampa, Fla.
Cartridge feeding mechanism. (Cl. 89–33)
Cartridge handling mechanism for use with a multibolt combination of character described in Patent 2,466,577. Effective extractor mechanism for breech bolts which automatically withdraw live rounds from ammunition belt and later inserts empty cases into belt. Cartridge sprocket and multiple bolts coordinated.

Patent 2,473,373 14 Jun 1949
Howell, John D. Westport, Conn.
Bolt head and extractor for firearms. (Cl. 42–25)
Improved ring extractor for breech loading bolt action guns. Adapted to be readily assembled and secured on face of the bolt. Arranged to preclude excessive tolerance build-up. Extracting claw has transverse movement only.

Patent 2,479,844 23 Aug 1949
Koucky, Josef and Frantisek Prague, Czechoslovakia
Cartridge extractor, especially for one-shot firearms. (Cl. 42–25)
Extractor is extended beyond lip to form support and conveyor for cartridge to be introduced into chamber.

Patent 2,484,444 11 Oct 1949
Benson, Carl H. New Haven, Conn.
Cartridge ejector for firearms. (Cl. 42–25)
Ejector adapted to eject automatically either loaded cartridges or empty shells at substantially equal speed. Consists of two spring-pressed pointed members extending into receiver, the first one lying in path of movement of empty shell, and the second in path of movement of loaded shell.

Patent 2,500,139 7 Mar 1950
Swebilius, Carl G. Hamden, Conn.
Ejector detent. (Cl. 89–33)
Spring-loaded ejector detent detained in the bolt assembly of the weapon, as applied to Browning M2 machine gun. Positioned in bottom of T-slot. Acts as stop to position the in-feeding cartridge in the bolt face after new round has forced the empty case past spring arms of device.

Feeding and Chambering

Patent 26,919 24 Jan 1860
Morris, Wm. H. and Charles L. Brown New York, N. Y.
Improvement in repeating fire-arms.
The use in a firearm of a series of stationary chambers converging to a common barrel, giving the advantages of a revolver without the disadvantage of windage between cylinder and barrel, and greater safety from fire being communicated from one charge to another.

Patent 206,852 13 Aug 1878
Bailey, Fortune L. Indianapolis, Ind.
Improvement in machine guns.
Hopper fed, crank operated machine gun. Rammer block moves back and forth to ram and extract cartridge.

Patent 207,747 3 Sep 1878
Leonard, Harvey R. San Francisco, Cal.
Improvement in machine-guns.
Consists in forming extension on rear end of breech-loading cannon, on which removable breech slides, the forward-and-back motion being imparted to the breech by cams operated by a crank. Devices lock breech to cannon at proper moment and also for releasing it, so it may be slid back. Arrangement for recoil-springs whereby strain is on direct line with springs in any position of gun. Self-cocking and discharging lock. Removable chamber in which cartridges are placed so that cold one may be substituted as needed.

Patent 211,737 28 Jan 1879
Hotchkiss, Benjamin B. New York, N. Y.
Improvement in machine-guns.
Improvement in single-barrel repeating cannon. Loading-plunger-actuating mechanism operating so that while continuously revolving it sustains loading plunger stationary at forward end of stroke to support cartridge in chamber of gun sufficient time to be manipulated therein, and at rearward end of stroke for a period sufficient to permit entrance of new cartridge in loading chamber. At each revolution of crank arm firing pin is withdrawn and loading plunger retracted to permit entrance of cartridge, said plunger is advanced to charge gun and firing pin tripped to explode cartridge.

Patent 216,266 10 Jun 1879
Gardner, William Cleveland, Ohio
Improvement in machine guns.
Combination with a cartridge bed or carrier with transverse intermittent reciprocating motion of a plunger with intermittent reciprocating motion longitudinally with axis of barrel. Cartridge extracting device holding cartridge securely by means of two bearing surfaces. Groove placed above carrier in relation to hook of extractor to assure proper positioning of cartridge.

Patent 217,987 29 Jul 1879
Burgess, Andrew Owego, N. Y.
Improvement in magazine guns.
Magazine delivers cartridges from beneath barrel to carrier in ordinary manner. Carrier has spring sides to hold feeding cartridges in place, and an elastic buffer. This prevents danger of explosion from shock of cartridges as they spring from magazine into carrier. Bolt provided with pivoted dog to take up shock of bolt in closing and to start back bolt in act of unlocking.

Patent 218,371 12 Aug 1879
Elliot, William H. New York, N. Y.
Improvement in magazine fire-arms.
Construction and arrangement of magazine, carrier, pivot, and spring in relation to each other and to receiver, whereby charging of magazine is effected through bottom of receiver and over carrier. Movable guide and carrier and actuating spring with magazine composed of 2 or more stationary tubes, whereby cartridges from the several tubes are delivered into one receiving chamber.

Patent 222,414 9 Dec 1879
Marlin, John M. New Haven, Conn.
Improvement in magazine fire-arms.
Combination of barrel and magazine, both opening to rear, with a charging-opening in the side of the frame in rear of magazine, and a slide operating to close said opening and guided in the frame, and a tail piece extending forward from said slide and supported forward directly on barrel.

Patent 228,777 15 Jun 1880
Parkhurst, Edward G. Hartford, Conn.
Machine gun.
Improvement in crank-operated breech loaded automatic machine gun. Better and more positive feeding and ejecting mechanism; improved lock mechanism. Reciprocating sliding feed plate which moves from side to side in suitable guides in fixed case and serves to force cartridges into proper position to be pushed into barrel. Ejecting lever operated by a dog on the lock bar and arranged to serve as a rear stop for cartridge.

Patent 241,130 10 May 1881
Farrington, De Witt C. Lowell, Mass.
Machine gun.
Improvement on Patent 165,318. Single cartridge carrying roll for transferring cartridge from hopper to alignment with bore of gun barrel. Combined with a feed table which receives cartridge directly from hopper and allowing cartridge to be transferred to carrying roll by reciprocating finger.

Patent 285,284 18 Sep 1883
Mason, William New Haven, Conn.
Magazine for fire-arms.
Construction of magazine with internal shape, which, while permitting cartridge to move freely within magazine under pressure of magazine spring, will prevent contact of the primer of one with the head of the next when cartridges are standing in magazine. Magazine constructed with internal irregularities longitudinally.

Patent 299,686 3 Jun 1884
Scott, Charles B. Las Vegas, Terr. of N. M.
Machine gun.
Magazine or machine gun capable of being fired at any angle without changing position of base on which it rests. Cartridges horizontally conveyed to and exploded at exact moment of passing breech of barrel and fed consecutively into position in unlimited numbers.

Patent 314,515 24 Mar 1885
Chaffee, Reuben S. Springfield, Ill.
Feeding mechanism for breech-loading fire-arms.
Provides means for connecting loading bars to and disconnecting them from a cartridge extractor attached to firing bolt, means being held stationary upon the gun instead of moving back and forth with the firing bolt.

Patent 332,741 22 Dec 1885
Palmer, C. H. New York, N. Y.
Machine-gun.
Number of barrels mounted on wheel or revolving frame; cartridges are strung together by flexible connection to facilitate mechanical feeding. Cartridges are held at moment of firing between 2 stout wheels each of which is recessed to a depth to receive half of cartridge. Wheels support cartridge laterally, while breech is covered with strongly-backed disk. Firing hammers are mounted in disk. Cartridges fired in succession as rapidly as desired, each through a different barrel until barrels have made complete revolution.

Patent 341,371 4 May 1886
Bruce, Lucien F. Springfield, Mass.
Cartridge charger for machine gun feeders.
Improved device for placing cartridges one by one in magazine feeders of Gatling gun class, from which they are delivered to gun to be fired. Consists in rotating charging wheel inclosed in cylindrical case and having recesses which mesh with feeder.

Patent 343,532 8 Jun 1886
Bruce, Lucien F. Springfield, Mass.
Cartridge feeder for machine guns.
Improved means for so directing movement of each cartridge after it leaves feeder above the hopper that it invariably reaches cartridge carrier from which it is driven into barrel in a line with the bore of the latter. Misplacement of cartridge due to overweight of its ball end made impossible. (For Gatling guns)

Patent 347,072 10 Aug 1886
Spencer, George N. Three Rivers, Mich.
Magazine fire-arm.
Improvement in weapon in manner of loading gun and of discharging empty shells through a side exit in the breech chamber. Bowed lever pivoted at center to wall of breech chamber in position to be titled on its pivot by sliding breech block and an open-top magazine having spring actuated bottom to press up on cartridges whereby lever holds down upper cartridge and throws empty shell out of side of breech chamber.

Patent 351,960 2 Nov 1886
Bruce, Lucien F. Springfield, Mass.
Cartridge feeder for machine guns.
Means whereby cartridges may be put into feeder (Gatling type) or into others having like grooves for receiving cartridges while the gun to which feeder is attached is being fired at an excessive elevation. Placed in feeder directly from packing case.

Patent 367,825 9 Aug 1887
Maxim, Hiram S. London, Eng.
Machine gun.
Use of 2 sets of wheels designated as "feed and delivery" wheels. Over feed wheel is carried a belt of cartridges which are delivered to delivery wheel and then into barrel by a reciprocating breech block. Loading, firing and extracting all performed by manipulation of crank. Also water jacket for cooling barrel and device for permitting escape of steam.

Patent 372,531 1 Nov 1887
Franklin, William B. Hartford, Conn.
Magazine fire-arm.
Relates to fire-arms in which breech-piece is part of a sliding bolt provided with handle extending radially therefrom and in which breech-piece is secured by imparting rotation to bolt, and in which cartridges fall in front of breech piece when open and forced into chamber by forward movement. Invention provides separating device between cartridges and receiver to prevent choking of passage; provides deadlock for magazine while in place; makes engagement between extractor and head of cartridge positive; other locking and safety devices.

Patent 373,277 — 15 Nov 1887
Ehbets, Carl J. — Hartford, Conn.
Magazine fire-arm.
Relates to fire-arm in which breech-piece is arranged in rear of barrel, to be moved backward in opening, with magazine arranged under barrel, with carrier block arranged in receiver in rear of barrel, into which cartridge will pass from magazine when carrier is in down position. Improvements in extractor mechanism, in magazine, in carrier feed, etc.

Patent 380,682 — 10 Apr 1888
Holmes, Francis G. D. — Phillipsburg, N. J.
Breech-loading fire-arm.
Cartridges having metallic shells previously deposited in revolving cylinder are by working of lever brought up in line with barrel and partially thrust forward into latter so shell covers and packs joint between barrel and cylinder when explosion occurs. Improvements in means for bracing sliding breech-block, by providing stout vertically-transverse slide connected with breech-block by link, which extends vertically across path of breech block in rear thereof and engages with breech above and below same. Operates by oscillating broad arm having cam groove acting on pin on link.

Patent 386,889 — 31 Jul 1888
Mallen, Rafael — Mexico City, Mex.
Magazine fire-arm.
Improved rifle with fixed breech block and firing chamber at base of barrel which is rectangular in cross-section. Cartridge-receiving chamber incloses barrel and is placed parallel with firing chamber. Reloading takes place at time firing chamber is opened to discharge fired shell by means of sliding carriage. This comprises in single piece the 2 side walls of firing chamber and firing pin and is adapted to be drawn back toward stock of rifle, by utilization of portion of gases resulting from explosion of cartridge. Forward movement of carriage is spring actuated.

Patent 395,791 — 8 Jan 1889
Maxim, Hiram S. — London, Eng.
Machine-gun.
Improvements in Maxim gun, including carrier for holding cartridges and lowering them into position to be thrust into barrel; facilitating cleaning or inspection of barrel or bore or extraction of part of a broken cartridge by hand; intermittent movement of cartridge belt by slide, carrying pawls and acting in combination with retaining pawls.

Patent 400,679 — 2 Apr 1889
Hepburn, Lewis L. — New Haven, Conn.
Magazine gun.
Opening in receiver made in side, being closed by breech-block in its forward position. Rear end of barrel is extended farther back so it enters the cavity in receiver; lower end of this projecting portion of barrel is cut away to permit front end of carrier to pass, permitting cartridge to be raised high enough to enter bore of barrel. Carrier pivoted at its rear end. Improved ejector and extractor.

Patent 444,666 — 13 Jan 1891
Dinsmore, Robert — Weston, W. Va.
Magazine gun with pneumatically operated magazines.
Increase capacity of magazines; one movement of carriage will withdraw and eject empty shell, reload and throw firing mechanism into position for firing, which will obviate necessity for usual springs in magazine for feeding cartridges to barrels and to accomplish same by means of pneumatic pressure operated by the movements of the plunger simultaneously with discharge of the piece.

Patent 465,340 — 15 Dec 1891
Browning, John M. and Matthew S. — Ogden, Utah
Magazine fire-arm.
Relates to guns in which receiver is constructed in 2 parts, rear part attached to stock and forward part carrying barrel on forward end, parts sliding on each other so as to open breech for introduction of charge. Produces rapid firing without removing gun from shoulder. Column of cartridges in magazine forced rearward and successively delivered into receiver at rear, as opening and closing movement produces corresponding up-and-down movement of carrier.

Patent 475,276 — 17 May 1892
Garland, Frank M. — New Haven, Conn.
Machine gun.
Relates to automatic machine-guns having stationary barrels. To provide positive-feeding and rapid-firing gun wherein one or both barrels may be used for firing, without danger of shell sticking in barrels. Utilizes feed-chain connected with driving shaft, with pushers normally in front of and adjacent to chain and reciprocated across path of chain by driving shaft for passing cartridges rearward from feed-chain into path of lifting chains which are moved vertically by driving shaft for raising upward to level of barrels.

Patent 479,799 — 2 Aug 1892
Garland, Frank M. — New Haven, Conn.
Machine gun.
To provide machine gun in which cartridges are positively fed to barrels from a belt in which one or both of the barrels may either be discharged slowly or with great rapidity. Feeding mechanism consists of pair of wheels having pocketed peripheries mounted upon shafts on each side of the shell beneath the barrels. After belts have been stripped from cartridges, they pass through guides to spindles which place them in barrels until discharged.

Patent 499,534 — 13 Jun 1893
Gatling, Richard J. — Hartford, Conn.
Feed for machine guns.
Simple feed by which a number of cartridges may be rapidly placed from package in which they are stored and directly forced into breech of gun (Gatling) for rapid discharge. Consists of flanged plate with mortised groove adapted to receive heads of cartridges.

Patent 504,516 — 5 Sep 1893
Broderick, Clement M. and Vankeirsbilck, John
Hartford, Conn.
Feed for machine guns.
Relates to guns of Gatling type. Simple means by which ordinary ammo can be quickly packed at factory or on field, whereby cartridges can be rapidly fed surely and positively into gun regardless of angle of elevation or depression.

Patent 504,517 — 5 Sep 1893
Broderick, Clement M. and Vankeirsbilck, John
Hartford, Conn.
Machine gun.
Relates to Gatling guns. To construct such a gun that the cartridges may be fed by metallic strips positively and accurately to revolving carrier in front of the reciprocating locks, regardless of angle of elevation or depression of gun. Strips pass through hopper.

Patent 518,821 — 24 Apr 1894
Mannlicher, Ferdinand — Vienna, A.-H.
Feed mechanism for magazine-guns.
Relates to magazine arms in which cartridge clasps each containing certain number of cartridges are inserted from

above into permanent or fixed magazine below breech. Upon closing breech uppermost cartridge carried into barrel. Object of invention to construct cartridge clasp, fixed magazine and feeder so that when clasp is emptied it falls from fixed magazine through an opening in bottom of latter.

Patent 547,717 — 8 Oct 1895
Dougherty, Albert G. — Chambersburg, Ind.
Machine gun.
Crank operated machine gun, with mechanism for feeding cartridges forward into cartridge elevator. Breech block simultaneously feeds cartridge into position for firing and firing it; mechanism for preventing recoil of breech block and mechanism for extracting shell.

Patent 557,358 — 31 Mar 1896
Burgess, Andrew — Buffalo, N. Y.
Magazine fire-arm.
Magazine gun in which cartridges may be arranged in a volute or spiral direction; spring follower placed under control of operator, so that spring may be operative or not, as desired; place breech-locking mechanism of gun under control of some part actuated by the shock of firing.

Patent 579,401 — 23 Mar 1897
Maxim, Hiram S. — London, Eng.
Recoil-operated gun.
Improved means for actuating cartridge carrier, whereby latter is caused to complete upward movement before breech block or lock terminates forward movement in closing breech. Muzzle device increases energy of recoil movement of barrel so that a quantity of water can enter gas-chamber of muzzle device to prevent corrosion by gases of discharge and also to prevent muzzle of barrel and muzzle device from becoming overheated.

Patent 607,681 — 19 Jul 1898
Cochrane, Douglas M. B. H. — London, Eng.
Ammunition-holder for machine-guns.
Combination with vertical axis and a gun mount arranged to be rotated about axis, of a sleeve arranged to be rotated about said axis independently of gun-mount, a plurality of ammunition boxes detachably supported on said sleeve means for adjustably locking mount to sleeve whereby the two are caused to rotate in unison and boxes successively brought into operative position.

Patent 630,136 — 1 Aug 1899
Travaglini, Antonio, — Philadelphia, Pa.
Gas-operated firearm.
Rotary magazine supplied with cartridges and journaled in stock of firearm. Means for automatically imparting a partial rotation to magazine at intervals so as to remove a tube in the magazine from alignment with the passage forming communication with chamber and tube when tube has been emptied of cartridges, this rotation bringing a subsequent tube, filled with cartridge in alignment with the passage to maintain uninterrupted feeding. May be fired single-shot. Extraction device.

Patent 644,969 — 6 Mar 1900
Dawson, Arthur T. and Silverman, Louis — London, Eng.
Automatic gun.
Refers to hopper fed automatic guns. Obviates necessity of throwing cartridges from hopper into carrier by arranging hopper immediately above the carrier so that they drop directly into carrier. Other improvements in carrier for safety purposes.

Patent 676,094 — 11 Jun 1901
Linville, Robert W. — Gwinmine, Calif.
Magazine-firearm.
Combination, with a magazine, of a carrier by which cartridges are transferred from the magazine to the line of the barrel and a longitudinally slidable breech-bolt by which cartridges are transferred to barrel of a mechanism, and connections whereby the parts are automatically actuated and gun loaded and fired continuously until cartridges are exhausted.

Patent 680,488 — 13 Aug 1901
Kjellman, Rudolf H. and Andersson, Gustav L.
Stockholm, Sweden
Automatic firearm.
Satisfactory means for guiding cartridge while being pushed by breech bolt into bore of barrel. Yielding lugs which are actuated by frame in which receiver reciprocates so as to form supports for the cartridges at certain moments.

Patent 681,481 — 27 Aug 1901
Johnson, Thomas C. — New Haven, Conn.
Automatic firearm.
Improved weapon of type in which breech mechanism is automatically operated for reloading and recocking by the firing of same. Improved cartridge-feed so that cartridges are always presented properly into opening. Breech block not positively locked but balanced in weight to absorb shock of recoil by its aggregate mass. Improved ejector and take-down feature.

Patent 682,230 — 10 Sep 1901
Perino, Giuseppe — Rome, Italy
Machine-gun.
Recoil-operated machine gun, in which gas at muzzle end of barrel is utilized to force movable mass rearward. Cartridges carried in metallic clip-band, wound spirally on a drum and charged into gun by swinging arm. Spring mechanism permits regulation of speed of firing. Water or air cooled.

Patent 687,448 — 26 Nov 1901
Burgess, Andrew — Owego, N. Y.
Automatic gun.
To produce magazine gun which shall be loaded and shell ejected by a barrel movement depending on position of the trigger under control of the operator; also prompt and powerful shell ejecting mechanism; also cartridge feed placed under control of barrel movement.

Patent 688,216 — 3 Dec 1901
Whiting, William J. — Handsworth, Eng.
Automatic revolver-firearm.
Provides breakdown revolver-type gun with rotating chamber-cylinder with means for automatically holding cylinder stationary when arm is opened for purpose of insuring correct alignment of next chamber of cylinder relative to barrel and hammer when again closed ready for firing.

Patent 693,105 — 11 Feb 1902
Burgess, Andrew — Owego, N. Y.
Automatic gun.
Magazine gun which is loaded and shell ejected by barrel movement under control of operator by special trigger mechanism; control of barrel movement in reference to cartridge feeding; firing lock adapted to this class of guns.

Patent 701,815 3 Jun 1902
Rasmussen, Julius A. N. Copenhagen, Denmark
Automatic firearm.
Improved recoil-operated magazine gun, especially shoulder arms. Improved cartridge feeder movable in guide grooves. Recoil arm holds trigger mechanism inoperative until parts are moved forward into closed position.

Patent 702,240 10 Jun 1902
Noble, Andrew Newcastle-upon-Tyne, Eng.
Automatic gun.
Improved method of feeding cartridges from a hopper above gun to a position behind the opening in the breech and of injecting cartridge into chamber. Also method of operating the breech.

Patent 715,971 16 Dec 1902
Burgess, Andrew Owego, N. Y.
Automatic gun.
Gun in which cartridge-feeder operates with a certainty to hold a cartridge in line with the reciprocating barrel; also to cause magazine follower and feeder to cooperate and cause follower to be held back under certain conditions; cocking of hammer to be effected by closing movement of barrel with predetermined control of firing mechanism.

Patent 723,719 24 Mar 1903
North, Thomas K. Westminster, Eng.
Mechanism for feeding cartridges into machine guns.
Rotatable drum having on its inner periphery longitudinal grooves or projections adapted to hold the rimmed bases of cartridges so that these are carried around with the drum, and a deep groove of helical form stationary within drum adapted to contain bodies of cartridges carried by drum and by rotation of latter made to travel in groove to discharge opening.

Patent 765,491 19 Jul 1904
Kjellman, Rudolf H. Stockholm, Sweden
Recoil-operated firearm.
Object to provide comparatively short breech mechanism to reduce weight. Cartridge box is fixed to frame, room being provided for the top cartridge under breech bolt in receiver. This cartridge takes part in rearward movement of barrel and receiver while others remain in box.

Patent 781,503 31 Jan 1905
Driggs, William H. Washington, D. C.
Automatic gun.
Improvements in small caliber automatic guns. Cartridges stored in revolving hopper divided by radial partitions into a plurality of chambers and piled in each chamber one above other with small end pointing to center. Combines with gun body having breech-block chamber with intersecting grooves in walls therein, a breech block having ribs adaptable to slide in grooves, automatic means for moving block out of engagement with grooves near end of recoil, means for restoring gun to initial position on counter-recoil.

Patent 785,971 28 Mar 1905
McClean, Samuel N. Cleveland, Ohio
Gas-actuated magazine-gun.
Relates to automatic breech-loading magazine-guns. Provides magazine, preferably tubular in form and located beneath barrel and a cartridge carrier for transferring cartridges from magazine to barrel, operated by means of gas-actuated slide which may also operate breech-block.

Patent 794,852 18 Jul 1905
Clarke, Charles M. Pittsburgh, Pa.
Rapid fire gun.
Relates to belt-fed gas-operated rapid fire guns, particularly the mechanism for removing cartridge from belt into revolving breech, breech itself, and means for intermittently actuating it, packing devices, firing pin, extractor, and actuator by which mechanism is operated at each discharge. (Similar to DeKnight Patent 709,883.) Water jacket may be dispensed with; number of chambers in breech may be varied as desired.

Patent 813,694 27 Feb 1906
Fidjeland, Terje A. Fostvedt, Norway
Automatic rifle.
Reloading effected automatically by means of gas pressure. Reloading mechanism consists in only 2 parts, only one being movable.

Patent 821,766 29 May 1906
Taylor, Cecil H. Philadelphia, Pa.
Firearm.
In a gun, the combination of a reciprocating, rotatable cartridge feeder, grooved longitudinally to engage and feed cartridges transversely, a reciprocating breech-block having a bearing for said feeder, means to reciprocate feeder and means to rotate said feeder as it is reciprocated.

Patent 821,921 29 May 1906
Burgess, Andrew Owego, N. Y.
Automatic magazine gun.
Front end of lengthwise feeding magazine shall serve as carrier to move cartridge sufficiently into alinement with barrel to cause it to enter chamber of barrel; to improve firing mechanism so it shall be fully under control of operator and act to open in part the breech of gun and to swing magazine to feeding position.

Patent 829,163 21 Aug 1906
Knowles, William H. Hartford, Conn.
Automatic recoil-operative firearm.
Relates to recoil-operated machine guns. Provides means for automatically "feeding in" belt carried ammunition and for transferring cartridges successively to chamber in barrel, also means for extracting and ejecting shells. New system of firing mechanism including firing-pin-engaging sear. Disassembly without tools.

Patent 851,196 23 Apr 1907
Bevans, William H., Bridgeport, Conn. and Bartholmes, Charles W., Ilion, N. Y.
Automatic gun.
Construction for use in connection with semi-automatic gun for automatically feeding and delivering rounds of ammunition to gun and ramming same to proper position for firing. Hopper for loaded rounds, feeding member in hopper adapted to swing below lowermost round and supply and separate such round to feeder.

Patent 863,101 13 Aug 1907
Schwarzlose, Andrea W. Charlottenburg, Ger.
Automatic gun.
Improved means of feeding ammunition in automatic guns having ammunition arranged in form of single projectile one behind the other on flexible belt. Star roller advances cartridge belt step by step; also pushes out cartridges from belt and finally brings cartridge into loading position in extension of barrel axis so that it can be pushed into barrel by breech mechanism when latter moves forward.

Patent 894,531 28 Jul 1908
Punches, Bert W. Toledo, Ohio
Gun.

Improvement in means of feeding cartridges from magazine into barrel and means for compelling locking of breech-block prior to the firing of the gun. Spring-pressed follower in magazine for feeding series of cartridges from magazine into space vacated by breech-block when retracted and an extractor constituting a stop for limiting initial inward movement of the foremost cartridge.

Patent 903,998 17 Nov 1908
Mauser, Paul Oberndorf, Ger.
Recoil-loading small-arm.

Self-loading weapon with changeable magazine. Device for automatically putting weapon in readiness for firing when changing magazines, comprising a spring ejector for holding breech bolt back when the magazine is removed, a detent for engaging said ejector, said detent being adapted to be disengaged from ejector by a fresh magazine whereby breech bolt can resume its closed position and thereby push a cartridge from magazine into barrel.

Patent 958,078 17 May 1910
Benet, Laurence V. Paris, France
Feed apparatus for automatic guns.

Improvement in semiautomatic gas operated guns, as in Patent 861,939 (1907). Simple and effective cartridge clip, stamped out of single strip of metal and capable of being used again and again. Moved forward by motor piston. Spring plunger engages each cartridge as it is detached from strip near the loading position.

Patent 963,171 5 Jul 1910
Pedersen, John D. Jackson, Wyo.
Firearm.

Improved left-hand slide action firearm, particularly adapted to high power ammunition. Combination with a breech block of a reciprocating tubular magazine action bar independent of breech block and having means for securing a cartridge therein against longitudinal movement and means, operating in the initial rearward movement of said magazine action-bar, for shifting position of cartridge vertically into engagement with said securing means.

Patent 1,007,911 7 Nov 1911
Bjorgum, Nils Asker, Norway
Automatic firearm.

Includes recoil-operated feed system. Breech closing devices have locking member capable of a movement independent of breech bolt proper or slider. "Clever method of positioning round."

Patent 1,008,498 14 Nov 1911
Toborg, George Chicago, Ill.
Automatic firearm.

Means in connection with recoil-operated, spring-pressed breech-block for passing the cartridges from the magazine up to the barrel for firing. Magazine arranged in front of breech under barrel.

Patent 1,028,884 11 Jun 1912
Johnson, Ivar Redlands, Calif.
Automatic firearm.

Improved magazine firearm wherein cartridge carrying plunger is operated by an auxiliary trigger mounted in cocking and firing trigger in such manner that 1st part of movement of operator's finger will feed cartridge from magazine into alinement with barrel and firing pin and further movement will cock and fire. Fired shell automatically ejected when triggers are released, through opening in side of firearm. Improved means for firing.

Patent 1,038,555 17 Sep 1912
Frommer, Rudolf Budapest, A.-H.
Automatic firearm.

Automatic firearm with sliding barrel in which cartridge to be taken from cartridge holder and transferred to loading chamber is withdrawn by means of an extracting member connected with barrel. Withdrawn cartridge transferred to transverse slide which conducts it in front of loading chamber so it can be pushed into chamber by breech bolt in its forward movement. Cartridge securely seized and conducted into chamber in entirely positive manner.

Patent 1,040,692 8 Oct 1912
Kjellman, Rudolf H. Stockholm, Sweden
Automatic firearm.

To provide device whereby rapid and reliable feeding of cartridges from the cartridge band and the like into the barrel and the ejecting of the empty shell is afforded. Combines slotted reciprocating tail piece, extractors carried by breech block, a transporter also on breech block which is slotted to guide cartridge when moved transversely, lever for effecting transverse movement having lateral projection engaging slot in tail piece.

Patent 1,073,709 23 Sep 1913
Revelli, Bethel A. Rome, Italy
Automatic gun.

Improved loading system in automatic gun. Combination of a barrel, a barrel extension with a slot, a body or frame, a closing mechanism consisting of a lever turning upon a pivot fixed to the frame part or body, which lever passes through said slot of barrel extension and a breech block having a notch for said lever and sliding in barrel extension and containing striking pin and spring adapted for double use of percussion and restoring breech block to normal position after recoil.

Patent 1,091,640 31 Mar 1914
Dawson, Arthur T. and Buckham, George T.
London, Eng.
Cartridge feed mechanism of automatic guns.

Relates to feed mechanism of kind in which top and bottom levers are made integral with pivot pin and in which feed box is provided with movable slide in order to permit levers and pin to be placed in position in feed box. Slide is in the form of a cap having a semi-circular recess and mounted in vertical guides on feed box so that pivot pin is completely surrounded by bearing surfaces.

Patent 1,104,947 28 Jul 1914
Winks, John O. San Francisco, Calif.
Automatic firearm.

In recoil-operated firearm, to provide means in which cartridge is locked in barrel at time of firing. Novel means of conveying cartridge from magazine to barrel; improved firing mechanism.

Patent 1,123,530 5 Jan 1915
Heinemann, August A. K. Berlin, Ger.
Machine gun.

Improved cartridge feeding mechanism of class in which belt slide which after each firing feeds the cartridge belt through feeding casing, receives its transverse to and fro movements in cartridge feeding casing by movement of sliding barrel. Provides means whereby length of stroke of belt slide is terminated and made independent of varying length of recoil of barrel so that feeding stroke will always be uniform.

Patent 1,126,726 — 2 Feb 1915
Diestelkamp, Frederick A. — Bland, Mo.
Automatic magazine-firearm.
Positive means for shifting magazine follower upward to feed cartridges one by one into receiver. Means to indicate number of cartridges remaining in magazine. Means actuated upon explosion of cartridge for locking trigger from any tripping movement. Breech block may be drawn back by hand to cock hammer in case of misfire. Flexible follower operating band or chain, and returnable to normal position by spring action. Breech block that will lock behind barrel and give projectile time to clear barrel while block is unlocking and while barrel remains stationary.

Patent 1,130,312 — 2 Mar 1915
Mauser, Paul — Oberndorf, Ger.
Automatic firearm.
Improved means, in firearms with detachable magazine and means for locking breech block in open position after last shot from magazine is fired, for holding breech block in open position when magazine is removed.

Patent 1,146,536 — 13 Jul 1915
Swebilius, Carl G. and Hanitz, Hans T. R.
New Haven, Conn.
Repeating firearm.
Improvements in repeating firearms to improve cartridge handling mechanism to guarantee effective loading and ejecting.

Patent 1,150,435 — 17 Aug 1915
Laird, Charles W., London, Eng., and Menteyne, Paul M. and Degaille, Pierre A., Paris, France.
Cartridge belt.
Charging band or belt for feeding cartridges to automatic firearms. Band formed by union of a number of elements formed of 2 shells inclosing and gripping a cartridge. Connected together by means of a pin acting as a spring.

Patent 1,161,384 — 23 Nov 1915
Fitzpatrick, Kirby — Oklahoma City, Okla.
Automatic gun.
To adapt a rotary breech block to magazine breech loading gun so that breech block may be used to transfer the cartridges from the magazine to the barrel and also to eject the empty shells.

Patent 1,273,078 — 16 Jul 1918
McManus, Luis M. — Houston, Tex.
Machine gun.
Structure wherein the cartridges are positively and consecutively fed to explosion chamber of gun and firing pin is positively actuated at each step of feeding mechanism. Provision for discharging the cartridges when on the belt without the provision of auxiliary feeding devices dependent upon recoil of gun for their operation.

Patent 1,290,842 — 7 Jan 1919
Mottin, Willie F. — Noel, Mo.
Machine-gun.
Improved means for feeding cartridges into gun and means for engaging the cartridges from the carrying strip and conveying them into barrel of gun; also means for extraction and ejection. Feeding roller provided with teeth fitting into openings formed in cartridge carrying tape.

Patent 1,290,851 — 7 Jan 1919
Sturgeon, John C. — Erie, Pa.
Automatic gun-cartridge supply and feed mechanism.
Detachable cylindrical cartridge supply device having clips on its periphery to hold cartridges removably therein so they may be readily detached by the feeding mechanism of the arm. Also mechanism to rotate cartridge supply so as to remove one cartridge at each forward movement thereof, and means for moving such cartridge in front of the bolt at end of its backward traverse, thereby expelling spent shell of previously fired cartridge.

Patent 1,290,852 — 7 Jan 1919
Sturgeon, John C. — Erie, Pa.
Automatic gas-operated firearm.
Cylindrical magazine secured to under side of gun-frame and fed to breech bolt by flexible band operated by sprocket wheel on frame. Spring-actuated arm pivoted to gun frame prevents displacement of belt and cartridges on sprocket wheel.

Patent 1,290,854 — 7 Jan 1919
Sturgeon, John C. — Erie, Pa.
Automatic rapid-fire gun.
Improved cartridge feeding mechanism, mechanism for preventing premature discharge of arm prior to complete locking of breech-bolt and gas regulating and sediment trapping mechanism.

Patent 1,294,295 — 11 Feb 1919
Mendoza, Rafael — Chihuahua, Mex.
Rifle.
Means whereby parts are moved into firing position and cartridges moved into and ejected from breech casing by longitudinal movement of the barrel, so gun may be shot a number of times without removing it from shoulder. Stationary breech block containing firing mechanism parts. Single spring for actuating firing pin, moving cartridges in magazine and working ejecting mechanism. Detachable barrel.

Patent 1,294,636 — 18 Feb 1919
Dovell, Harper H. — Baltimore, Md.
Machine-gun.
Combination of a rotating cartridge carrying drum provided with a plurality of radially disposed rows of bores adapted to receive cartridges; central supporting member on which said drum rotates provided with a single row of bores with each of which a pair of bores is adapted to simultaneously register; etc.

Patent 1,298,091 — 25 Mar 1919
Redpath, Robert and Hellberg, Helge — Coventry, Eng.
Feed mechanism for automatic guns.
Magazine consists of trays pivoted at their rear ends to a drum and having their front ends locked to the drum by means of catches. On running out of the gun the magazine is turned by means of a spring plunger actuated by a sleeve on gun, catches being released and trays turned down by means of a pivoted lever.

Patent 1,314,734 — 2 Sep 1919
Dawson, Arthur T. and Buckham, George T.
Westminster, Eng.
Machine gun.
Feed box for Vickers gun interchangeable with existing right hand feed box and arranged to feed belt from left hand side without altering construction of gun.

Patent 1,329,979 3 Feb 1920
Lang, Charles W. Philadelphia, Pa.
Rapid fire gun.
Primary object to provide an efficient magazine of rotary hopper type for rifle caliber gun adapted to be operated semi-automatically or with full automatic rapid fire at will. Magazine will receive and feed cartridges in a spiral series and positively force them toward throat of receiver.

Patent 1,333,571 9 Mar 1920
Pedersen, John D. Jackson, Wyo.
Firearm.
Improved small arm provided with magazine having spring actuated followers or cartridge feeders. Device whereby barrel may be detachably united with frame by means of transverse bar. Bar also combined with a slide lock member continuously subjected to frictional control by a force derived from breech-slide-actuating spring and transmitted to slide-lock through barrel and said cross-bar.

Patent 1,350,961 24 Aug 1920
Farquhar, Moubray G. and Hill, Arthur H.
Birmingham, Eng.
Automatic firearm.
Improvement on Patent 1,019,620 (1912) on automatic firearms suitable for machine gun. Employs breech opening spring or springs arranged under barrel of gun, but body and bolt cover are inverted, i. e., breech opening in body is presented downward and cartridges fed into chamber from magazine or other feed situated and working over body or shoe of gun.

Patent 1,366,210 18 Jan 1921
O'Malley, John F. Mount Vernon, N. Y.
Machine-gun.
Improvement on Patent 1,307,316 (1919) having double reversible barrels. Provides for supply of cartridges to barrel in use at the time from an intermittently revolving magazine wheel instead of from a cartridge belt. Quick replacement of empty wheel by another.

Patent 1,369,426 22 Feb 1921
Harper, Angelo C. Washington, D. C.
Machine-gun.
Novel form of breech and firing mechanism adapted to retain cartridges used in connection with the gun in position such as will permit discharge of projectiles into and from gun barrel under full influence of liberated gases given off by the explosions. Firing mechanism operated by rotary movement of gun magazine and breech mechanism as tubes of latter are brought into alinement with barrel.

Patent 1,399,119 6 Dec 1921
Hodges, Lloyd E. Glendora, Calif.
Machine gun.
Means whereby succession of cartridge containers or holders may be fed through the gun, i. e., to and from firing position, together with means for holding cartridges and containers stationary while gun is fired and ejecting shells with containers thereafter. Provides pair of opposed rotors having chambers formed therein for holding and centering cartridges before barrel of gun, one rotor being positively driven as gun is cocked for moving cartridges into position and other rotor being operated by movement of cartridge containers.

Patent 1,441,517 9 Jan 1923
Miskunas, Anton Oglesby, Ill.
Machine gun.
Operation of the drums feeding the cartridge tape or belt operates the hammer or trigger mechanism.

Patent 1,464,864 14 Aug 1923
Browning, John M. Ogden, Utah
Firearm.
Relates to autoloading magazine firearms. Improved feeding of cartridges from magazine to chamber to obviate jams. To facilitate filling of magazines and loading of removable magazines into the gun.

Patent 1,481,042 15 Jan 1924
Walther, Fritz and Georg Zella-Mehlis, Ger.
Automatic firearm.
Characterized by the slide block being coupled to breech block and travelling in a straight line in the receiver, a pin on the feed lever engaging grooves in said slide block in such a manner that feed lever is raised during advance in breech block and therefore of slide block whereby feed lever introduces a cartridge into barrel which cartridge is shoved thereinto by advancing breech block while feed lever is gradually lowered.

Patent 1,485,460 4 Mar 1924
Johnston, James S. Utica, N. Y.
Machine gun.
Assembled without screws. Automatic mechanism for loading and firing cartridges, fed automatically from magazine into cartridge carrier. May be used as rapid firer or single shooter by throwing in or out of connection the gas chamber, and may be shot from shoulder or tripod.

Patent 1,504,393 12 Aug 1924
Sutton, Harry A. and Verville, Alfred V. Dayton, Ohio
Cartridge feeding mechanism for automatic guns.
Plurality of magazines, each adapted to contain a number of heavy cartridges and to feed same downward by force of gravity into chamber of breech; and means operated automatically by firing of gun which will move a train of loaded magazines toward discharging position as other magazines are emptied.

Patent 1,504,584 12 Aug 1924
Swebilius, Carl G. New Haven, Conn.
Automatic gun.
Mechanism for feeding cartridge belt into proper position to have cartridges removed therefrom. Mechanism can be moved rearwardly step by step only. Pawl for normally preventing rearward movement and a member to release pawl from feed mechanism to allow rearward movement of mechanism. Arm on pawl limits movement.

Patent 1,504,714 12 Aug 1924
Russell, Herbert O., Detroit, Mich. and Paulus, Charles L., Dayton, Ohio
Machine gun and hopper feed box therefor.
Feed box adapted to a flexibly mounted machine gun for feeding loose cartridges to gun. Insures cartridges being delivered into feed way of gun in proper alignment at right time.

Patent 1,525,067 3 Feb 1925
Browning, John M. Ogden, Utah
Cartridge feeding device for automatic firearms.
To provide a feed plate adapted to be automatically fed step by step through a transverse feed channel of gun to

bring cartridges successively into central plane of gun. Plate can be readily inserted into feed channel and fed there through with either end first, thereby requiring less attention on part of operator supplying loaded plates to gun and aiding in keeping up continuous automatic fire.

Patent 1,541,282 — 9 Jun 1925
Russell, Herbert O., Detroit, Mich., and Paulus, Charles L., Dayton, Ohio
Feed box for cartridge belts of machine guns.
Box adapted to house and guide cartridge belts such as are used on machine guns, particularly for use on flexibly mounted aircraft gun of Browning type. Mounted and demounted by a simple shifting movement of the box laterally with respect to gun. Ample clearance between abutting walls of box and the gun. May be operated by one hand.

Patent 1,553,992 — 15 Sep 1925
Dawson, Arthur T. and others — London, Eng.
Automatic gun.
Relates to Vickers type guns. Hollow trunnion provided on cartridge feed side of gun of sufficiently large bore to permit passage of ammunition through it to cartridge feed mechanism of gun. Avoids impedance of entrance of ammo to feed box of gun. When belt ammo is used, the other trunnion is also hollow and of sufficient bore to permit passage of empty belt, etc.

Patent 1,617,683 — 15 Feb 1927
Grill, Calvin E. — San Francisco, Calif.
Automatic gun.
Automatic action for gun wherein cartridge supply mechanism to gun barrel is mechanically controlled and operated in unison with breech block. Improved breech block and extractor.

Patent 1,629,652 — 24 May 1927
Browning, John M. (deceased).
Cartridge feeding mechanism for automatic firearms.
Improvement on recoil operated gun (Pat. 1,293,021—1919). Uses rotary drum feed for guns flexibly mounted or mounted on opposite sides of airplane fuselage in position to fire through propeller blades. Avoids necessity for providing belt container in first case and need to have reversible feeding mechanism for right and left hand feed.

Patent 1,660,590 — 28 Feb 1928
Baldwin, Augustus M. — New York, N. Y.
Machine gun.
Gun having a number of bores through which cartridges may be simultaneously fired so that fire will be dispersed over a certain area. Improved removable or detachable cartridge containers adapted to be filled with cartridges outside of the gun and formed to encase cartridges and hold them in position for firing. Automatic means whereby containers are fed into operative position for firing and ejected after firing.

Patent 1,709,399 — 16 Apr 1929
Herlach, Fritz and Rakula, Theodor — Dusseldorf, Ger.
Automatic firearm.
Firearm designed to receive simultaneously 2 separate cartridge magazines, adapted to be exchanged independently of each other and brought successively into range of the members of the arm that shift the cartridges in direction of bore of barrel into cartridge chamber. Means for automatic adjustment of feed of each magazine. Mechanism by which firing of last present cartridge is made impossible until new full magazine is inserted.

Patent 1,719,126 — 2 Jul 1929
Pfeiffer, Christian and Moore, Frederick T.
Hartford, Conn.
Magazine feed mechanism for machine guns.
Relates to magazine (for Browning m/g) adapted to contain a cartridge feed belt which is withdrawn therefrom by means of mechanism of gun. Magazine has opening therein located between 2 belts containing portions of such size as to permit convenient sighting of gun. Means serving to hold belt normally against outward movement but released to permit free movement of belt when needed. Other improved constructions.

Patent 1,784,355 — 9 Dec 1930
Herlach, Fritz and Rakula, Theodor — Dusseldorf, Ger.
Automatic firearm with two cartridge magazines.
Improvement on invention in which 2 magazines are provided (Patent 1,709,399) and in which after one has been emptied and ejected, the second is automatically switched into feeding position. Adapts weapon for using the ordinary magazines in which foremost cartridge is held by inwardly bent lips of open end of magazine and seized by parts of the breech at beginning of forward movement. Facilitates insertion of filled magazine into weapon.

Patent 1,801,071 — 14 Apr 1931
Browning, Jonathan E. — Ogden, Utah
Automatic firearm.
Rifle caliber shoulder arm requiring manual operation of trigger to effect firing of each shot. Improvement on Patent 1,801,070 relating to breech mechanism. Has link mechanism and a handle adapted for manually operating gun and connected to parts of the linkage. Link mechanism also effects cocking of gun.

Patent 1,803,351 — 5 May 1931
Moore, Frederick T. and Pfeiffer, Christian
Hartford, Conn.
Reversible feed mechanism for machine guns.
Simple and reliable mechanism whereby feeding in either direction can be effected. Reversal of direction of feed may be effected without use of any additional or substitute parts.

Patent 1,808,847 — 9 Jun 1931
Hatcher, James L. — U. S. Army
Belt feed mechanism for machine guns.
Improvement in Browning-type machine guns so that step-by-step advance of cartridge belt is produced by utilizing the energy of recoil to provide a force effective during counter recoil to automatically advance the cartridge belt.

Patent 1,811,694 — 23 Jun 1931
Larsson, Carl A. and Higson, Percy R.
Westminster, Eng.
Drum magazine for machine guns and automatic small arms.
Improvement in magazines of type in which cartridges are withdrawn rearwardly from magazine during rearward movement of lock or bolt. Base of stationary pan is provided with an inclined chute or conduit which communicates with discharge opening and conveys the cartridges into required position for being extracted. Outer end of chute has removable member to enable magazine to be re-charged, preferably by hopper.

Patent 1,839,621 5 Jan 1932
Umberto, Onorati Toledo, Ohio
Automatic firearm.

Relates to recoil operated firearms. Magazine carrying cartridges disposed directly beneath and parallel to barrel. Permits use of exceptionally large magazine. Length of barrel increased to insure greater accuracy and range of fire. Has pair of barrels which may be discharged simultaneously.

Patent 1,932,424 31 Oct 1933
Simpson. Clarence E., Springfield, Mass., and Bull, William R,. Longmeadow, Mass.
Gun. (Cl. 89–3)

Mechanism for adjusting head space in a machine gun. Permits barrel to be readily removed and replaced without disturbing action; permits barrel to be locked in place by interrupted threads; permits accurate adjustment of head space while gun is completely assembled. Attained broadly by varying locked position of breech bolt, by use of adjustable cam to cooperate with breech bolt lock.

Patent 1,993,887 12 Mar 1935
Kewish, John T. New York, N. Y.
Automatic firearm. (Cl. 42–3)

Simplified construction of firearms in which actuating power is derived from cartridge. Improved cartridge magazine whereby a large number of cartridges may be contained in removable cylinder without use of cartridge clips. Means for lubricating cartridges when gun is being fired. Improved trigger and ejecting mechanism.

Patent 2,027,893 14 Jan 1936
Williams, David M. Godwin, N. C.
Belt feeding means for guns. (Cl. 89–3)

Means for preventing feed belt pawl from feeding more than one cartridge during its overtravel. Mechanism capable of feeding large caliber ammunition. Extractor operates beneath the cartridges present in the belt and extracting cartridges therefrom, serving also as a cartridge support. Depressor feed cam to insure cartridge will be depressed in alignment with barrel bore in event gun mechanism fails to come to a full open position due to firing defective cartridge.

Patent 2,037,244 14 Apr 1936
Larsson, Carl A. and Higson, Percy R.
Westminster, Eng.
Machine gun. (Cl. 89–33)

Vickers aircraft type gun enabled to feed from either side. Reversible feed slide and operating levers in feed box and feed mechanism.

Patent 2,050,038 4 Aug 1936
Browning, John Ogden, Utah
Repeating firearm. (Cl. 42–17)

Improved arrangement for effectively feeding cartridges from magazine to firing chamber of repeating rifle of take down type.

Patent 2,057,169 13 Oct 1936
Swenson, Eric A. Beaukiss, Tex.
Automatic firearm. (Cl. 42 5)

Magazine firearm in which cartridges are carried upon an endless carrier and in which a motor is used to operate carrier to bring cartridges into register with barrel and operate gun.

Patent 2,073,632 16 Mar 1937
Green, Samuel G. Gray, Ga.
Cartridge feeding mechanism for automatic guns. (Cl. 89–33)

Mechanism which will accurately position a cartridge with its groove properly presented to extractor of breech bolt, irrespective of variations in length of cartridge and irregularity of loading in belt. Engages cartridge during final stage of movement during feedway, displacing it axially to its proper position for extraction and holding it against any force tending to move it forwardly in feedway.

Patent 2,090,656 24 Aug 1937
Williams, David M. Godwin, N. C.
Automatic firearm. (Cl. 42–3)

Invention comprises combination in a repeating firearm of a barrel member, a sliding member, said members being reciprocable with respect to each other, a vibrator arranged to engage one of said members and initiate movement of the members to spaced position, and a magazine for cartridges positioned to allow cartridges to be fed rearwardly of vibrator. Eliminates need for having returning means and consequently any retaining means. Vibrator devised with vibratory threads.

Patent 2,093,705 21 Sep 1937
Browning, Marriner A. Ogden, Utah
Automatic firearm. (Cl. 89 3)

In gas-operated machine gun, cartridge feed channel is below the barrel and cartridges are fed by means of a slide positioned below the feed channel and above the gas operated operating slide. Improved means of transferring cartridges to chamber and improved means of ejection.

Patent 2,113,202 5 Apr 1938
Stange, Louis Sommerda, Ger.
Automatic gun. (Cl. 89–33)

Cartridge belt or magazine plate is advanced to feed a cartridge forward when a cartridge is pushed into barrel by advancing breech block, whereas hitherto this feeding motion of belt or magazine could only occur after recoil. Increases speed of fire. Breech block does not have to advance cartridge belt during its recoil movement. Next cartridge is in position during firing of previous charge to be engaged by the yieldable member of breech block when latter recoils. Forward motion of breech block pushes cartridge into barrel.

Patent 2,113,793 12 Apr 1938
Larsson, Carl A. and Higson, Percy R.
Westminster, Eng.
Machine gun and drum magazine therefor. (Cl. 89 33)

Large capacity drum while maintaining size as small as possible. Magazine adapted to receive cartridges in substantially annular disposition with adjacent cartridges in contact with each other. Means for separating cartridges and feeding them singly through an outlet or mouthpiece. With rimmed cartridges, arranged with rims outermost and with rim of each overlapping rim of next cartridge on one side and beneath rim of next cartridge on other side.

Patent 2,121,794 28 Jun 1938
Green, Samuel G. Gray, Ga.
Cartridge guide and stop for machine guns. (Cl. 89–33)

Member having means for determining the correct longitudinal and vertical position for either a ball or blank cartridge. Eliminates malfunctions due to improper feeding.

Patent 2,124,911 — 26 Jul 1938
Darne, Regis — St. Etienne, France
Automatic firearm. (Cl. 89–2)
Parts of cartridge lifting container arranged so that cartridges cannot escape accidentally from conveyer under effect of vibrations; so arranged that when conveyer reaches its higher position it can move down only when cartridge is nearly wholly engaged into chamber. Servo-pawl device intended to render impossible "double feed".

Patent 2,167,495 — 25 Jul 1939
Wimmersperg, Heinrich — Vienna, Austria
Firearm. (Cl. 89–2)
Relates to double-barrel automatically repeating firearms. At least one of the two barrels is longitudinally movable and adapted during forward movement to push a cartridge into other barrel and fire same and during its recoil to eject empty case from other barrel while simultaneously loading itself with fresh cartridge. Latter is fired when barrel in question reaches its rearmost position. Thus alternate firing of the two barrels is obtained.

Patent 2,223,380 — 3 Dec 1940
Michal, Charles J., Jr. — Hinsdale, Ill.
Machine gun. (Cl. 42–49)
Improved many-round magazine for use with fully automatic pistol or with convertible fully automatic semi-automatic pistol which converts pistol into automatic gun.

Patent 2,282,903 — 12 May 1942
Swebilius, Carl G. — Hamden, Conn.
Tubular-magazine automatic firearm. (Cl. 42–17)
Improved cartridge-elevating means to insure feeding into chamber. One-by-one feeding of a column of cartridges from a tubular magazine for insertion into chamber. Gases escaping rearwardly from chamber when just-fired cartridge is extracted not permitted to clog magazine or submit marksman to discomfort.

Patent 2,359,263 — 26 Sep 1944
Webb, George — Hartford, Conn.
Automatic firearm and combined accessories. (Cl. 89–33)
Readily detachable cartridge supporting device such as a loading tray adapted to be attached to an automatic firearm, adjacent the feed channel thereof by novel securing means whereby a rigid feeder may be aligned with firearm for proper feeding. Also detachable magazine which may be substituted for feed tray; and loading plate detachably secured to magazine to facilitate loading of magazine with a feeder.

Patent 2,364,510 — 5 Dec 1944
Bertran, Edward M., Jackson Heights, and Lesnick, Robert N., Brooklyn, N. Y.
Gun ammunition magazine. (Cl. 89–34)
Improved mounting and magazine devices for aerial automatic guns. Improved means for mounting upon airplane wing or like. Improved method and means for feeding a relatively heavy caliber automatic gun when mounted upon wing. Magazine comprises walled elongate box-like casing, pair of relatively spaced and parallel track means mounted within casing. Chamber supports train of ammunition rounds operated by compression spring means.

Patent 2,365,459 — 19 Dec 1944
Dobremysl, Josef — Cambridge, Eng.
Automatic gun. (Cl. 89–33)
Improved means for loading cartridges into barrel chamber and for returning empty cartridge cases back into cartridge belt. Device actuated by a lever pivoted in the breech block carrier and having one arm operatively connected with carriage and other arm forked for cooperation with abutments.

Patent 2,367,488 — 16 Jan 1945
Dobremysl, Josef — London, Eng.
Automatic firearm. (Cl. 89–33)
Feed operating mechanism for guns in which movement of mechanism is derived from kinetic energy of recoiling breech mechanism. Arrangement by which kinetic energy of breech mechanism is transmitted to feeding mechanism by means of a member capable of a rocking movement. This movement of a lever is transmitted to carriage of feed mechanism by means of a crank arm and link.

Patent 2,375,452 — 8 May 1945
Webb, George — Hartford, Conn.
Automatic firearm. (Cl. 89–33)
Improved mechanical features of breech casing and breech mechanism of Browning-type machine guns. Cartridge supporting device such as a loading tray or magazine separably connected with feed box. Feed slide operatively connected with feed mechanism. Alternate flexible or articulated link cartridge feeder and magazine for holding it.

Patent 2,378,331 — 12 Jun 1945
Schirokauer, Henry — New York, N. Y.
Gun mechanism. (Cl. 89–2)
Improvement in machine guns in extracting, feeding and firing mechanisms. Special cartridge grasping mechanism carried by reciprocating member which operates breech block or firing mechanism. Affords extra grip on cartridge while being extracted, from belt for feeding into chamber.

Patent 2,379,185 — 26 Jun 1945
Reek, Royal J. — South Bend, Ind.
Gun feed mechanism. (Cl. 89–33)
Ammunition feed mechanism for guns using belted ammunition and mounted for movement in elevation. By placing cartridge initially at 90 degrees to axis of gun when both are horizontal and feeding belts over a tapered roller secured to gun, cartridges can be satisfactorily fed to gun at any point in the elevation arc thereof. Presents belted ammunition to feed mechanism in a position parallel to gun.

Patent 2,388,396 — 6 Nov 1945
Eklund, Hans E. — Malmo, Sweden
Firearm. (Cl. 42–3)
Improvements in automatic or semi-automatic firearms with barrel provided with a gas outtake, wherein breech block and a movable member adapted to actuate breech block directly form a loading mechanism to which driving gases are conveyed through a pipe conduit and wherein opposite ends of conduit and movable member of loading mechanism are formed into a working cylinder and into a driving piston and having a rectilinear path for said movable member.

Patent 2,392,012 — 1 Jan 1946
Swebilius, Carl G. — Hamden, Conn.
Belt-holding pawls for machine guns. (Cl. 89–33)
Adapted for use with Browning type guns. Will function despite misalignment of succeeding cartridges in a belt. Has plurality of independently-movable pawls to insure against retrograde movement of a cartridge belt.

Patent 2,405,207 6 Aug 1946
Green, Samuel G. Gray, Ga.
Gun feed mechanism. (Cl. 89–33)
Auxiliary ammunition feeding device directly coupled to main power source of a machine gun or other automatic weapon. Power booster feed directly coupled to main power source performs heavy belt lifting operation and permits conventional feed mechanism to move comparatively negligible load of but a few cartridges.

Patent 2,422,301 17 Jun 1947
Horan, Timothy F. New Haven, Conn.
Cartridge feeding mechanism for repeating firearms. (Cl. 42–17)
Lifting device for cartridge is in form of a lever with floating pivot having limited movement in addition to pivotal movement, whereby lifter may be thrown upwardly to extent permitted by bolt and given supplementary movement by a spring to insure lifting cartridge to position in which it will be positively thrust into chamber upon forward movement of bolt.

Patent 2,425,425 12 Aug 1947
Jorgensen, Bernhardt Marblehead, Mass.
Gun-loading mechanism. (Cl. 89–45)
Applied to large caliber gun for use in airplane. Shells transferred from a magazine by vertically moving tray so mounted that it is automatically moved to carry shell into alignment with gun at completion of its movement by engagement of tray with member carried by and extending rearwardly of gun. Moving member is in form of a housing supporting a rammer.

Patent 2,428,414 7 Oct 1947
Elliott, Daniel S. Middle River, Md.
Machine gun feed. (Cl. 89–33)
Power boost for feeding belt of ammunition to a machine gun. Aids movement of belt of ammunition as it passes from the drum to the gun. Has mean rate of feed equal to rate of feed provided by the automatic gun and need not be synchronized with gun. Provides motor driven sprocket wheels engaging belt between drum and gun.

Patent 2,453,830 16 Nov 1948
Chadwick, George A. and Burk, Paul W.
Washington, D. C.
Machine gun. (Cl. 89–190)
Improved machine gun having: ammunition supply permitting continuous fire without interruption for changing magazines or feeding in new belts; cartridge brought into line with axis of gun without employing moving fingers or pawls; breech block locking wedges with but slight movement; means to lock breech mechanism open when ammunition supply is exhausted; direct cooling of barrel at chamber by circulating water.

Patent 2,454,251 16 Nov 1948
Hamilton, Wallace Albany, N. Y.
Cartridge feeding mechanism for automatic guns. (Cl. 89–33)
Relates to 20 mm guns for use in aircraft. Operated by remote control, capable of rapid fire of order of 800 to 1,000 rounds per minute. Means driven by gas pressure for feeding rounds into position for ramming, including sprocket wheel to receive and advance rounds, and means operable by blowback impact to unlock wheel for a feeding step.

Patent 2,483,837 4 Oct 1949
Nettles, Isaac Detroit, Mich.
Gun with reciprocable breech block and rotary feeder. (Cl. 42–18)
To provide a firearm with dual magazines extending respectively upwardly and downwardly from loading chamber and to utilize a single automatic feed mechanism for delivering cartridges from both magazines to said chamber. Improved automatic ejector.

Patent 2,494,728 17 Jan 1950
Stacey, Ernest W. and Reinhold, Frank W.
Beverly, Mass.
Ammunition feeder. (Cl. 89–33)
Machine for automatically feeding ammunition to 37 mm guns installed in airplanes. Magazine or housing for receiving cartridges assembled in groups in separate clips, mechanism for successively moving clips to a transfer station adjacent to a feed box of a gun, and means for delivering in contacting succession loaded clips to feed box.

Patent 2,509,382 30 May 1950
Williams, David M. New Haven, Conn.
Cartridge-feeding mechanism for firearms. (Cl. 42–17)
Improvements in feed mechanism of self loading firearm of type having tubular magazine and cartridge-transfer means to move cartridge to chamber of barrel. Breech block and carrier coact to automatically deliver cartridges successively from magazine onto carrier free from detrimental effects of recoil.

Patent 2,541,530 13 Feb 1951
Meyer, Edward J. Normandy, Mo.
Ammunition feed and control system. (Cl. 89–33)
Improvement in operation of ammunition booster systems so that feeding of ammunition to automatic gun may be accurately synchronized with gun operating cycle. Utilizes booster to move belted ammunition to an automatic gun from a remotely located magazine. System initially operative through gun trigger system and functions thereafter at rate just sufficient to assure normal gun action.

Patent 2,541,616 13 Feb 1951
Sasser, John D. Springfield, Ohio
Feeding device. (Cl. 89–33)
Provides an ammunition feeding device for supplying a string of ammunition to a gun while maintaining same at a substantially uniform level, entirely automatic and without necessity of operator operating the control. Casing adapted to be mounted in fixed relation to gun and to receive the string of ammunition in layers, said casing having a delivery passage for ammunition through the top and adjacent side thereof.

Firing Mechanisms

Patent 51,440 12 Dec 1865
Elliot, W. H. Ilion, N. Y.
Improvement in many-barreled fire-arms.
Causes firing point of breech loading arm to oscillate, so as to move it from one chamber or charge to other or to move it away from before a chamber and back again; and so constructing cam and firing pin of said arm that they may also serve the purpose of ratchet and pawl to revolve the cam.

Patent 157,783 15 Dec 1874
Berdan, Hiram New York, N. Y.
Improvement in breech-loading fire-arms.
Firing pin so constructed that its point is made separate from its body, so that it can be renewed without renewing

whole pin. Latch provided in under side of hammer working in a slot in under side of breech-piece or bolt, for purpose of preventing hammer from coming forward before breech piece is fully closed.

Patent 249,406 — 8 Nov 1881
Scharf, C. William — New Haven, Conn.
Magazine gun.
Object to withdraw firing pin in rear movement of breech-piece so that when latter is returned the firing pin will not be brought into forcible contact with primer until struck by hammer; also, to provide breech-piece with ejector that will forcibly eject exploded shell after withdrawal from chamber.

Patent 317,545 — 12 May 1885
Kinsman, Frank E. — Plainfield, N. J.
Electric fire-arm.
Fires cartridge in a gun or other portable fire-arm by an electric battery contained within the stock or below the barrel. Cartridge has insulated metallic conductor and a fine wire of platina or similar metal in the powder space connected at one end to conductor and at other end to metallic portion of exterior of case. Trigger operates circuit closer.

Patent 319,898 — 9 Jun 1885
Frost, Joseph W. — New York, N. Y.
Electric fire-arm.
Relates to fire-arms in which charge is ignited by electric spark or heat. Charge is contained in a cartridge having a penetrable head and is ignited by means of either a spark generated between 2 points penetrating head of cartridge by closing an electric circuit or by the heat generated in a thin wire penetrating head of the cartridge by closing the circuit.

Patent 332,071 — 8 Dec 1885
Gavitt, James K. G. — Philadelphia, Pa.
Electric fire-arm.
Combination of stock and breech chamber of a magazine gun and an electric battery carried thereby with a sliding breech block carrying the igniting points or wire to come into contact with the explosive charge of each cartridge and a circuit-closing trigger. Sliding breech-block carrying on its face a cutter to make incision in the end of the cartridge and having behind said cutter the igniting points or wire.

Patent 365,842 — 5 Jul 1887
Monfort, Edgar A. — New York, N. Y.
Electric cartridge.
Electric cartridge having an annular depression with a conductor and a central depression with a conductor, the inner ends of said conductors being connected by a metal piece embedded in the powder, constructed and adapted to serve with an arm having projections to agree with the depressions and electrical connections.

Patent 365,843 — 5 Jul 1887
Monfort, Edgar A. — New York, N. Y.
Electrical breech-loading fire-arm.
Breech-loading fire-arm in which an accumulator secondary battery or any suitable electric generator is located within the stock and the charge fired by means of an electric current derived from said battery and passed through a platinum wire which connects the terminals of the conducting wires within the charge of powder on a cartridge with which the gun is loaded. Improvement insures connection between wires in cartridge and poles of the battery when gun is closed. Two non-corrodible metal contacts are provided.

Patent 808,118 — 26 Dec 1905
Sjogren, Carl A. T. — Stockholm, Sweden
Gun.
Improvement on guns described in Patent 739,732 (1903). Provision of suitable means for compressing in the forward motion of the weights or weight, the spring or springs actuating the firing pin, whereby the spring or springs adapted to throw the weight or weights backward may be made much weaker than before.

Patent 855,427 — 28 May 1907
Bevans, William H. — Bridgeport, Conn.
Electric and percussion firing mechanism.
Improved mechanism by means of which gun may be fired either electrically or by percussion, the mechanism being so arranged that should percussion-gear fail to perform, electric gear will operate without necessitating changing of any part by the gunner. Applies to Hotchkiss type of ordnance.

Patent 877,657 — 28 Jan 1908
Mason, William. — New Haven, Conn.
Gas-operated gun.
Improvement in movable barrel tubular magazine shot-guns operated by gases, except for loading and firing. Timing mechanism to prevent premature firing of gun; pulls sear out of play except when gun is fully closed and when trigger has been released and allowed to move forward. Cartridge stop controls feeding of cartridges out of magazine.

Patent 882,594 — 24 Mar 1908
Talbot, Henry H. — St. Joseph, Mo.
Firearm.
Relates to firearms with magazine feed. Shortened breech-block with accompanying firing pin and spring of sufficient length only to cover magazine and extend back over magazine guide lugs. Unobstructed path for hammer; novel construction of hammer to place it in a more forward position in frame. Automatic safety to restrain hammer when cocked. Trigger lock permits free movement of trigger and allows it to actuate sear when action is closed, but when action opens obtains mechanical possession of trigger and returns it to forward position and locks it.

Patent 936,806 — 12 Oct 1909
Pedersen, John D. — Jackson, Wyo.
Combined firing-pin and ejector for firearms.
Combined firing pin and ejector mounted in the breech block, having means for producing a lateral throw to the cartridge engaging end.

Patent 954,546 — 12 Apr 1910
Sjogren, Carl A. T. — Stockholm, Sweden
Recoil-loading gun.
Improvements in recoil loading guns in which recoil causes an inertia weight to move forward and thereby compress firing-pin spring. Improved retaining device to prevent weight from backward movement before firing as well as from forward movement and premature firing of gun. Abutment on shoulder forming anterior wall of notch of retaining device is formed by a pawl pivotally connected to said device, being actuated by a spring.

Patent 965,538 — 26 Jul 1910
Raines, Richard — New York, N. Y.
Machine-gun.
Electrically fired machine-gun firing projectiles in manner known as "fan fire" and also to fire projectiles at one spot. Improved cartridge tray adapted to feed cartridges to a cylinder. Improved form of contact closer adapted to close

circuit between battery and cartridge. Rotatable cartridge cylinder carried by barrel having a plurality of spaced cartridge grooves and a feed plate having spaced grooves to correspond.

Patent 1,045,549 — 26 Nov 1912
Heinemann, Karl — Berlin, Ger.
Automatic gun.
Relates to Maxim-type guns. Construction of mechanism controlling operation of firing pin so that spring of firing pin is not in same degree subject to breakage and can be easily replaced when broken without use of special tools. Provides coiled spring common to firing pin and safety sear and disposing the said spring between a nose of the pin and end of safety sear, so that after removing bolt of safety sear and slightly depressing breech block, sear and spring can be removed and replaced with new parts.

Patent 1,073,588 — 23 Sep 1913
Brauning, Karl A. — Herstal, Belgium
Firing mechanism for automatic firearms.
Relates to firing mechanism for automatic firearms in which percussion bolt is provided with a part subjected to the action of a spring which part comprises the sear, retains the percussion bolt or hammer in cocked position by striking against a stop on breech bolt, firing being effected by releasing the engagement of the said part and the stop.

Patent 1,150,364 — 17 Aug 1915
Heinemann, August A. K. — Berlin, Ger.
Machine gun.
Improved firing-pin safety device. Means for securing firing pin in its tensioned position and preventing it flying forward unintentionally.

Patent 1,150,611 — 17 Aug 1915
Mauser, Paul — Oberndorf, Ger.
Firing mechanism for automatic firearms.
Firing mechanism in which breech block is guided on the breech frame, its object being to hold the sear in the engaged position during the engagement of the firing pin so that firing pin is prevented from being accidentally released owing to shocks or vibrations. Utilizes one of lateral guiding ribs of breech block.

Patent 1,159,004 — 2 Nov 1915
Frommer, Rudolf — Budapest, A.-H.
Firing mechanism for automatic firearms.
To provide an arrangement of firing pin in which while the ordinary size of pin is maintained or increased, the spring which pushes it back can be very weak, thus offering great security against premature explosions. Pin made in 2 parts, one being a front point, and the other a rear transmitter, both parts being held separated during operation of breech.

Patent 1,200,685 — 10 Oct 1916
Young, Franklin K. — Winthrop Highlands, Mass.
Firearm.
Convertible automatic arm having few parts in which firing pin is automatically operated without the provision of a hammer operating thereagainst. May be used as semi or full automatic.

Patent 1,352,891 — 14 Sep 1920
Green, Samuel G. — U. S. Army
Electrically controlled mechanism for firearms.
Electrically controlled mechanism for firing machine gun from a distance. Saddle adapted to be secured to firearm, an electro-magnet supported by said saddle and having an armature, a trigger-engaging member, a lever for moving said member and actuated by the armature of said magnet and an electric circuit including said magnet.

Patent 1,359,609 — 23 Nov 1920
Lang, Charles W. — E. Orange, N. J.
Firing mechanism for firearms.
Firing pin especially adapted for cooperation with a striker in form of a hammer by giving firing pin a considerable mass. Hammer control which in addition to finger trigger sear embodies a full automatic sear that arrests hammer in cocked position until after breech block is closed and tripped off by movement of breech locking mechanism to locked position. Safety devices to secure hammer.

Patent 1,384,769 — 19 Jul 1921
MacLaren, Frederick B. — Jersey City, N. J.
Electric gun.
Method of discharging or propelling projectiles which consists in generating traveling magnetic fields, annular in form, propagated in direction of flight by means of polyphase electric current developed by a generator. Projectile subject to effect of current induced in it by traveling magnetic fields and moved through bore of gun barrel with increasing velocity ultimately approximating that of the traveling magnetic fields.

Patent 1,412,252 — 11 Apr 1922
Martin, Helmuth P. and Lucas, Owen D.
Westminster, Eng.
Machine gun and similar weapon.
Relates to control of machine guns, etc., firing electrically detonated ammunition. Object to provide improved means for controlling period of firing of machine guns, particularly in aircraft in which gun is fired between blades of the propeller. Electric control of instant of firing in accordance with movement of propeller.

Patent 1,425,627 — 15 Aug 1922
Bardelli, Arturo — Milan, Italy
Automatic firearm.
Release of striker which is projected forward to cause firing of cartridge is made to depend on the breech block closing levers.

Patent 1,444,890 — 13 Feb 1923
Swebilius, Carl G. — New Haven, Conn.
Automatic gun.
Provides means whereby impulses or pulsations of a higher frequency than rate of fire of gun may be utilized to fire gun whenever it is breeched. Also firing mechanism such that an automatic gun equipped therewith may be used on airplanes in conjunction with a synchronizer system. Reciprocating member is caused to oscillate the trigger.

Patent 1,460,800 — 3 Jul 1923
Johnston, Millard L. — Utica, N. Y.
Cartridge feeding mechanism for machine guns.
Device to revolve cartridge carrier of an automatic machine gun in such a manner as to bring successively the cartridges into loading position. Embodies carrier, latch carrier, demountable latch in said carrier, spring means for actuating latch laterally, and means for periodically striking latch carrier, whereby to revolve carrier into position for loading.

Patent 1,558,566 — 27 Oct 1925
Rockwell, Hugh M. — Bristol, Conn.
Automatic gun.
Relates to heavy Browning guns used in connection with airplanes. Provides trigger or firing control that adapts

itself to position of gun so it may be readily operated in any position gun may assume so gunner will not have to assume cramped or unnatural position to fire; also to provide trigger operated by pressure exerted either by whole hand or by thumb.

Patent 1,563,751 1 Dec 1925
Kewish, John T. New York, N. Y.
Automatic firearm.
Improvements on automatic machine rifles in Patents 1,472,126 (1923), and 1,502,676 (1924). Reduction in weight and number of parts. Arrangement whereby firing pin and actuator are locked together at moment of firing, the recoil thrust of primer acting directly on firing pin. Combined safety locking and remounting device which also serves to release firing pin and actuator at proper times. Other improvements.

Patent 1,564,014 1 Dec 1925
Pedersen, John D. Jackson, Wyo.
Firearm.
Improved firing pin and ejector construction in which a spring encircles the firing pin to retract ejector as well as firing pin. Parts retain each other in place without aid of pins, screws, etc.

Patent 1,782,148 18 Nov 1930
Ross, Oscar A. New York, N. Y.
Synchronized machine gun.
Cartridge powder charge fired by an electric spark, eliminating movable firing pin and incident mechanisms. Cartridges formed without use of percussion caps. Plurality of machine guns may be fired not only in synchronism with propeller blades, but also sequentially. Time of firing increased as speed of propeller is increased.

Patent 1,854,833 19 Apr 1932
Gobbo, Domenico Turin, Italy
Breech loading gun.
Closing device for semi-automatic firearms with recoiling barrel for firing as repeating arms. Striker only capable of rectilinear movement and one compression spring, acting on a key mounted in a cross slit on striker causes breech bolt to perform feed and closing stroke, final forward motion of striker being effected when bolt is closed and caused by a suitable cock.

Patent 1,897,099 14 Feb 1933
Woody, George A., Tilden, Tex., and Coupland, Richard C., Norfolk, Va.
Operating mechanism for machine guns.
Arrangement of parts whereby an operator adapted for proximate or remote control may be selectively adjusted to permit or prevent its retention in retracted position. Utilized for manual retraction of bolt in aircraft machine guns, such as Browning.

Patent 1,926,816 12 Sep 1933
Podrabsky, Antonin Brunn, Czechoslovakia
Automatic gun. (Cl. 42–4)
Improvement in firing mechanism in which fixing means are provided which enable a catch arranged for displacement in path of movement of breech block mechanism to be fixed without actuation of trigger. Whole firing mechanism capable of adjustment and fixing relative to breech block; permits carrying member to serve as carrier for cocking mechanism and cover of ejector opening.

Patent 1,966,592 17 Jul 1934
Moore, Frederick T. E. Hartford, Conn.
Firing mechanism for machine guns. (Cl. 89–27)
Mechanism adapted for remote control of aircraft guns. Comprises bracket, lever vertically pivoted to bracket and having an extension at one end moving transversely through opening in casing to engage and operate horizontally movable sear element, 2nd lever vertically pivoted to bracket and adapted to move 1st lever and flexible power transmitting tension member connected with second lever and extending to gun from remote position of control.

Patent 2,075,837 6 Apr 1937
Studler, Rene R. Washington, D. C.
Blank ammunition firing attachment for automatic guns. (Cl. 42–1)
Designed primarily for use with Browning machine gun. Removable attachment which will lend itself to use with blank ammo and ball cartridges; in which accumulation of deposit at muzzle of gun will be comparatively slight. Quick detachable barrel jacket, muzzle attachment adapted to receive a wad disintegrating plug.

Patent 2,093,169 14 Sep 1937
Holek, Vaclav Brunn, Czechoslovakia
Automatic firearm, in particular machine gun. (Cl. 42–3)
Gas operated gun in which recoil shocks caused by the firing of the shot are damped within firearm itself, without substantial alteration in manner of construction of gun. Firing mechanism of firearm together with firing casing and butt form one unit and breech block casing, together with barrel and gas pressure unit form second unit, which is connected for longitudinal movement with first unit.

Patent 2,093,707 21 Sep 1937
Browning, Marriner A. Ogden, Utah
Firing mechanism for automatic firearms. (Cl. 89–27)
Firing mechanism includes a firing pin which is automatically cocked and released by movement of a gas operated actuating means.

Patent 2,100,097 23 Nov 1937
Beharrell, George E. and others London, Eng.
Machine gun fire control apparatus. (Cl. 89–27)
Apparatus for operating machine guns of kind in which the recoiling breech block is displaced from an initial position to an intermediate safety position, from thence it returns to initial position thereby rendering gun ready to be fired. Pneumatic operating means comprising compressed air supply connected to a trigger motor comprising a cylinder and piston, which piston is displaceable into contact with trigger by operation of a valve. For remote control firing.

Patent 2,116,139 3 May 1938
Browning, Marriner A. Ogden, Utah
Firing mechanism for automatic firearms. (Cl. 89 27)
Improved hammer mechanism which is controlled directly by main operating slide so as to insure closing of breech before firing occurs. Improved retarding mechanism whereby gun may be caused to operate at a slower speed.

Patent 2,116,140 3 May 1938
Browning, Marriner A. Ogden, Utah
Firing mechanism for automatic firearms. (Cl. 89–27)
Improved retarding mechanism whereby gun may be caused to operate at a slower speed than it otherwise would. Construction whereby movement of sear into its operative position is of a snap-action character.

Patent 2,135,005 1 Nov 1938
Hoagland, Reginald W., Washington, D. C., and Shepherd, Charles M., Cottage City, Md.
Firing pin arrangement for guns. (Cl. 42–69)
Improved association of elements for controlling operation of the spring-propelled firing pin. Provision of a pair of sears for catching the head of firing pin and holding same against forward movement during final closing of breech mechanism. Other controls for firing pin.

Patent 2,135,688 8 Nov 1938
Wright, Joseph, Stoke Park, Eng., and Trevaskis, Henry, Sutton Coldfield, Eng.
Firing device for automatic guns. (Cl. 89–27)
Improved device of type that may be operated by fluid pressure or pneumatically. May be fired pneumatically or manually as desired. Provides means for normally holding mechanism in inoperative position.

Patent 2,159,485 23 May 1939
Loomis, Crawford C. Ilion, N. Y.
Firearm. (Cl. 42–16)
Mechanism adapted for bolt action firearms having firing pin separate from the striker which cooperates in unique manner with extractor and ejector. Ejector floats loosely in a recess in firing pin and actuated by engagement with a part of trigger. Expansion of striker spring is stopped before striker engages firing pin. Cocking head joined to striker so that a blow on it is cushioned and partly absorbed.

Patent 2,186.969 16 Jan 1940
Green, Samuel G. Gray, Ga.
Machine gun structure. (Cl. 89–27)
Means for automatically firing a gun that is mounted for movement in recoil. Trigger on gun maintained in inoperative position except at a predetermined position of recoil and counter recoil both as to the bolt firing mechanisms and gun as a unit. Gun will always fire at proper position in cycle of operation.

Patent 2,235,201 18 Mar 1941
Cole, Arthur A. Newark, N. J.
Electric gun. (Cl. 124–3)
Barrel provided with spaced electro-magnets arranged along same, in combination with a plurality of photo-electric cells and cooperating electric light bulbs arranged adjacent to cells, whereby rays of light to cells will be intercepted by the movement of shot along the barrel to successively energize alternating magnets to draw the shot through the barrel and project same from muzzle thereof.

Patent 2,259,397 14 Oct 1941
Smith, Wilfred I. Chicopee Falls, Mass.
Firing pin selector device for firearms. (Cl. 42–42)
Device for selecting one of two or more separate firing pins to be operated by the single hammer released by the single trigger in a gun having 2 or more barrels. Uses movable, preferably sliding selector or selector plate interposed between movable hammer and series of firing pins.

Patent 2,313,030 2 Mar 1943
Tauschek, Gustav New York, N. Y.
Firearm and ammunition therefor. (Cl. 42–3)
Firearm in which projectiles are fired by gas pressure from a barrel and fired by means of an electric ignition bridge. Projectile train consists of a number of interconnected projectiles insulated from each other. Bridging wire ignites powder charge in first projectile and train is then fed forward for successive firing.

Patent 2,340,991 8 Feb 1944
Severance, Glen R. Detroit, Mich.
Electrically operated gun. (Cl. 89–13)
Motor-operated magazine type gun constructed to shoot flare shells and the like. Manually controlled motorized unit for operating same. Electric switch controls motor circuit.

Patent 2,341,641 15 Feb 1944
Mejean, Jacques G. Geneva, Switzerland
Gun actuator. (Cl. 121–48)
Expansible bellows device for use in a system for firing rapid-firing guns. Has a portion adapted to be connected with firing mechanism of gun to actuate same when the device is supplied with compressed air or some other medium under pressure. Adapted for use in aircraft.

Patent 2,359,517 3 Oct 1944
Gebeau, Robert D. Bridgeport, Conn.
Simplified artillery mechanism. (Cl. 89–2)
Gun designed for sustaining fire over extended periods of time, such as a/a and machine guns. Constructed to avoid overheating of firing chamber. Means for continuously feeding shells individually enclosed within shell blocks into firing chamber, automatically firing shells and utilizing recoil for ejecting shell blocks containing exploded shells from chamber. Electrical means for firing shells, utilizing recoil action of gun for automatically making and breaking electrical firing circuit.

Patent 2,385,057 18 Sep 1945
Browning, Val A. Ogden, Utah
Firing mechanism for repeating firearms. (Cl. 42–3)
Improved firing mechanism for firing either semi-automatic or full automatic at selection of shooter. Manually adjusted selector which also serves to lock trigger in "safety" position.

Patent 2,403,315 2 Jul 1946
Trevaskis, Henry W. Birmingham, Eng.
Solenoid. (Cl. 175–341)
Improved electric solenoid of type having core positioned axially in solenoid casing by coil springs adapted to permit core to be rotated for adjustment of a plunger connected to core but prevented from rotating relative to solenoid casing. Incorporates improved spring mechanism adapted to locate core within casing.

Patent 2,432,486 9 Dec 1947
Patchett, George W. Chigwell, Eng.
Fire controlling mechanism for automatic firearms. (Cl. 89–142)
Relates to trigger and fire controlling mechanism, particularly applicable to firearms which fire on forward stroke of bolt and in which bolt recoils against a spring after firing. Trigger operated pivoted sear actuating member, sear pivoted coaxially with said pivot, sear controlling lever pivoted on sear actuating member. Safety to prevent accidental firing; whole group removable as unit.

Patent 2,440,381 27 Apr 1948
Phillips, Harry Beverly, Mass.
Firing mechanism for guns. (Cl. 89–136)
Provides plural gun mount for twin machine gun assemblies and the like so organized that gunner can operate mount with both hands when one gun is absent from mount in same manner in which he operates it when all guns are present. Consists of firing mechanism for each gun including a sear and alternative right- and left-hand means for operating all of the sears in unison.

Patent 2,451,526 19 Oct 1948
Weiss, Saul Washington, D. C.
Firing mechanism. (Cl. 89–27)
Relates to continuous pull firing mechanism for firearms. Has single spring for both driving and for partially retracting striker or firing pin.

Patent 2,451,527 19 Oct 1948
Albree, George N. Winchester, Mass.
Rearwardly striking firing mechanism. (Cl. 42 69)
Detonation of rim fire cartridge is produced by impact of firing element against front face of cartridge rim. Breech block or bolt constitutes anvil member of firing mechanism.

Gas Operation

Patent 319,595 9 Jun 1885
Maxim, Hiram S. London, Eng.
Magazine fire-arm.
Applies principle by which feeding, loading, firing, extracting and ejecting are automatically performed by the explosive force of the discharge for automatically loading and firing rifles and small arms. If trigger is forcibly held back, all cartridges in magazine will be fired successively and automatically.

Patent 319,596 9 Jun 1885
Maxim, Hiram S. London, Eng.
Machine-gun.
Utilizes force of gases issuing from muzzle at discharge of cartridge to be used directly to effect the operations of reloading, firing, and extracting. Diameter of sleeve is diminished at front end so that bullet can pass through same but gases issuing from muzzle will, by reason of their expansion, act on series of shoulders and force sleeve forward upon barrel when gun is fired, producing rearward movement of connecting rods to breech mechanism.

Patent 321,514 7 Jul 1885
Maxim, Hiram S. London, Eng.
Machine-gun.
Utilizes force of the gases which issue from muzzle of gun at each discharge for extracting and ejecting empty case, cocking hammer, bringing another cartridge into position for firing, and firing same or preparing arm for the next discharge. Vacuum or partial vacuum around muzzle end of barrel is caused by explosion and invention provides means for operating breech mechanism by this vacuum.

Patent 397,143 5 Feb 1889
Pitcher, Henry A. Neillsville, Wis.
Magazine-gun.
Mechanical device suitable for attachment to magazine repeating gun, making it automatic in loading at each discharge. Utilizes portion of explosive gas generated by combustion in barrel on two springs operating conjointly and alternately on working mechanism of gun, thereby imparting the 2 necessary motions to load.

Patent 454,403 16 Jun 1891
Odkolek, Adolf Vienna, A.-H.
Recoil-operated machine-gun.
Combination, with the breech and cartridge-feeding mechanisms, of an actuating device operated by the gases resulting from combustion of the explosive charge and a power-storing device or accumulator controlled by the actuating device and cooperating to impart necessary movements to breech and cartridge-feeding mechanisms to effect rapid loading and firing. Combines with gun, receiver and breech-bolt a piston cylinder, an inlet-port leading from forward end of cylinder to bore of gun, piston contained in cylinder and a radial arm on piston-rod to engage breech bolt.

Patent 459,828 22 Sep 1891
Maxim, Hiram S. London, Eng.
Automatic gun.
Applies to guns operated partly by force of the recoil and partly by force of pressure of gases expelled from muzzle. Provides means whereby guns of this character may be operated either with blank or ball cartridges. Utilizes force or pressure of gases to operate or assist in operation of breech mechanism. Muzzle attachment comprising 2 cup-shaped pieces for varying area of space between them to increase or diminish force exerted by gases to operate weapons automatically. Gas pressure is sufficient to operate gun either with or without recoil force when ball cartridge is employed.

Patent 471,782 29 Mar 1892
Browning, John M. and Matthew S.
Ogden, Utah Terr.
Automatic magazine-gun.
Improvement in construction of guns whereby firing is automatic after 1st discharge so long as cartridges are supplied. Employs gases generated in discharge as means for opening breech, cocking hammer, ejecting, introducing new cartridge, reclosing breech, and releasing hammer for discharge, etc. Cap over muzzle end of barrel is thrown by gas pressure against power of a spring to initiate this automatic action.

Patent 471,783 29 Mar 1892
Browning, John M. and Matthew S.
Ogden, Utah Terr.
Machine-gun.
Relates to gas-operated machine guns, object being the combination of mechanism whereby cartridges will be successively presented, introduced into barrel, primer struck for explosion, exploded shell withdrawn, 2d cartridge introduced and in turn exploded, etc. Force of gases under explosion operate disk end of lever forward of front end of barrel to give it a forward and downward swinging movement, the lever being returned after explosion to normal position.

Patent 471,784 29 Mar 1892
Browning, John M. and Matthew S.
Ogden, Utah Terr.
Machine gun.
Improvement in gas-operated machine guns, object being employment of a wheel with blades upon which the gases may act to impart rotation to wheel, the rotation of wheel being utilized to operate the mechanism of the gun, and also so that blades of wheel may serve as a fan to produce a blast for cooling the barrel.

Patent 486,938 29 Nov 1892
Odkolek, Adolf. Vienna, A.-H.
Quick-fire gun.
Improvement on Patent 454,403 (1891) in which breech and cartridge feeding mechanisms are operated by gases in gun barrel and by a spring-actuated lever respectively. Improvements in breech mechanism and feeding devices, also in provision of means whereby gun may be fired either from shoulder or from a gunrest, and other structural modifications.

Patent 502,549 1 Aug 1893
Browning, John M. Ogden, Utah Terr.
Gas-operated breech-loading gun.
Improvement in breech loading machine guns in which mechanism is arranged to be automatically operated by means of gases produced by explosion. Barrel is constructed with gas escaping openings in opposite directions, whereby escape of gas through both openings will be simultaneous, and force of the gases will produce balance of such force, preventing operation of mechanism from throwing barrel out of line.

Patent 515,064 20 Feb 1894
Unge, Wilhelm T. Stockholm, Sweden
Firearm operated by gases of explosion.
Improvement in guns by which force of explosion is utilized to cause gun to perform automatically the whole or some parts of work required for loading and firing. Compressed air or gas is caused to act upon a piston and tension thus stored up is used for releasing locking mechanism opening breech mechanism and storing up supplemental power for subsequently loading gun, closing breech, locking and firing.

Patent 532,380 8 Jan 1895
Johnson, Christ Wausau, Wis.
Gas-operated firearm.
Expansive force of gas generated by explosion of cartridge may be utilized and properly directed to actuate certain power transmitting mechanisms and effect withdrawal or extraction of exploded shell and final ejection of same, also elevation and placing of loaded cartridge into firing position and readjustment of bolt. Has vent adjacent to breech, a cylinder communicating with vent and piston rod and toothed rack bar integral therewith for operating breech mechanism.

Patent 544,657 20 Aug 1895
Browning, John M. Ogden, Utah Terr.
Gas-operated machine-gun.
Improvement in mechanism adapted to be operated by gases of explosion previously applied for by inventor. To arrange breech-piece so that its locking and unlocking movements are produced by a lateral swing instead of vertically, as well as other improvements. By providing for extraction of cartridges from feed-wheel by their heads, possible to use feed-belt having forward edge closed with resulting advantages. Force of ejection reduced by arranging ejecting block on opposite side of breech piece to extractor hook, causing shell to fall close by gun.

Patent 544,658 20 Aug 1895
Browning, John M. Ogden, Utah Terr.
Gas-operated machine gun.
Improvement in Browning guns previously patented. Breech block is confined to longitudinal reciprocal movement; object is to simplify mechanism of gun with reference to breech-block, operating connections thereof, firing-hammer, firing-lever, carrier, operating slide and trigger and sear.

Patent 544,659 20 Aug 1895
Browning, John M. Ogden, Utah Terr.
Gas-operated machine-gun.
Improvements to simplify Browning gun, adapting it to continuous or intermittent fire. Improved breech block. Feeding mechanism consists in notched feed-wheel arranged directly below butt end of barrel and above slide. It engages feed belt to bring it into right side of receiver.

Patent 544,660 20 Aug 1895
Browning, John M. and Matthew S.
Ogden, Utah Terr.
Gas-operated breech-loading gun.
Mechanism adapted to receive action of or be actuated by pressure of gases of explosion before projectile shall have left and by means of which movement is transmitted to breech mechanism of the arm for its operation, mechanism being provided with means for its perfect control and the interruption of its operation at any time at will.

Patent 544,661 20 Aug 1895
Browning, John M. Ogden, Utah Terr.
Gas-operated firearm.
To avoid fouling and clogging of mechanism by the gases and to prevent escape of gases until after the lever shall have commenced its opening movement and received its initial force, and to prevent the lateral spread of the gases.

Patent 550,262 26 Nov 1895
Ehbets, Carl J. Hartford, Conn.
Gas-operated machine gun.
Application of pressure of powder gases generated in barrels of Gatling-type multi-barrel gun as a means for revolving the barrels and thereby operate the breech mechanism and fire successive cartridges as long as cartridges are supplied.

Patent 564,043 14 Jul 1896
Benét, Laurence V. and Mercié, Henri A. Paris, France
Automatic machine gun.
Gas-operated machine gun using motor piston in perpetual engagement with a power accumulator. Feed strips carry cartridges. Valve regulates rate of fire by controlling point at which exhaust of powder gas is applied in cylinder.

Patent 570,888 27 Oct 1896
Ehbets, Carl J. Hartford, Conn.
Gas-operated magazine gun.
Utilizes expansive force of gases of explosion and also blows struck by a jet of such gases when escaping from a narrow opening in a gun-barrel to operate breech mechanism—attained by providing inclined vent in rear of muzzle leading from bore to cylinder in which a piston reciprocates. Improved means of storing energy from gas, preventing waste of gases, unlocking breech and opening it by action of gases, and positive control of firing shots.

Patent 572,771 8 Dec 1896
Richmond, Romulus R. Chariton, Iowa
Automatic machine-gun.
Brings about the several operations necessary to automatic loading and discharge of a gun, and upon firing of first discharge to store a sufficient amount of energy from gases generated by exploding material to bring about a continuous operation of mechanisms thereof without attention on part of operator. Means by which continuous discharge of gun may be arrested by cutting off communication between storage tank and power cylinder.

Patent 577,485 23 Feb 1897
Maxim, Hiram S. London, Eng.
Automatic gas-operated gun.
Employs non-recoiling barrel which extends into and is affixed to a jacket. Latter divided by transverse partition near forward end into water chamber and gas chamber. Breech mechanism worked by gases escaping from muzzle into gas chamber and actuating flap at outer end of chamber. Breech end of barrel affixed to rear end of water jacket and

muzzle end secured by joint to allow expansion and contraction of barrel within water jacket. Cartridge feed box at rear of barrel and cartridges driven directly from belt into chamber by plunger; after firing cases drawn back into same clip of belt from which taken.

Patent 580,926 — 20 Apr 1897
Browning, John M. — Ogden, Utah
Firearm.
Improvements in gas-operated weapon, as adapted to magazine-pistol. Combination with frame and barrel of sliding breech-bolt and forward extension or arm alongside frame and barrel, said extension having sleeve surrounding barrel, whereby movement of extension and bolt is guided by barrel and limited rearwardly by contact of rear end of sleeve with front of frame.

Patent 580,935 — 20 Apr 1897
Ehbets, Carl J. — Hartford, Conn.
Firearm.
Improved automatic magazine firearm. Improved design of frame and construction of holder in firearm which receives cartridges and is itself inserted within frame for better delivery and control. Vent in rear of muzzle permits gases to escape and act on mechanism for extraction and ejection, insertion of new cartridge, using sliding barrel.

Patent 586,362 — 13 Jul 1897
Maxim, Hiram S. — London, Eng.
Gas-operated gun.
Relates to automatic gun with non-recoiling barrel in which breech mechanism is actuated by discharge gases. Gun is provided with firing pin which will not be blown backward at instant of firing, said pin being so arranged that it is locked in its fired position, but is unlocked again after gun has been discharged. Device for holding lock firmly in position at instant of firing. Improved crank handle for better feeding of cartridges.

Patent 588,380 — 17 Aug 1897
Benét, Laurence V. and Mercié, Henri A. — Paris, France
Gas-operated gun.
Relates to machine guns in which portion of powder gas is utilized for operating breech action and feed mechanism of firearm. Means for regulating pressure of gas acting on piston, utilizing variable-capacity chamber. Use of series of ribs on barrel for cooling barrels by increasing surface of radiation. Other improvements on Hotchkiss gun, e. g., extractor, trigger-stop, absorption of recoil, etc.

Patent 589,120 — 31 Aug 1897
Burgess, Andrew — Buffalo, N. Y.
Gas-operated firearm.
System of unlocking breech-block by pressure of charge in firing and opening breech by recoil of the arm, mechanism to close the breech, also to load the magazine, together with other improvements.

Patent 598,822 — 8 Feb 1898
Simpson, William E. — Mansfield, Eng.
Gas-operated gun.
Relates to improvements in Gatling type guns. Enables portion of gas pressure generated within barrels by explosion of cartridges to be utilized for revolving barrels, so that after first shot is fired gun will work automatically as long as supplied by ammunition. Utilizes ports or passages leading from barrels to recessed disk or wheel through which barrels extend, and sliding abutment working in stationary ring surrounding disk and bearing against said disk.

Patent 606,115 — 21 Jun 1898
Benét, Laurence V. — Paris, France
Gas-operated gun.
Improvement on Patent 564,043, whereby gun will operate automatically when firing "blank" ammunition. Applies a pierced plug to muzzle of gun for reducing area of exit of the frangible blank bullet or wad and gas, thereby forcing sufficient gas to pass through port and operate mechanism.

Patent 618,743 — 31 Jan 1899
Silverman, Louis — Crayford, Eng.
Gas-operated machine-gun.
Improvement in Maxim guns in which breech mechanism is operated by pressure of gas escaping from muzzle when gun is discharged. Breech block made in 2 portions: forward portion carries vertically sliding cartridge carrier and rear portion is pivoted to forward portion so that it is capable of slight amount of independent vertical movement, allowing it to securely retain the breech closed at moment of firing. Action bar operated by piston effects this movement by rear portion of breech-block. Improvements in feed system. Air cooling if desired.

Patent 636,196 — 31 Oct 1899
Burgess, Andrew — Buffalo, N. Y.
Automatic gun.
To produce automatic gun in which breech mechanism is operated by pressure developed in bore of gun on firing. Also improved construction by which breech may be opened and hammer raised by hand as well as automatically. Improved ejection and magazine.

Patent 649,393 — 8 May 1900
Benét, Laurence V. and Mercié, Henri A. — Paris, France
Semi-automatic gun.
Means by which breech is automatically opened upon discharge of piece with consequent extraction and ejection of empty case; means for automatically locking breech in "open" position; means for automatically unlocking breech upon introduction of fresh cartridge; and means for automatically closing breech when unlocked.

Patent 663,954 — 18 Dec 1900
Burgess, Andrew — Buffalo, N. Y.
Automatic firearm.
Relates to automatic firearms in which loading operation is or may be effected by gas pressure, for use with either a small or large magazine. Gun-frame and barrel, a bolt reciprocating in gun frame and locking thereto to close breech by rigid shoulders on bolt engaging abutments on the frame, and means extending to the bore of the gun by which the bolt is pressed sidewise and unlocked by action of the gas pressure on the firing of the gun, so as to be opened by pressure from the bore of the gun.

Patent 663,955 — 18 Dec 1900
Burgess, Andrew — Buffalo, N. Y.
Automatic firearm.
Gun in which gas pressure may be utilized to open the breech with as little lost motion as practicable; also improved construction so that pressure of gas will unlock fastening device by slight rocking of a movable part of gun on its axis so that breech opening may be quickly effected; also improvements in feed and extractors.

Patent 680,327 13 Aug 1901
Hay, William G. Liverpool, Eng.
Colt gun.
Improvement in guns in which lock mechanism is worked by lateral escape of gas (Colt). Relates to means of adapting for blank firing a Colt gun. A cap secured to the muzzle and having a gas-passage through it and means for regulating escape of gas through said passage.

Patent 684,173 8 Oct 1901
Bjerkness, Karl K. Kaslo, Canada
Firearm.
Attachment to firearms which is connected with a lever in magazine-chamber and which has such relation to muzzle portion of barrel that through expansion of gases escaping from barrel the device will automatically operate lever each time charge is fired, whereby as such charge is fired, empty shell is extracted, new shell loaded and hammer carried to firing position.

Patent 696,306 25 Mar 1902
Benét, Laurence V. and Mercié, Henri A. Paris, France
Automatic gun.
Relates to guns in which a motor-piston in perpetual engagement with a power-accumulator is operated by gases resulting from the explosion. To produce mechanism whereby when a certain part thereof is given a reciprocating motion by action of gas acting in one direction and a spring acting in opposite direction and by other mechanical means all operations are automatically performed. Includes varied features for continuous and intermittent firing at will of operator.

Patent 698,107 22 Apr 1902
De Knight, Victor P. Washington, D. C.
Automatic rapid-fire gun.
Rapid-fire machine gun wherein gas evolved in each discharge is utilized as motive force for automatic operation; combines receiver having screw-threaded boss on forward end, barrel projecting from receiver, a gas conduit communicating with barrel in rear of muzzle, water jacket embracing conduit and barrel, and a coupling collar taking over the flange of the jacket and engaging the screw-threads of said boss.

Patent 709,880 30 Sep 1902
De Knight, Victor P. Washington, D. C.
Automatic rapid-fire gun.
Improvement on gun in Patent 698,107 (1902) to simplify construction and reduce number of parts. Provides for quick assembly without use of tools.

Patent 709,881 30 Sep 1902
De Knight, Victor P. Washington, D. C.
Automatic rapid-fire gun.
Relates to gas-operated guns of character described in Patent 709,880. Simplified construction, reliable means for actuating cartridge feeding mechanism by direct and positive action of actuator for breech mechanism; simplified trigger and sear devices; buffer spring to receive backward thrust of actuator and breech-block.

Patent 709,882 30 Sep 1902
De Knight, Victor P. Washington, D. C.
Rapid-fire gun.
Gas-operated machine gun in which portion of gas evolved at each discharge is utilized to actuate mechanism. Uses water jacket; belt fed. See other De Knight patents (698,107, 709,880, 709,881, 709,883).

Patent 709,883 30 Sep 1902
De Knight, Victor P. Washington, D. C.
Automatic rapid-fire gun.
Relates to gas-operated gun of character described in Patent 698,107 and others. Modifications in assembly and connections and other features.

Patent 729,413 26 May 1903
Reifgraber, Joseph J. St. Louis, Mo.
Automatic firearm.
Automatic magazine arm that will discharge one at a time every cartridge in magazine by act of pulling trigger and holding it. Firing of cartridges produces automatic action by gas actuation of piston to move mechanism back.

Patent 729,858 2 Jun 1903
Gass, William G. Bolton, Eng.
Machine-gun.
Relates to automatic machine guns actuated by pressure of gases generated in barrel. Improved features for quick disassembly; barrel may be provided with means for increasing area of its surface that is exposed to air and causing current of air to impinge on barrel for cooling. Actuating handle is carried by block secured to or forming rear part of a breech-bolt, which slides longitudinally in a guide, bolt also carrying mechanism which actuates firing pin contained within it and devices to withdraw live cartridges from feeder, insert same, extract and eject.

Patent 735,131 4 Aug 1903
McClean, Samuel N. Washington, Iowa
Gas-operated firearm.
To construct gun consisting of gun barrel and a receiver provided with a breech block with a reciprocatory movement from and to barrel to open and close breech and a turning movement to lock it into engagement with or unlock it from breech, combined with an automatic power device which imparts movements to breech mechanism upon each discharge. Uses gas-operated slide connected to breech-bolt.

Patent 749,214 12 Jan 1904
McClean, Samuel N. Washington, Iowa
Breech-loading and discharge-actuated firearm.
Strengthened machine gun to sustain strain of firing at line of greatest strength. Use of controlling devices to govern action of actuating force of gas on operating parts and transmit, store and utilize this force in operation of the arm.

Patent 754,691 15 Mar 1904
Petersen, Charles San Francisco, Calif.
Automatic gun.
To provide gun which may be loaded and discharged continuously through medium of the expanding gases in the barrel. Combination of barrel, compression chamber, a piston moving therein, a port opening between barrel chamber and one end of compression chamber, valve in said piston through which gases pass to equalize pressure, piston rod extending through each end of compression chamber, breech mechanism connecting with one end of rod.

Patent 783,453 28 Feb 1905
McClean, Samuel N. Washington, Iowa
Gas-operated firearm.
Means for controlling and modifying force of discharge and cause force of discharge to operate on different parts of arm in safe, easy and advantageous manner. Regulating devices for controlling application of force to bolt-action. Bolt action connected with gas-controlling device utilizing the ball as a

valve to govern and prolong power of gas in operating bolt. Mechanism for throwing breech mechanism to open position while ball is passing through chamber.

Patent 784,966 — 14 Mar 1905
Smith, Morris F. — Philadelphia, Pa.
Gas-operated machine gun.
Improved means for operating automatic or semiautomatic machine guns by gas pressure; also improved construction of breech-closing bolt. Employs cylinder communicating through a controllable gas-port in forward part of barrel; piston in said cylinder actuated by gas pressure; return spring compressed by gas pressure and suitable piston rod extending rearwardly from piston to transmit reciprocating action of gas pressure. Hopper feed.

Patent 785,974 — 28 Mar 1905
McClean, Samuel N. — Cleveland, Ohio
Gas-operated gun.
To provide a construction of gun-barrel having circumferential grooves associated with vents, part of which communicate with action of gun and part with the air and to provide auxiliary automatically-controlled valve for controlling gas pressure. Combines construction of gun barrel for counteracting recoil and controlling gases and utilizing powder energies with a gun-operating device so connected to barrel as to be assembled and disassembled without tools.

Patent 804,986 — 21 Nov 1905
Stamm, Hans — St. Gall, Switzerland
Self-loading firearm.
Relates to rapid fire gas-actuated guns. Arrangement alongside receiver of a piston housing and cylinder for gas-actuated piston, a positive connection of this piston with breech-bolt carrier, and means whereby piston, together with breech-bolt carrier, can be bodily removed in case of need through rear end of breech-casing. Integral construction of receiver, piston-housing and cylinder. Tubular gas-actuated piston open at forward end.

Patent 811,595 — 6 Feb 1906
Taylor, Cecil H. — Philadelphia, Pa.
Gas-operated mechanism for firearms.
Provides gun with attachment or turbine that shall be rotated by the impact of the expanding gases of explosion.

Patent 814,242 — 6 Mar 1906
Smith, Morris F. — Philadelphia, Pa.
Automatic gas-operated firearm.
Uses reciprocating plunger, piston on said plunger to receive gas pressure from barrel to drive plunger rearward; return spring moving plunger forward when pressure is exhausted; breech closing bolt reciprocated by movement of plunger; locking dog automatically rising in rear of breech-bolt as latter reaches its seat; spring driven hammer; elongated dash-pot which traps air for use in returning parts to position.

Patent 816,591 — 3 Apr 1906
McClean, Samuel N. — Washington, Iowa
Automatic gas-operated firearm.
Strain of discharge received in line of greatest strength, resisted by strength of the metal distributed equally on every part of arm. Barrel integrally formed with receiver. Actuated by hand or by discharge gases. Automatically operated by discharge operated slide having piston moving in tube and connected with bolt-action.

Patent 817,197 — 10 Apr 1906
Smith, Morris F. — Philadelphia, Pa.
Gas-operated machine-gun.
Means by which reciprocating motion is developed from pressure of gases; means whereby gases taken off for this purpose are utilized to partially neutralize recoil, a novel form of muzzle attachment being also employed for completing neutralization of recoil; means for developing vertical locking and unlocking movements in bolt; means for rendering gun semi-automatic or automatic.

Patent 827,259 — 31 Jul 1906
McClean, Samuel N. — Cleveland, Ohio
Discharge-actuated gun.
Relates to means whereby force of discharge gases not only operates action of gun but also controls the recoil of the weapons so that greater accuracy of fire and easier manipulation result. May be rendered automatic or semiautomatic and hand- or magazine-fed at will of gunner.

Patent 834,354 — 30 Oct 1906
Ashton, Thomas R. R. — London, Eng.
Magazine-firearm.
Relates to magazine rifles having sliding breech bolt or block with vertical locking action. Means for operating breech-block by pressure of a small portion of the powder gases acting on a piston. Improved extraction and ejection, protection from dust, trigger mechanism, safety devices.

Patent 834,753 — 30 Oct 1906
Reifgraber, Joseph J. — St. Louis, Mo.
Automatic firearm.
Improvement on Patent 729,413 (1903) on gas-operated pistol. Shock of recoil reduced to minimum. Moving parts incased within frame or gun body. Safe for handling and carrying whenever cocked or ready for firing. Other improvements.

Patent 846,591 — 12 Mar 1907
Mason, William — New Haven, Conn.
Automatic firearm.
Improvement in gas operated firearm. Right hand side wall of gun frame formed near its forward end with an ejection opening, and its left hand side wall with gas escape opening which extends alongside of forward end of breech block when said block is in closed position, whereby escape of gas is provided for when breech block is in closed position.

Patent 853,715 — 14 May 1907
Mondragon, Manuel — Tacubaya, Mexico
Firearm.
Improvements in gas-operated firearms, either single-loader or repeater. Combination of a barrel, a gas-receiving chamber located adjacent thereto and communicating therewith, rotary valve mounted in forward end of chamber and controlling passage between chamber and barrel, collar screwed into forward end of gas chamber and holding valve in place. Sleeve secured about forward end of gas-chamber, sleeve having outwardly projecting arms which prevent collar from turning, and means for properly positioning the valve.

Patent 858,745 — 2 Jul 1907
McClean, Samuel N. — Cleveland, Ohio
One-pounder machine-gun.
Gas-operated machine gun. To lessen or eliminate recoil movement of gun and to provide means for so controlling and applying gases of discharge as to render their use harmless

to damage weapon. Gas motor for utilizing gases as motive fluid to oppose and prevent recoil movement. As gases flow into and through motor they impinge on certain areas of resistance and then escape to atmosphere. Non-recoiling m. g. automatically operated by energy of discharge, for opening and closing breech, ejecting shells, feeding loaded cartridges. Positive cartridge feed.

Patent 861,939 — 30 Jul 1907
Benét, Laurence V. and Mercié, Henri A.
Paris, France.
Gas-operated gun.
Improved breech closure, firing mechanism, feed mechanism and extracting mechanism in gas operated gun. Combination with a gun barrel and a reciprocating breech block provided with interrupted screw threads, of a breech nut revolubly mounted in rear of said barrel but held against longitudinal motion, said breech nut being provided with interrupted screw threads registering with those of breech block, and means for rotating said breech nut to cause its threads to engage and disengage with those of breech block.

Patent 862,384 — 6 Aug 1907
Bristol, Mortimer L. — W. Hartford, Conn.
Automatic gun.
Gun provided with simple mechanism to be actuated by gas pressure in barrel, to interlock barrel and breech block in firing position, to support and guide them while recoiling still locked together, then unlock them and return them separately, and finally fire the gun. Reliable means for controlling rapid automatic fire. Interrupts operation of breech mechanism at time when breech is fully opened and before charged cartridge is inserted. Safety feature.

Patent 875,209 — 31 Dec 1907
Prinke, Carl L. H. — Baltimore, Md.
Automatic firearm.
Gas-operated firearm. When breech bolt moves rearward after firing, it is cocked in its retracted position and cartridge automatically fed from magazine into bolt's path. No independently movable firing pin is used, but breech bolt carries a fixed firing point or spur. When bolt is unlocked it moves forward, inserts cartridge in barrel and simultaneously fires it. Shell blown into receiver by explosion gases and expelled by an ejector carried by bolt.

Patent 885,166 — 21 Apr 1908
Mason, William — New Haven, Conn.
Gas-operated gun.
Power derived from gas intercepted at muzzle of gun used in the operation of toggle-link breech mechanism. Sliding sleeve-like gas chamber having bullet opening at forward end in line with bore of barrel. Lateral gas-escape holes in forward end of chamber which may be left open or plugged up to properly gage amount of gas intercepted at muzzle. Gas check prevents rearward movement of intercepted gas until sufficient pressure of gas has been accumulated to effect operation of breech mechanism.

Patent 904,646 — 24 Nov 1908
Prinke, Carl L. H. — Baltimore, Md.
Automatic firearm.
Improvements in gas-operated firearm described in Patent 875,209 (1907), having firing pin carried by breech bolt. Breech bolt is pressed forward by a spring and carries rigid or integral firing pin. No extractor is used and ejector is movable independently of firing bolt which latter, at instant of firing, is engaged by sear to resist the recoil, thus holding breech closed until accumulated power of gases is such as to forcibly expel bullet and insure proper recoil of bolt. Pneumatic check for recoil also provided. Improved trigger and magazine.

Patent 908,294 — 29 Dec 1908
Marga, Uldarique — Dieghem, Belgium
Firearm.
Relates to gas operated firearm. Consists in a bolt for closing cartridge magazine which is placed between base of cartridge and a cylinder into which is conveyed by a lateral canal a portion of the gases of the firing. A striker is adapted to move independently of this bolt which it crosses on its axis. Backward movement of bolt is cushioned by its engagement with an element moving in a cylinder placed on an incline on the barrel and by the gases carried behind said bolt.

Patent 918,646 — 20 Apr 1909
Berthier, Andre V. P. M. — Constantinople, Turkey
Automatic gun.
Device in automatic guns whereby force necessary to operation of mechanisms of gun is borrowed from gases evolved at moment of firing. Comprises cylinder arranged to communicate with the barrel-chamber and containing a spring-pressed piston adapted to be actuated by gases of explosion in one direction, a receiver, a bolt arranged in said receiver operated by piston and equipped with locking lugs, and a firing pin connected with bolt by means of groove in bolt. Bolt locking lugs having sliding engagement with receiver.

Patent 952,765 — 22 Mar 1910
Sunngard, Harald — Christiania, Norway
Rifle.
Arrangement by which piston mechanism acted upon by powder gases and during automatic firing to actuate breech is enabled to enter into a position of rest, where it is entirely out of engagement with the opening and locking surfaces of the breech bolt. May be operated direct by hand by means of fixed knob lever on insertion of first cartridge. Permits use of sliding and turnable breech bolt with fixed knob lever in automatic arm.

Patent 956,431 — 26 Apr 1910
Schmeisser, Louis — Suhl, Ger.
Automatic firearm.
Relates to gas-operated automatic firearm. To obtain necessary weight of parts and length of recoil without exceeding limits admissible for length and weight of arm and at same time guard against the accidental projection of the recoiling parts to the rear past the proper limits.

Patent 960,825 — 7 Jun 1910
Colleoni, Giuseppe — New York, N. Y.
Automatic gun.
Improved gas operated rapid fire gun. Improved means for maintaining barrel at comparatively low temperature; means for regulating quantity and pressure of gas delivered to piston; means for more effectively transferring cartridges from feed strip to breech piece; means for bracing breech block against return movement at instant of explosion.

Patent 984,489 — 14 Feb 1911
Redfield, Edward E. — Glendale, Oreg.
Automatic firearm.
Improvements in gas operated firearm. To take down gun and take apart extracting, ejecting and reloading mechanism without tools; improved feeding mechanism; improved firing mechanism.

Patent 1,003,632 19 Sep 1911
McClean, Samuel N. Cleveland, Ohio.
Gas-operated gun.
Object is to provide means for determining pressure which powder gas will exert upon piston, whereby breech mechanism of gas-operated gun is operated; and to provide a device in which the gas will be mixed with air as it flows to the cylinder included in such actuating devices, whereby any flame present will be snuffed out and temperature of gas reduced. Operating cylinder and piston so located that a quantity of air is interposed between gas and piston, protecting the latter from the high temperature of said gas.

Patent 1,004,424 26 Sep 1911
Hennick, Daniel G. Mitchell, Ont., Can.
Automatic firearm.
Automatic weapon in which breech mechanism is operated automatically to eject the shell and reload immediately following the firing by a spring operated mechanism actuated by the gases of the explosion and whereby firing may be operated either singly or in automatic succession.

Patent 1,005,263 10 Oct 1911
McClean, Samuel N. Cleveland, Ohio
Gas-operated machine-gun.
Invention comprises gas-operated machine gun having a reciprocating and rotating breech block engaged by a gas-driven piston to operate breech mechanism, and provided with air cushion to check terminal movement of piston and to control speed of firing. Piston rod engages and operates oscillating cartridge feed and cooperates with sear and trigger to control firing action. Frame of gun has vertical magazine for consecutive feeding and is provided with spring pressed feed fingers to control feeding action.

Patent 1,010,899 5 Dec 1911
Halle, Clifford R. S. J. London, Eng.
Automatic firearm.
Relates to automatic small arms in which a portion of the gas is taken from the barrel during flight of bullet down barrel and used to compress spring or air, this power being utilized to work the mechanism after bullet leaves barrel and gas pressure is relieved. Invention provides means whereby opening and return springs are compressed simultaneously and directly by the action of the single plunger on which the gases act. Permits also delay in functioning of weapon at will of firer.

Patent 1,025,132 7 May 1912
Douglas, William M. Galveston, Tex.
Automatic gun or rifle.
Firearm automatically operated to eject and reload by utilizing portion of pressure from exploding shell. Compressed air used to actuate element to release breech bolt, move same after it is unlocked, gas-cylinder communicating with barrel and receiving gas therefrom on discharge, gas-piston operating in cylinder, etc.

Patent 1,029,720 18 Jun 1912
Schellenger, Newton C. Salt Lake City, Utah
Automatic firearm.
Improvement in gas-operated firearm. Barrel is substantially stationary during discharge and position of breech-block with respect to barrel, during a portion of the time that it takes bullet to pass through barrel is controlled by positively acting mechanism either to lock breech block to barrel during this time or allow gradual movement of breech block away from barrel. Provides locking member adapted to engage breech block. Inertia of barrel and its tendency to move forward with bullet holds locking member in engagement until sufficient pressure of powder gases is built up.

Patent 1,042,135 22 Oct 1912
McClean, Samuel N. Cleveland, Ohio
Automatic machine-gun.
Machine gun operated by gases of discharge to automatically eject an empty shell, feed a fresh cartridge to position, insert it in breech of gun barrel and fire it. Also cartridge magazine and feed capable of feeding cartridges with positive regularity whatever angle to which gun may be elevated or depressed.

Patent 1,066,207 1 Jul 1913
Jolidon, Charles J. Hartford, Conn.
Magazine-firearm.
Magazine firearm having breech-bolt arranged to be moved in one direction by forces of explosion, means exerting force in opposite direction to retard its movement, a member arranged to receive the thrust of retarding means, holding means for thrust receiving member and connection between breech-bolt and holding means to move latter to disengage it.

Patent 1,066,487 8 Jul 1913
Giletta, Annibale Turin, Italy
Firearm.
Arrangement owing to which the gases escaping from the muzzle operated driving means in a gradual and regular manner, imparting to said means simple rectilinear or helical movement. Driving means provided, if desired, with brushes or other fitting adapted to clean surfaces on which gases have left deposit.

Patent 1,082,916 30 Dec 1913
Squire, William H. St. Denis, France
Gas-operated gun.
Improvements in guns described in Patent 861,938 (1907) in which portion of powder gas escapes through an orifice in barrel and then impinges on movable element of breech-actuating mechanism. Provides means whereby practice ammunition may be utilized to fire gas-operated gun, without use of muzzle fixtures. Provides practice barrel for detachable association with gun in lieu of ordinary service barrel.

Patent 1,099,245 9 Jun 1914
Fittipaldi, Rafael Buenos Aires, Argentina
Automatic repeating firearm.
Improvements whereby escape of gases through breech is prevented absolutely. Movement of mechanism for bringing about firing causes obturation of the breech and only after this can explosion of cartridge take place, breech remaining closed until compressed gases have been entirely evacuated through barrel. Uses obturating cylinder which closes breech before firing and during complete recoil.

Patent 1,125,937 26 Jan 1915
Benét, Laurence V. and Mercié, Henri A. Paris, France
Automatic shoulder rifle.
Comparatively light gun used either as gas-operated gun or as an ordinary rifle, adapted to be fired from shoulder of a soldier when lying down. Improved breech mechanism, firing mechanism, feed mechanism, extractor, support for muzzle, etc.

Patent 1,128,310 16 Feb 1915
Heinemann, August A. K. Berlin, Ger.
Machine gun.

Improvements in hand machine guns with reference to arrangement and attachment of stock; breech block mechanism: cartridge feeding mechanism; cover of receiver; and muzzle attachment. End face of stock located in direction of axis of bore, improving steadiness of gun during firing. Feed mechanism wherein length of stroke of belt-slide is terminated and made independent of varying lengths of recoils of barrel. Muzzle attachment adapted to be acted on in downward direction by propelling gases leaving muzzle in order to steady the latter, thereby counteracting bucking of muzzle.

Patent 1,136,695 20 Apr 1915
Miclaus, Alexander Washington, D. C.
Automatic gun.

Improvements in guns in which breech mechanism is unlocked by pressure of powder gases on motor piston and forced backward for ejection, then returned by spring to initial position. May be fired single shot or automatic. Cartridges fed from magazine by sprocket chain. Magazine consists of box having series of vertical channels feeding cartridges by gravity.

Patent 1,138,376 4 May 1915
Hammond, Grant Hartford, Conn.
Firearm.

Mechanism for automatic pistol that will withstand to a maximum degree the injurious effects from the gases and other products of combustion produced in the discharge of the piece. Breech-bolt actuating section including a casing composing a muzzle section and a breech section, the breech section being connected with breech-bolt and muzzle section having a chamber to receive gases of explosion to actuate it.

Patent 1,140,245 18 May 1915
Bubar, Dean B. Roseburg, Oreg.
Magazine rifle.

Improvements in gas operated automatic rifles. Portion of gases generated in firing utilized to operate breech block in automatically unloading and loading same. Improved means for operating breech block for unlocking and locking it: construction, arrangement and operation of hammer, sear and trigger.

Patent 1,142,896 15 Jun 1915
Lewis, Isaac N. New York, N. Y.
Automatic firearm.

Air cooled gun provided with rotary magazine feed and intended to be supported by tripod when in use. Gases of discharge used for effecting automatic fire. Spring for driving feeding and firing mechanism located in structure outside the heated zone. Single spring mounted at rear of gas cylinder and gun barrel and connected to piston rod for driving entire mechanism.

Patent 1,144,994 6 Jul 1915
Berthier, Andre V. P. Paris, France
Machine gun.

Relates to gas pressure loading machine gun in which locking and unlocking are produced by oscillation of a locking member. In invention locking member is rockably mounted directly on breech block itself, its rear end being raised or lowered when block advances or retreats respectively.

Patent 1,176,873 28 Mar 1916
Swebilius, Carl G. and Hanitz, Hans T. R.
New Haven, Conn.
Firearm.

Improved gas-operated firearm of repeating type. Cam slide is detachably locked to action rod and will reciprocate therewith. Slide is guided in receiver and supports and carries breech block.

Patent 1,195,693 22 Aug 1916
Lewis, Isaac N. U. S. Army
Gas regulator and trap for automatic gas-operated firearms.

Attachment whereby amount of gases of combustion utilized for actuating gun mechanism may be regulated. Also separated solids from gases in transit from the gun barrel to the chamber of the operating piston.

Patent 1,207,612 5 Dec 1916
Northover, Harry R. Winnipeg, Canada
Gas-lever-operating mechanism for use in connection with certain types of machine guns.

Relates to gas-operated machine guns of "Colt" type which work by pressure of gases acting through a piston on a "gas-lever". Manual actuation frequently necessary when gun is in action, exposing personnel to danger. Invention consists in attachment providing for manual operation of gas lever from breech end of gun. Also permits easy manipulation in trenches or other confined places. System of gearing mounted on left hand side of front part of body of gun.

Patent 1,233,096 10 Jul 1917
Martinez-Silva, Luis Bogota, Colombia
Automatic mechanism for firearms.

Comprises two springs (one for opening breech and other for closing same) which are compressed simultaneously by a single member acted on by a piston which is operated by the gases. Opening spring cannot expand until ball has issued from barrel. Gases drawn off from barrel at comparatively long distance from breech. All parts liable to foul can be cleaned without removing stock by drawing out a single member. Mechanism incased in 2 tubes screwed one within other and each forming an extension of the other.

Patent 1,234,071 17 Jul 1917
Northover, Harry R. Winnipeg, Can.
Gas cylinder for machine guns.

In machine guns of Colt-type, embodies in gas cylinder a band which is expansible and contractible and adapted to be adjusted to or upon the dismountable barrel by mechanical means, whereby a gas-tight joint can be obtained under all conditions, while removal of barrel, even when hot, is facilitated. Band constructed with adjustable spring-clip capable of being tightened or slackened by hand screw.

Patent 1,249,622 11 Dec 1917
Hedrick, Floyd C. Kentland, Ind.
Automatic firearm.

Gas pressure throws bolt and firing pin rearwardly upon firing. Breech bolt and firing pin disposed within the breech bolt being provided with actuating springs disposed so that they are located at a place remote from firing point of cartridges so as not to be affected by heat of firing. Only 2 moving principal parts breech bolt and firing pin.

Patent 1,256,923 19 Feb 1918
Nelson, Charles A. Utica, N. Y.
Machine gun.

Improvement on Savage-Lewis gas-operated gun to avoid or prevent fracture of reciprocating plunger mechanism in vicinity of joint between piston rod and part actuated by it. The 2 sections connected with a loose joint and a spring for controlling the joint.

Patent 1,290,849 7 Jan 1919
Sturgeon, John C. Erie, Pa.
Automatic gas-operated firearm.
Provides supplemental piston connected with and operating bolt-locking mechanism, which operates first to unlock the bolt and compress a retracting spring, and then continues to move in unison with breech-bolt locking mechanism, until again locked for firing. Improved feeding mechanism with attachable cartridge supply device.

Patent 1,291,690 14 Jan 1919
Smith, Morris F. Philadelphia, Pa.
Gas operated gun.
Cartridges are clip-fed; barrel fluted to enlarge its radiating surface and readily detachable; grip frame mounted on open under side of receiver; interchangeable parts; weapon readily taken down.

Patent 1,293,022 4 Feb 1919
Browning, John M. Ogden, Utah
Automatic machine rifle.
Improved portable machine rifle adapted to fire highly charged military cartridges from shoulder. All operations of mechanism except trigger effected by gas force automatically. (BAR)

Patent 1,293,396 4 Feb 1919
Fox, Ansley H. Philadelphia, Pa.
Gas-operated machine-gun.
Relates to gas-operated breech-loading machine guns. Improved air-cooling means for cooling barrel; improved cartridge-feeding device for retaining and releasing cartridges and maintaining continuous automatic firing of gun; improved ejector mechanism.

Patent 1,317,633 30 Sep 1919
Squire, William H. and Mercié, Henri A.
St. Denis, France
Automatic firearm.
Gas operated light gun intermediate between rifle and machine gun, intended for use in firing from prone position. Magazine operated; improved firing speed regulator; means for locking magazine; closing gates for protection against dust during transport; means for keeping residual gases from getting in mechanism of firearm; other features.

Patent 1,335,839 6 Apr 1920
Johnston, James S. Utica, N. Y.
Machine-gun.
Tripod mounted gun designed to be operated automatically by expansion of gases or manually at will. Has revoluble cartridge carrier for bringing cartridge into loading position, a ratchet attached to carrier, spring pressed tooth having transverse movement adapted to engage ratchet, means for compelling expanding gases of explosion to control movements of tooth and means for locking carrier in given position.

Patent 1,342,358 1 Jun 1920
Storle, Ole O. Tacoma, Wash.
Machine-gun.
Utilizes gas pressure for reloading, firing and ejecting cartridge shells, without diminishing force with which bullets are discharged; automatically stops firing whenever magazine is emptied and while cylinder is supplied with cartridges; to prevent overheating while gun is in action.

Patent 1,348,733 3 Aug 1920
Pedersen, John D. Jackson, Wyo.
Autoloading firearm.
Improved autoloading firearm operated by powerslide actuated by force of the powder gases transmitted through a rearwardly moving member or device usually consisting of shell or portion thereof. Furnishes breeching mechanism so arranged that force of gases will be transmitted through a rigid block without any intervening spring. Fire control action cooperative with retractably supported breech action. Grip operated safety member. Barrel supported free of any direct dependence on frame.

Patent 1,366,863 25 Jan 1921
Berthier, André V. P. M. Neuilly-sur-Seine, France
Firearm.
Provide means whereby fluid flow of pressure in fluid-operated apparatus may be controlled or variably adjusted as circumstances may require. Applied to gas-operated machine gun to compensate for changes in climatic conditions or changes in altitude.

Patent 1,367,453 1 Feb 1921
Bourdelles, Emile A. L. St. Denis, France
Small-arm.
Improvement in small arms of kind in which reloading is automatically effected by gas operated piston. Gases in barrel keep breech closed until moment in which a system of springs compressed by force of the gases and bearing against movable breech counterbalance force resulting from friction of the lugs of the movable head against their support.

Patent 1,371,351 15 Mar 1921
Cassetta, Vincenzo and Capaldo, Francesco
Naples, Italy
Machine gun.
Novel construction and combination of ignition and obturation mechanism; also new arrangement of the firing means and provision of air cooling system for gun barrel.

Patent 1,381,016 7 Jun 1921
Reising, Eugene G. E. Hartford, Conn.
Firearm.
Improved gas-operated firearm. Includes movably mounted breech-bolt operative by gases of explosion, separate locking means movably mounted to support breech-bolt and reduce results of the force applied to such locking means by firing action. Supporting means positioned by breech-bolt locking means to transmit force from breech-bolt to receiver and means for initially actuating one of locks without actuating the breech-bolt.

Patent 1,382,058 21 Jun 1921
Bourdelles, Emile A. L. St. Denis, France
Automatic firearm.
In a gas-operated automatic firearm, a plug having a plurality of holes enabling the action of the gases of discharge to be increased or diminished, said plug being capable of adjustment from outside by means of a lever-handle at right angles to barrel. Plug has conical head, a seat for the head and a spring active to retain the conical head on its seat to form a gas-tight joint.

Patent 1,387,889 16 Aug 1921
Johnston, James S. Utica, N. Y.
Gas-delayer for firearms.
Device for delaying progress of explosion gases for sufficient length of time in order that they may actuate piston controlling mechanism for automatically reloading gun.

Patent 1,388,856 — 30 Aug 1921
Fox, Ansley H. — Philadelphia, Pa.
Machine-gun.
Construction and coordination of parts by which gas tube and related mechanism for operating bolt and firing pin are mounted on barrel and in top of receiver; cartridge magazines connected to bottom of receiver by means permitting quick change; simplified extractor mechanism; improved control for bolt.

Patent 1,388,879 — 30 Aug 1921
Nelson, Charles A. — Utica, N. Y.
Gas-operated firearm.
Strengthened connection between muzzle and gas cylinder in gas operated firearms. Provides ready adjustment of gas transmission.

Patent 1,401,667 — 27 Dec 1921
Brown, Charles W. — Indianola, Iowa
Machine-gun.
Comprises: firing mechanism controlled by gas pressure derived from barrel; means for water-cooling barrel, including pump operated by breech block; means for feeding cartridges with respect to breech block and for ejecting same; control for firing mechanism stopping operation when ammunition is used up; novel form of muffler and flame check; auxiliary cartridge magazine.

Patent 1,402,459 — 3 Jan 1922
Swebilius, Carl G. — New Haven, Conn.
Automatic firearm.
Improved gas-operated machine gun in which gas cylinder is arranged parallel to barrel and easily removable from gun for cleaning. Inlet port of cylinder registers with gas port of barrel without leakage. Ready access is furnished to the cartridge as it occupies any of a number of positions intermediate the feed wheel and chamber in barrel. Window or opening in one of side plates provided for this access. Convenient charging of gun preliminary to firing by starting handle located at one side of gun near handle and trigger.

Patent 1,402,564 — 3 Jan 1922
Bourdelles, Emile A. L. — St. Denis, France
Machine gun.
Improved machine gun of gas-operated type. Gases pass vent in usual way and act on piston which drives back operating fork. At back end of fork is fixed a special screw the end of which forms the striking pin. When breech is locked striking pin, if allowed to do so, still moves.

Patent 1,430,660 — 3 Oct 1922
Lewis, Isaac N. — Montclair, N. J.
Method of operating firearms.
Utilizes gases of discharge resulting from firing of a powder charge in firearm to produce a shock or very rapid pressure impulse, which is transmitted to actuating mechanism of the firearm to cause operation thereof. Effects either automatic or semi-automatic operation. Gases also used to effect a circulation of cooling air over and around the barrel.

Patent 1,430,661 — 3 Oct 1922
Lewis, Isaac N. — Montclair, N. J.
Firearm.
Automatic or semi-automatic firearm in which means are provided for influencing gases of discharge resulting from firing of powder charge to produce a shock or very rapid pressure impulse, together with means for transmitting said shock to operate firearm. Discharge gases utilized to effect air cooling of barrel and to reduce or neutralize recoil.

Patent 1,430,662 — 3 Oct 1922
Lewis, Isaac N. — Montclair, N. J.
Automatic pistol.
Improved pistol in which gases of discharge produce shocks or rapid pressure impulses which are employed to re-energize actuating mechanism of the pistol.

Patent 1,431,057 — 3 Oct 1922
Sutter, Charles — Suresnes, France
Automatic machine gun.
Gas-operated machine gun with improved feed mechanism, breech closing and locking device and firing regulator. Also means for closing all apertures and muzzle supporting arrangement which fold up alongside the barrel. Improvement on Benét-Mercié Patent 1,125,937 (1915).

Patent 1,431,059 — 3 Oct 1922
Sutter, Charles — Suresnes, France.
Gas-controlling attachment for gas-operated guns.
Combination with barrel and carrier ring delivering a portion of the powder gases from bore of the gun to the motor piston, of a revoluble plug having a series of transverse separate ducts in the walls thereof, both orifices of which ducts debouch from the periphery of said member. Insures perfect gas-tight joint between gas ports of barrel and nozzle head.

Patent 1,447,246 — 6 Mar 1923
Hazelton, George — London, Eng.
Machine gun.
Improvement in machine guns in which barrel recoils and lock reciprocates, e. g., Vickers, and has for chief object more rapid rate of fire. At muzzle end of gun a piston-like member is formed or secured to barrel and contained in a fixed cylinder having an opening in line with bore of barrel for bullet to pass through. One or more lateral apertures disposed behind piston-like member when barrel is stationary, so that member must move rearwardly with barrel a certain distance before apertures are uncovered to allow escape of gases. Also auxiliary spring acting as buffer for barrel.

Patent 1,455,880 — 22 May 1923
Hammond, Grant — New Haven, Conn.
Firearm.
Improved hand-fired pistol operated by gases of explosion. Lock operating member secured to lock located in handle and means for disengaging receiver and lock by impact of breech bolt at time it strikes the receiver.

Patent 1,521,730 — 6 Jan 1925
Swebilius, Carl G. — New Haven, Conn.
Automatic firearm.
Direct positive application of the high pressure of the gas within the barrel immediately after explosion of a cartridge to means for locking breech mechanism in its closed position and subsequent release of said locking means upon decrease of gas pressure to allow decreased pressure to operate breech mechanism.

Patent 1,524,974 — 3 Feb 1925
Hazelton, George — Paris, France
Gas chamber for automatic guns.
Easily detachable member embodying a conduit communicating with the forward end of the expansion cylinder and with a hole pierced in the gun barrel, said member preferably embodying a gun sight and support pivot means. Apparatus for drawing off gases in machine guns and other automatic firearms.

Patent 1,534,486 — 21 Apr 1925
Bang, Soren H. — Copenhagen, Denmark
Self-loading firearm.
Improvement in gas-pressure loaders for firearms for automatically cleaning cylinder of the powder slush deposited by gases. Piston projects somewhat into the powder gas chamber. Means for readily detaching hood on front of barrel.

Patent 1,572,450 — 9 Feb 1926
Swebilius, Carl G. — New Haven, Conn.
Automatic rifle.
Machine rifle of gas operated type, capable of using highly charged ammunition, so designed that gunner may operate either in prone position or standing and supporting rifle with hands (or hands and shoulders).

Patent 1,603,684 — 19 Oct 1926
Garand, John C. — Somerset, Md.
Automatic gun.
Automatically loading firearm in which forces of explosion are utilized to expel spent cartridge and reload piece for another shot. Specific breech mechanism in which cartridge is inserted into barrel at instant of firing, eliminating danger of accidental firing. Novel actuator and breech bolt to insure positive operation of firing pin in exploding cartridge. Novel trigger mechanism which positively controls automatic action of gun, whereby it may be fired with single shot or repeatedly.

Patent 1,713,954 — 21 May 1929
Destree, Joseph — Brussels, Belgium
Firearm.
Relates to automatic firearms and to obturating and percussion mechanism employed in conjunction with cartridge. Cartridge case has inwardly directed flange to permit engagement by a hooking organ situated on obturating mechanism. Case recoils under pressure without distortion or tearing. Also obturation device permitting employment of cartridge in an automatic firearm.

Patent 1,713,955 — 21 May 1929
Destree, Joseph — Brussels, Belgium
Automatic firearm.
Consists in leading in the gases in gas-operated firearm through a fairly large orifice which allows gases to pass away rapidly when piston makes its return stroke, movement of the piston being gradually restrained during forward stroke before reaching end of stroke.

Patent 1,733,231 — 29 Oct 1929
Mascarucci, Giuseppe — Turin, Italy
Automatic firearm with recoiling barrel and without movable breech.
Invention eliminates movable breech in weapons with recoiling barrel. Provides direct locking device between barrel and obturator comprising a member for producing a direct locking between said parts. Obturator disconnected from barrel automatically only when said parts have travelled a determined portion of recoil stroke.

Patent 1,735,160 — 12 Nov 1929
Destree, Joseph — Brussels, Belgium
Automatic firearm.
Relates to arm in which pressure of gases is employed to produce displacement of a member taking part in operation of firearm, such as breech block or bolt. Consists in employing gases for exerting a braking action on the movement which they produce to permit comparatively gentle movements.

Patent 1,738,501 — 3 Dec 1929
Moore, Frederick T. — E. Hartford, Conn.
Gas-operated automatic firearm.
Improvement on BAR (Patent 1,293,022—1919). Provides greater reliability in repeated and continuous firing by improved construction for gas cylinder or piston or both. To minimize any sticking tendency between piston and cylinder, cylinder is made of a material having a greater coefficient of expansion than that of the piston.

Patent 1,743,472 — 14 Jan 1930
Meyer, Charles D. — Seattle, Wash.
Semiautomatic rifle.
Improved semiautomatic shoulder rifle which is gas operated. Improved safety and trigger action. No auxiliary rotary movement necessary to hold and lock bolt and slide together. Gas retarder retards gases issuing from bore of barrel after firing; power of this retarded gas utilized to operate gun.

Patent 1,786,207 — 23 Dec 1930
Hudson, Robert F. — Richmond, Va.
Machine gun.
Improvement on Patent 1,749,137 (1930) in which gases of explosion act to reduce the recoil. Provides power storing device actuated by explosion gases for operating means for reciprocating breech block. Provides motor operated synchronized machine gun positively controlled to prevent opening of breech in case of misfire or hangfire. Adapted to use for various calibers. Stationary barrel gun with least possible recoil in which gases are used merely as a setting means.

Patent 1,799,981 — 7 Apr 1931
Holek, Emanuel — Brunn, Czechoslovakia
Firearm.
Barrel is axially displaced with respect to other parts of firearm so rifleman may keep arm in its normal position so as to aim conveniently even if rifleman carries gas mask or helmet. Piston rod forms part of gas-pressure-operated charging device. Gas cylinder of gas-pressure-operated charging device made integral with carrier for the gun-sight to permit both being easily exchanged by a single manipulation.

Patent 1,802,816 — 28 Apr 1931
Holek, Emanuel — Brunn, Czechoslovakia
Gas-pressure-regulating device for firearms.
Provides within the connecting channel intermediate the barrel and the gas cylinder of the firearm a regulating organ of very simple construction permitting quick and exact adjustment of gas pressure.

Patent 1,811,693 — 23 Jun 1931
Larsson, Carl A. and Higson, Percy R.
Westminster, Eng.
Gas operated machine gun and automatic small arm.
Gas plug is made in two parts, viz, a main part which is adapted to be secured in the block and a subsidiary part which fits into the main part and is provided with a curved gas passage in form of a recess opening onto one of faces of subsidiary part. Reduces blockage with solid fouling matter from gases.

Patent 1,828,108 — 20 Oct 1931
Flowers, Thomas E. — Memphis, Tenn.
Magazine gun.
Improvements in self-loading or semi-automatic rifle which uses portion of gases generated by explosion of cartridge to operate the mechanism. Capable of using special pre-rifled and hardened cartridges; non-detachable magazine; strengthened breech block for cartridges of higher intensity; link mechanism for loading and extracting cartridges; etc.

Patent 1,843,916 — 9 Feb 1932
Cole, Charles S. — Sandy Hook, Conn.
Automatic firearm.
Gas operated shoulder rifle in which barrel is fixed, breech movable, using cylinder and piston for functioning of gun. Gun action provided in which a barrel and a breech are opened, closed, locked together and unlocked by means of a toggle pair actuated and controlled in direction and extent of movement by a third toggle link driven by gun discharge power.

Patent 1,846,993 — 23 Feb 1932
Destree, Joseph — Brussels, Belgium
Automatic firearm with gas extraction.
Passage by which braking gases are admitted to cylinder opens into the barrel of firearm nearer to the breech block than the passage by which the motive gases are admitted to cylinder. Resulting extraction of gas from barrel reduces pressure of motive gases, but this is compensated for by provision of larger cross section for passage by which motive gases pass into cylinder than for braking gases.

Patent 1,895,719 — 31 Jan 1933
Lahti, Aimo J. — Jyvaskyla, Finland
Automatic firearm.
Relates to automatic firearm in which the reaction of the gunpowder gas pressure and a spring force counteracting the gas pressure act automatically at the firing of the weapon thus effecting feeding, cocking, firing and ejection.

Patent 1,907,163 — 2 May 1933
White, Joseph C. — Wakefield, Mass.
Automatic gun.
Improved service rifle of semi-automatic, gas-operated type. Novel gas-operating mechanism; gas utilized expansively rather than by way of a violent initial impulse, the parts moving back under control rather than being blown back by initial gas impulse. Improved action slide and breech closure and other mechanisms.

Patent 1,907,164 — 2 May 1933
White, Joseph C. — Boston, Mass.
Automatic gun.
Improved semi-automatic rifles adapted to be fired from shoulder. Gas mechanism affords a safe and positive means for operating breech closure. Improved safety, trigger mechanism, extractor, firing pin, ejector.

Patent 1,975,236 — 2 Oct 1934
Palmer, Arthur J. and Higson, Percy R.
Westminster, Eng.
Machine gun and automatic small arm of the gas operated type. (Cl. 42-3)
Cooperating faces on stop member to stop forward motion of gas operated piston and on the piston rod are arranged at a suitable angle to direction of movement to produce a cushioning effect so that rebound of the piston rod is prevented or substantially reduced.

Patent 2,003,066 — 28 May 1935
Brondby, Fridtjof N. — Oslo, Norway
Firearm of the gas reloading type. (Cl. 42-3)
Piston is used whose length is so proportioned in relation to the travel thereof that piston can separate from cylinder and thereby put the cylinder in connection with the atmosphere for so long a time after each shot that gases of combustion may be thoroughly scavenged and before next shot may be filled with air.

Patent 2,027,892 — 14 Jan 1936
Williams, David M. — Godwin, N. C.
Gun. (Cl. 89-3)
Machine guns which normally require high intensity ammunition to operate the same are adapted to operate by low intensity ammunition (containing low ballistic properties). Operating energy of gun can be controlled by using a constant gas pressure and varying the pressure area over which it acts.

Patent 2,052,368 — 25 Aug 1936
Sutter, Charles, Suresnes, France, and Dugied, Eugene A., Courbevoie, France
Gas-controlled automatic firearm. (Cl. 42-3)
Device by which all powder gases in gas-controlled automatic firearms are vented to the front of the barrel. Expansion cylinder is capped by a sleeve surrounding the piston. Eliminates poisoning of atmosphere when gun is fired in a sheltered place.

Patent 2,058,897 — 27 Oct 1936
Marek, Anton — Vienna, Austria
Gas-pressure-operated gun. (Cl. 42-3)
Object is to provide a gas-pressure loader which, even when using powder of inferior quality, which on combustion leaves considerable sediment, possesses great reliability of operation, so that even with continuous firing the motor of the gun, driven by explosion gases, is not prejudiced in its operation by the sediment. Combustion sediment is kept in loose state and removed automatically by combustion gases.

Patent 2,091,672 — 31 Aug 1937
Cleereman, Peter J. — Kenosha, Wis.
Rapid firing rifle. (Cl. 42-3)
Machine gun of little greater weight than army rifle embodying gas-operated motor for operation. Magazine and feed wheel eliminates need for belts or disks for carrying cartridges. Hopper forms part of magazine. Detachable barrel.

Patent 2,101,862 — 14 Dec 1937
MacGregor, Stephen H. — Savannah, Ga.
Gas-operated gun. (Cl. 42-3)
To provide a delay action without loss of actuating power and to apply the necessary power smoothly without violent or sudden contact of moving parts.

Patent 2,112,660 — 29 Mar 1938
Hudson, Robert F. — Richmond, Va.
Automatic gun. (Cl. 89-2)
Gas-set, mechanically operated automatic gun, the power for operation being obtained by passing a portion of the powder gases into a gas cylinder for compressing a spring in a forward direction, energy stored in main spring being used to operate gun. Designed to utilize total energy available.

Patent 2,128,243 30 Aug 1938
Green, Samuel G. Gray, Ga.
Recoil check and barrel accelerator for a machine gun. (Cl. 89-14)
Involves an arrangement of a baffle with respect to the barrel whereby the discharge of high pressure and high temperature gases is controlled by a restricted passage and so directed as to prevent the accumulation of carbon and fouling of the bearing for the barrel.

Patent 2,144,241 17 Jan 1939
Eiane, Halvor O. Washington Island, Wis.
Automatic rifle. (Cl. 42-3)
Improvements in gas operated automatic arms. Utilizes bolt-action principle in conjunction with automatic operation; means for quick and easy dismounting of breech bolt mechanism; provides straight striking firing pin; automatic warning signal when magazine is empty; utilizes stored gas from a reservoir on the expansion principle as automatic motive power instead of impulse principle.

Patent 2,149,512 7 Mar 1939
Eiane, Halvor O. Washington Island, Wis.
Automatic gun. (Cl. 42-3)
Improvements in gas-operated guns. Means for entrapping a sufficient quantity of gas in a special reservoir to enable a piston in a cylinder to operate a connected breech mechanism; means for automatically filling and closing gas reservoir to enable the bore of a barrel to discharge its gases before piston in cylinder is set in motion by gas pressure from reservoir.

Patent 2,186,582 9 Jan 1940
Gebauer, Ferenc Budapest, Hungary
Gas-operated firearm. (Cl. 42-3)
Provides special construction of gas cylinder, gas cylinder closure and gas piston in which no harmful deposition can occur in firearm between gas piston and gas cylinder. Vent of gas passage extends with its muzzle into a cavity of gas piston and an annular dead pocket is provided at bottom of cavity in gas piston where flow direction of gas is reversed. Impurities deposited in this dead pocket and thrown out by centrifugal force.

Patent 2,196,852 9 Apr 1940
Browning, Jonathan E. Ogden, Utah
Repeating firearm. (Cl. 42-3)
Improved piston and cylinder arrangement through which the gases of explosion withdraw the breech block, said arrangement being so constructed and mounted that sticking of piston in cylinder due to expanded or contracted parts is avoided. Improved arrangement between piston rod and breech block whereby latter is unlocked with a slight delayed action after firing of arm and upon retraction of breech block firing pin is automatically cocked.

Patent 2,211,405 13 Aug 1940
Browning, Jonathan E. Ogden, Utah
Gas-operated automatic firearm. (Cl. 42-3)
Provision for avoiding the cramping or binding of the tubular piston despite strains placed thereon as a result of its operative connection to action of firearm.

Patent 2,223,671 3 Dec 1940
Brondby, Fridtjov N. Oslo, Norway
Gas-operated automatic firearm. (Cl. 42-3)
Channel leading from barrel to a cylinder for gas arranged in such a manner that it makes an acute angle with the portion of the barrel located rearwardly of point of entry of channel into barrel. Ejector effect is obtained which causes a sucking out of powder gas after each shot.

Patent 2,252,754 19 Aug 1941
Browning, Jonathan E. Ogden, Utah
Gas-operated automatic firearm. (Cl. 42-3)
Lessened "kick" in gas-operated firearm. Piston is employed for operating action of the firearm and impulse imparted to piston by burning or burnt gases is automatically diminished as piston approaches limit of its travel under impulse of said gases. Gases actuating piston also set up counterrecoil forces to offset recoil initiated by discharge of cartridge.

Patent 2,287,032 23 Jun 1942
Garand, John C. Springfield, Mass.
Barrel and gas cylinder assembly for firearms. (Cl. 42-3)
Gas cylinder carries a plug in front of the muzzle of barrel and this has previously required very close manufacturing tolerances to insure that bullet exit hole in plug is in alignment with bore of barrel. Invention provides an assembly which will eliminate need for precision in manufacture and provide for rapid assembly and a firm mounting.

Patent 2,330,737 28 Sep 1943
Pedersen, John D. Jackson, Wyo.
Rifle mechanism. (Cl. 42-50)
Improvement on Patent 1,737,974 (1929) for semi-automatic rifle. Power for operating breech mechanism is obtained from discharge gases at muzzle of barrel. Piston rod in gas operating cylinder made easily detachable and usable by soldier as part of his cleaning rod for rifle. Gas ports and passages readily accessible for cleaning. Enbloc clip is of double row reversible type for either right or left hand feed. Bolt mechanism of combined rotary and reciprocatory type.

Patent 2,331,347 12 Oct 1943
Rehnberg, Per H. E. Enskede, Sweden
Firearm. (Cl. 42-3)
Automatic rifle in which a gas nozzle is mounted slidably on free end of barrel in such a manner that bullet after having left barrel has to traverse only a very short distance within the gas nozzle.

Patent 2,331,703 12 Oct 1943
Koucky, Josef Brunn, Czechoslovakia
Stopper for the gas cylinders of gas-pressure loaders in firearms. (Cl. 42-3)
Stopper comprises a cylindrical body adapted to be pushed into the gas cylinder in an axial direction and provided with an actuating member for effecting rotation of said stopper when pushed into position. Also means to secure stopper against axial displacement. Ram rod for barrel employed as securing member, mounted in front part of butt and beneath barrel.

Patent 2,340,293 1 Feb 1944
Balleisen, Charles E. Philadelphia, Pa.
Gas cylinder unit for guns. (Cl. 138-45)
Provides for regulation of input of power into automatic action of guns. Gas port regulator for use with a gun barrel having a gas port therein, comprising a cylinder having a port adapted for registry with said gas port, a ring in the cylinder provided with spaced ports of different sizes.

Patent 2,340,962 — 8 Feb 1944
Humeston, Frederick L. — Hamden, Conn.
Gas-operated actuating mechanism for firearms. (Cl. 42-3)
Arrangement of parts whereby gas pressure emanating from bore of barrel may be directed outwardly in a substantially-radial direction to actuate a simple piston and then have the energy thus developed converted into motion lengthwise of the firearm to actuate the breech bolt. Not necessary to provide integral piston-chamber means.

Patent 2,341,005 — 8 Feb 1944
Williams, David M. — New Haven, Conn.
Piston means for gas-operated firearms. (Cl. 42-3)
Superior piston means for gas operated firearms. Piston member may be guided in a predetermined path of movement without occasioning the binding of such piston.

Patent 2,341,260 — 8 Feb 1944
Barnes, Charles H. — Bridgeport, Conn.
Firearm. (Cl. 42-3)
Relates to firearms with gas-operated breech blocks. Mechanism for converting manually operated firearm into a semi-automatic firearm. Provides a gun barrel with a movable portion on muzzle end operated by the force of gas pressure in the barrel, on discharge of arm, for effecting automatic operation of breech block mechanism.

Patent 2,341,680 — 15 Feb 1944
Williams, David M. — New Haven, Conn.
Piston means for gas-operated firearms. (Cl. 42-3)
Gas-operated self-loading firearm with superior piston means whereby deleterious effects of residues from powdered gases are minimized without materially affecting efficiency. Means for limiting the stroke of the piston proper. Removable stop-member for limiting stroke together with means for retaining said member in place.

Patent 2,341,780 — 15 Feb 1944
Horan, Timothy F. — New Haven, Conn.
Automatic firearm. (Cl. 42-3)
Improved gas-operated firearm of simple and economic construction. Mechanism to transmit the motion of the piston to breech bolt, which also serves to change direction of motion of piston. Gas-operated member to effect rearward movement of breech bolt, which member will be limited to a very short stroke as compared with that of bolt.

Patent 2,346,954 — 18 Apr 1944
Williams, David M. — New Haven, Conn.
Gas-operated self-loading firearm. (Cl. 42-3)
Relatively long distance retirement of breech bolt may be reliably effected by means of a gas-operated piston having a total stroke of but a fractional part of stroke of breech bolt. Fouling of piston and cylinder minimized.

Patent 2,348,872 — 16 May 1944
Williams, David M. and Roemer, William C., New Haven, Conn.
Gas-operated automatic firearm. (Cl. 42-3)
Adapted for military use by having means for mounting bayonet. Gas cylinder located beneath barrel so that length is not unduly extended. Readily cleaned and demounted.

Patent 2,365,142 — 12 Dec 1944
Turner, Russell J. — Butler, Pa.
Firearm. (Cl. 42-3)
Improved breech loading gas-operated automatic firearm. Convertible from full automatic to semi-automatic. Improved gas cylinder and gas cylinder barrel connection that may be quickly disconnected. Straight gas vent in barrel. Cam surface locks breech block into firing position. Other improvements. Embodied in light semi-automatic carbine.

Patent 2,369,669 — 20 Feb 1945
Garand, John C. — Springfield, Mass.
Gas regulator for firearms. (Cl. 251-35)
Method and apparatus for controlling energy imparted by actuating gases of gas-operated firearms. Eliminates accumulation of powder residue and carbon within gas cylinder. Pressure regulator comprises a plug adapted to be threaded into the interior of the cylinder having an axial hole extending therethrough, and two valve members.

Patent 2,373,204 — 10 Apr 1945
Swebilius, Carl G. — Hamden, Conn.
Gas-operated self-loading firearm. (Cl. 42-3)
Improved means for operatively interconnecting piston and breech bolt. May be readily disconnected from structure for inspection, repair or replacement.

Patent 2,376,466 — 22 May 1945
Williams, David M. — New Haven, Conn.
Piston means for gas-operated firearms. (Cl. 42-3)
Power stroke of piston during normal operation of firearm is effectively limited but with provision for ready release of piston for dismounting from the firearm structure. Applies to firearms wherein the stroke of the piston under the urge of gases from bore of barrel is but a fraction of stroke of breech bolt or its equivalent which piston serves to actuate.

Patent 2,377,703 — 5 Jun 1945
Loomis, Crawford C. — Ilion, N. Y.
Firearm. (Cl. 42-22)
Relates to autoloading rifle having a transversely swinging breech block and a gas operated slide for actuating the breech block. Improved means for enabling primary extraction of a fired cartridge case. Enables simultaneous transverse and longitudinal movement of breech block. Has gas operated slide and a fore-end arranged to enable manual operation of the slide. Means for selectively converting gun from gas operated to manually operated.

Patent 2,382,411 — 14 Aug 1945
Green, Samuel G. — Gray, Ga.
Speed regulator for automatic guns. (Cl. 42-3)
Gas regulator so proportioned to the port and the displacement of a piston in communication with gas chamber that ratio of expansion of gas admitted to chamber with respect to piston displacement imparts uniformly increasing acceleration to piston, maintains temperature of gas in chamber sufficiently high to effect combustion of particles passing to chamber, and has such volumetric capacity to receive an excess of gas so volume passing to atmosphere will not minimize effect of initial volume received in chamber as to reduce pressure below critical operating pressure.

Patent 2,386,205 — 9 Oct 1945
Garand, John C. — Springfield, Mass.
Firearm. (Cl. 42-3)
Firearm of light weight and small size for use by mounted soldiers and paratroopers. Gas-propelled operating rod actuates bolt and strikes firing pin. Improved means for producing semi-automatic fire. Means for changing gun for automatic to semi-automatic, and vice versa. Requires partial dismantling to convert in this manner.

Patent 2,388,291 6 Nov 1945
Ruger, William B. Greensboro, N. C.
Machine gun. (Cl. 89–33)
Gas-operated, air-cooled and belt fed machine gun. Large proportion of total weight is in barrel where weight is needed to resist overheating.

Patent 2,393,627 29 Jan 1946
Garand, John C. Springfield, Mass.
Actuating mechanism for gas operated firearms. (Cl. 42–3).
Mechanism wherein the accumulation of deleterious substance deposited by the operating gases is substantially eliminated through utilization of a gas blast as a cleaning agent. Blast directed towards muzzle end of firearm and away from operator. Maximum gas pressure developed within actuating mechanism may be conveniently adjusted without disassembly. Adjustable for optimum performance with all types of cartridges regardless of variation in gas pressure.

Patent 2,394,986 19 Feb 1946
Crockett, Harry L. New Haven, Conn.
Gas-operated self-loading firearm. (Cl. 42–3)
Improvements in self loading firearms of type wherein gas pressure from bore of barrel actuates piston to extract, eject and reload. Parts arranged to minimize distortion of bolt-operating slide under stress of piston. Piston applies its thrust upon a bolt-operating slide at a point laterally intermediate the guide means for said slide and portion of slide which is operatively connected to bolt to operate same.

Patent 2,409,225 15 Oct 1946
Schaich, Wilbur A. Springfield, Mass.
Gas system for firearms. (Cl. 42–3)
Mechanism for deriving motive power from gases developed within barrel to operate breech mechanism. Particularly adaptable for operation by high pressure gases. Self compensating with respect to variations in pressure of operating gases. Operate on moving piston by expansion rather than by impact blow. Applicable to M1 carbine to reduce maximum velocity of moving parts.

Patent 2,428,398 7 Oct 1947
Summerbell, William and others Washington, D. C.
Obturator for guns. (Cl. 89–26)
Obturator for use with breechloading gun of separate loading type wherein a primer cartridge is fired through a passage in obturator to ignite and function main propelling charge. Provides sealing means for effectively confining gases within primer cartridge and the flash passage leading thereto and preventing their rearward escape around the primer cartridge.

Patent 2,449,560 21 Sep 1948
Marshall, Samuel W., Jr. U. S. Army
Gas operation of firearms action slides. (Cl 89–193)
Relates to guns like M1 carbine. Gas cylinder formed by a single simple bore and utilizing cylindrical bar as the piston without a head enlargement or special retaining means.

Patent 2,462,119 22 Feb 1949
Moore, Cyril A. Springfield, Mass.
Gas regulating device for firearms. (Cl. 89–193)
Apparatus for controlling energy imparted by actuating gases of gas-operated firearms and at same time eliminating any accumulation of powder residue and carbon within gas cylinder.

Patent 2,464,409 15 Mar 1949
Mossberg, Harold F. New Haven, Conn.
Gas-operated firearm. (Cl. 89–194)
Means whereby a firearm is adapted to use both gas pressure and/or recoil action in a novel manner whereby firing mechanism of firearm will be automatically replaced into an initial position when a cartridge is fired. Maximum gas pressure developed in barrel utilized to retract loading and firing mechanism.

Patent 2,482,880 27 Sep 1949
Sefried, Harry H. New Haven, Conn.
Gas-operated self-loading firearm. (Cl. 89–193)
Improved gas-operated means for actuating breech block and related mechanisms of arm; by confined and predetermined quantity of gas derived from the discharge of a cartridge. Initial high pressure gases derived from discharge of cartridge are dissipated in actuating a valve member which confines predetermined amount of gas in cylinder.

Patent 2,487,198 8 Nov 1949
Swebilius, Carl G. Hamden, Conn.
Gas-operated self-loading firearm. (Cl. 89–191)
Improved gas-operated action slide mechanism with symmetrical arrangement of elements therein. Substantially rectangular member supported beneath barrel by action slides serves as action slide block.

Patent 2,539,644 30 Jan 1951
Turner, Russell J. Butler, Pa.
Tilting breech bolt lock actuating mechanism. (Cl. 89–184)
Improvement on Patent 2,365,142 (1944) on breech-loading gas-operated automatic firearm. Convertible into automatic or semi-automatic using a double stepped trigger for latter. Other modifications.

High Velocity

Patent 200,740 26 Feb 1878
Lyman, Azel S. New York, N. Y.
Improvement in accelerating guns.
Consists in accumulating power behind the projectile by successive explosion of supplemental charges of powder after the explosion of initial charge. Series of chambers opening into bore through apertures smaller than chambers.

Patent 1,326,763 30 Dec 1919
Meinersmann, William Elizabeth, N. J.
High-velocity gun.
Increased velocity without materially increasing pressure within gun. Avoidance of recoil by having breech-block independent and movably mounted with respect to bore of gun. Projectile given preliminary velocity and then adding velocity derived from charge to it. Forward movement of breech block used for ejecting burnt gases out of gun and substituting cooler air instead.

Patent 2,360,217 10 Oct 1944
Francis, Louis Miami, Fla.
Multicharge gun. (Cl. 42–76)
Provides for increase in velocity of projectile as it advances through barrel. Initial charge is provided for purpose of initially moving projectile through barrel and at spaced points along length of barrel booster charges are set off progressively from gas pressure behind projectile. Means for relieving projectile from atmospheric resistance during passage through bore. Interposes air cushion between firing charge and projectile. Booster attachment mounted on forward end of barrel for increasing effective range.

Liquid Propellants

Patent 645,932 27 Mar 1900
Beck, Michael and Ferrant, Emil Minneapolis, Minn.
Automatic magazine-gun.
Improvements in repeating rifles. Involves use of an explosive fluid which is automatically generated and exploded, in connection with means for automatically delivering projectiles into barrel of gun and into position to be discharged by explosion of the fluid. Chamber in stock contains storage tank for fluid (such as gasoline), carburetor, electric battery and induction coil. Automatic operation produced by recoil force.

Patent 1,164,876 21 Dec 1915
Sayler, Daniel Orland, Calif.
Gas-gun.
Relates to guns in which force of an exploding gas is utilized to project bullet and provides structure having means for preventing movement of bullet while gas is being compressed. Fuel reservoir suspended under barrel and battery housed in stock of gun.

Patent 1,375,653 19 Apr 1921
McLain, Robert M. and Quick, William M.
Huntsville, Ala.
Machine gun.
Gun wherein projectiles may be automatically fed to barrel for discharge therefrom by an explosion in the breech of the gun due to the ignition of a combustible substance formed of an explosive aeriform fluid. Has internal combustion engine having explosive chamber opening into one end of the barrel and projectile feeding instrumentalities operated automatically by movement of engine.

Patent 1,391,252 20 Sep 1921
Hooker, Ray O. Utica, Kans.
Machine-gun.
Improved liquid fuel machine gun. Bullet discharged by explosion of internal combustion engine. Magazine for holding a plurality of bullets and means for feeding them to proper position for discharge. Gas drawn from carburetor under compression and exploded by spark plug.

Patent 1,653,171 20 Dec 1927
Hagen, Rudolf A. Mason City, Iowa
Machine gun.
Shoots without use of powder or the like; bullets not incased in cartridges. Utilizes internal combustion engine, valve controlled carburetor, means for feeding bullets into barrel to be fired by actuation of engine.

Patent 2,371,816 1 May 1945
Hansen, Sern L. Northfield, Ohio
Rapid-fire gun. (Cl. 89–7)
Designed to fire naked bullets, i. e., without any shell or powder. Combines barrel with an internal combustion engine to position bullets one at a time within bore of barrel. Means for feeding bullets at rear end of barrel. Bullet positioned and fired by forces within one of cylinders of same engine used for operating the device.

Locking and Unlocking

Patent 180,037 18 Jul 1876
Joslyn, Benjamin F. Worcester, Mass.
Improvement in revolving firearms.
To lock barrel to, and unlock it from, frame of revolver by same lever employed to start cartridges from the cylinder; to permit cartridges to be started from the cylinder or not, as desired.

Patent 182,583 26 Sep 1876
Keene, John W. Newark, N. J.
Improvement in magazine firearms.
Gun operates without permitting any portion of bolt to rotate by novel construction of locking sleeve and breechpiece. Improved ejector, extractor and sear. Pin sliding freely in top strap of sleeve prevents pulling of trigger and release of firing pin until breech is closed and locked and gun is cocked. Improvement of "broken-jointed cartridge carrier".

Patent 324,296 11 Aug 1885
Browning, John M. and Browning, Matthew S.
Ogden City, Utah Terr.
Magazine-gun.
Device for locking bolt when breech is closed, to provide indestructible dead-lock for bolt. Improved construction of ejector. Combination with a sliding bolt of a chamber therein, a locking-piece fitting within said chamber and pivoted to bolt at rear end thereof, lateral extensions on said piece adapted to fit into recesses in sides of receiver and an operating lever to which locking piece is pivoted.

Patent 574,350 29 Dec 1896
Catlin, Robert M. Tuscarora, Nev.
Recoil-operated firearm.
Improved breech movement in which links are open and lie substantially in a straight line in their normal position and locked in such position during recoil as to lock breechbolt to barrel while links are unlocked for return movement of barrel. Link connected to barrel is operated as lever to retract breech bolt and open breech, breech bolt being released at proper time and returned to position by opening of links and empty shell meanwhile ejected and new cartridge fed to barrel.

Patent 663,956 18 Dec 1900
Burgess, Andrew Owego, N. Y.
Automatic firearm.
Relates to self-acting weapons. Devices and methods of unlocking breech by the discharge with proper delay to then allow the later pressure to open breech, a magazine with stop, guide and aligning feeder, a safety-lock adapted to said magazine, combined extracting and ejecting device, etc.

Patent 676,995 25 Jun 1901
Roth, Georges and Krnka, Charles Vienna, A.-H.
Automatic firearm.
Relates to mechanism for locking and unlocking the breech-bolt and barrel of automatic firearms, and the object is to effect both these operations, the latter at the recoil and the former on the forward movement of the breech-bolt and barrel, without imparting a partial turn to either barrel or breech-bolt. Both parts guided longitudinally in stock of weapon. Coupling and uncoupling effected by a locking-cylinder inclosing part of breech-bolt and barrel and which effects locking and unlocking of parts by partial rotation on longitudinal axis.

Patent 683,072 24 Sep 1901
Roth, Georges and Krnka, Charles Vienna, A.-H.
Automatic firearm.
Means for locking barrel in a rearward position and in retaining same in such position until movable breech-block

has been properly locked and is in position for firing next shot. Also improvements in magazine, trigger-actuating mechanism, and safety device in hammer.

Patent 710,094 30 Sep 1902
Browning, John M. Ogden, Utah
Magazine-gun.
Improvement in recoil-operated gun in respect to bolt-locking and ejecting features. Combines with breech-bolt or bolt-closure a locking-block carried thereby and swinging from its rear end and means for operating said block. Also combination of extractor and ejection cam.

Patent 723,706 24 Mar 1903
McClean, Samuel N. Washington, Iowa
Magazine bolt-gun.
Means for automatically locking weapon in its loaded condition and retaining it locked until lock is released by discharge or by hand; strengthening of bolt and receiver at their forward end portions; series of cam guides to control positively through movement of an operating handle actions of the various mechanisms of weapon; improved sights; other improvements.

Patent 802,033 17 Oct 1905
Freeman, Charles Los Angeles, Calif.
Automatic firearm.
Employs barrel and allows a device—e. g., the breech-block—a short backward primary movement upon the discharge of the arm, the movement being stopped by suitable locking means. Great bulk of backward thrust from explosion in barrel is solidly opposed by this locking device and breech-block. Meanwhile a momentum block receives an impulse from short primary movement of breech-block, this momentum being sufficient to reciprocate it along the frame, unlock breech block, etc., and operate the arm.

Patent 804,985 21 Nov 1905
Searle, Elbert H. Philadelphia, Pa.
Firearm.
Relates to recoil-operated guns. Postive locking means to prevent recoil of breech closure until after projectile leaves barrel, which locking means is prevented from unlocking by the passage of the projectile through the barrel, thus preventing premature opening of breech. Utilization of inertia in projectile for purpose of actuating a working part in an automatic firearm.

Patent 831,923 25 Sep 1906
Odkolek, Adolf Vienna, A.-H.
Automatic machine-gun.
Unlocking of breech piece is effected by short backward movement imparted to a locking-piece, whereupon breech-piece, together with locking-piece, is thrown backward, owing to the unlocking impulse against action of a returning spring, whereby shell is extracted and ejected. Breech piece then pushed forward by returning spring and cartridge positioned. Cartridges fed by means of band moved by means of breech mechanism. Means for firing by hand or automatically, as desired. Improved means for imparting unlocking impulse to breech mechanism.

Patent 866,972 24 Sep 1907
Sjogren, Carl A. T. Stockholm, Sweden
Gun.
Improvement on guns described in Patent 808,118 (1905) to remove inconvenience that movable weight after having brought breech block into closed position, has a tendency to move backwards again, the said weight compressing somewhat its spring or springs. Provides a pawl which at moment weight has brought breech-block into closed position, engages weight thereby preventing latter from moving back. Pawl may be operated by trigger and disengaged when trigger is turned back for firing.

Patent 908,631 5 Jan 1909
Warnant-Creon, Julien Hoignee-Cheratte, Belgium
Automatic rifle.
Automatic rifle so constructed as to provide positive locking of breech-bolt to the arm with the objects of preventing escape of the gases and imparting to projectile greater power of penetration. Adjustable locking member adapted to be shifted by hammer of firing mechanism to engage breech bolt and momentarily prevent recoil thereof when gun is fired.

Patent 918,760 20 Apr 1909
Mauser, Paul Oberndorf, Ger.
Recoil-loading rifle.
Relates to arrangement of breech and to locking mechanism for locking breech bolt in recoil-loading rifles with sliding barrels. 2 separate movable locking and unlocking levers are provided to support breech bolt on either side symmetrically to longitudinal axis of breech and barrel. Lateral mounting keeps whole breech system with casing lower.

Patent 924,169 8 Jun 1909
Mauser, Paul Oberndorf, Ger.
Firearm.
Improvements in recoil-loading weapons with sliding barrels. Relates to breech bolt and its locking mechanism, as well as those parts arranged inside breech bolt or in exterior connection with same. Locking bolt is U-shaped block free to swing in the breech case with a cradle like rocking movement. Adjustable to single loading or automatic loading. Barrel spring-buffered at both ends for advancing as well as receding movement. Improved firing device to prevent premature ignition. Other improvements.

Patent 924,224 8 Jun 1909
Ebert, Karl J. Cologne, Ger.
Breech mechanism for small-arms.
Employs knee, or toggle link locking system which turns right through or can be brought to fully extended position. Link mechanism has pivotal connection with fixed part of gun, said member being adapted to move rearwardly to a point where its pivotal connection passes that of 1st member.

Patent 935,314 28 Sep 1909
Lewis, George S. Chicopee Falls, Mass.
Repeating firearm.
Improved breech locking devices in firearm in which breech block is moved backward and forward to extract empty shell, cock hammer and insert fresh cartridge through connection with a grip piece sliding on barrel. Also improved connection between coiled main spring and hammer to permit latter to be properly engaged by hammer lock and to prevent lateral displacement of such spring and its stem with respect to hammer. Also improved feeding and extraction devices.

Patent 936,967 12 Oct 1909
Whiting, William J. Handsworth, Eng.
Automatic small-arm.
Relates to automatic small arms of recoiling breech-block type, with rearward and return movements of breech slide limited by a system of stops and spring-trigger-guard utilized as cushioning spring for reciprocating parts. Improved means for fastening and spring cushioning barrel and breech

slide by means of securing the several parts to one another but admitting of their disengagement by a levering action of the guard on a special fulcrum part, by special adaption of spring trigger guard.

Patent 942,167 — 7 Dec 1909
Dawson, Arthur T. and Buckham, George T.
London, Eng.
Automatic gun.
Relates to Maxim rifle-caliber automatic guns having shoulder piece or handle block. Inverts lock mechanism by arranging tumbler, sear, main spring and lifting levers above axis of firing pin instead of below it.

Patent 943,949 — 21 Dec 1909
Mauser, Paul — Oberndorf, Ger.
Recoil-loader with fixed barrel.
Device by means of which locking parts are moved into the unlocking and into the locking position. The movement of the locking parts is effected by a slotted plate which is exposed to action of special actuating device which is compressed before discharge of weapon but then released to drive the plate into the unlocking position. Plate securely locked by means of a catch which is actuated by a weighted pivotal lever, which on discharge is caused to turn on its pivot owing to recoil and thereby releases the catch.

Patent 966,995 — 9 Aug 1910
Brown, Milton W. — Trenton, N. J.
Automatic rifle.
Automatic gas operated magazine rifle provided with means whereby breech bolt may be automatically locked previous to the firing, said breech bolt also automatically releasing itself after the cartridge has been fired. Combines compact formation of a safety lock for firing pin and a gas chamber for operating the breech bolt by means of powder gases.

Patent 975,256 — 8 Nov 1910
Krnka, Karl. — Hirtenberg, A.-H.
Automatic firearm.
Combination of cartridge holding, locking and safety devices in magazine guns so that number of pieces is reduced to three. Pivoted locking device adapted to engage breech block and striker and cartridge holder journaled on said locking device.

Patent 976,122 — 15 Nov 1910
Clement, Charles P. — Liege, Belgium
Automatic firearm.
Means for temporarily locking or retarding breech-bolt and maintaining breech closed during firing of cartridge, said bolt being disengaged and released under effect of recoil to allow its being thrown rearward for extracting and ejecting empty shell, cocking and introducing new cartridge.

Patent 985,847 — 7 Mar 1911
Searle, Elbert H. — Springfield, Mass.
Firearm.
Improvement in Patent 804,985 (1905), utilizing projectile inertia for actuating working parts in an automatic gun, to withhold breech bolt from recoil until projectile has left barrel. Novel means for ejection of spent cartridges at top of gun, and to accomplish which, means for holding barrel against rotation is disposed forwardly of shell ejector opening; means on gun handle for controlling sear locking means; device anchoring barrel to gun frame affords means to cause counter-recoiling movement in gun barrel when rotating to unlock.

Patent 1,019,620 — 5 Mar 1912
Farquhar, Moubray G. and Hill, Arthur H.
Birmingham, Eng.
Automatic firearm.
Improvements in automatic firearms. Gas pressure within barrel on firing of gun used to retain lugs of sliding bolt securely locked in grooves of breech end of barrel until forces tending to resist extraction of spent cartridge from breech chamber fall below that of compressed breech opening spring when unfastening of bolt and opening of breech automatically take place.

Patent 1,026,609 — 14 May 1912
Schwarzlose, Andreas W. — Charlottenburg, Ger.
Automatic firearm with fixed barrel and locked breech.
Process of unlocking breech by a part not influenced by the recoil is improved so that rotating cylindrical breech bolt may also be used as an automatic loader. Length of breech is considerably shortened and sear arrangement simplified. Improved safety device of firing pin.

Patent 1,033,625 — 23 Jul 1912
Schmidt, Franz — Dusseldorf, Ger.
Automatic gun.
Device for automatically opening and closing breech of a gun having a recoiling barrel with aid of a spring. When barrel runs forward again, rod comes against a fixed stop whereby breech is opened. As forward movement continues a second spring is compressed, whereupon springs close breech after a catch is released, and return rod to normal position.

Patent 1,041,046 — 15 Oct 1912
Dorn, Hans — Suhl, Ger.
Automatic-loading firearm.
Improvement in recoil loading firearms having a sliding barrel or a sliding cartridge chamber arranged behind a fixed barrel. In addition to breech closing spring and the brake acting on the sliding piece, a separate spring is employed which brings the locking member with locking faces, disposed perpendicularly against barrel core, into locking position, and by means of a handle, said locking member may be moved, at will, out of engagement against action of the spring without rearward movement of rearwardly braked barrel.

Patent 1,070,579 — 19 Aug 1913
Brauning, Karl A. — Herstal, Belgium
Gun.
In movable-barrel gun utilized either as automatic or ordinary gun, the locking levers in the latter case being controlled by a member movable relatively to the breech casing. Construction whereby during automatic firing the movable member in question moves with the breech casing without acting on the locking levers.

Patent 1,071,023 — 26 Aug 1913
Borchardt, Hugo — Charlottenburg, Ger.
Breech-mechanism lock for automatic firearms.
Relates to breech mechanism lock which is brought into locking position by the cartridge feed device. When magazine is empty, the locking device causes the closing action of the closing spring upon the breech block to cease. Spring may also exert a braking action upon breech block by the intermediary of the locking device.

Patent 1,091,857 31 Mar 1914
Mauser, Paul Oberndorf, Ger.
Automatic firearm.
Special arrangement of locking means in recoil loading firearm. The two retaining members mounted in front end of grip cooperated with a lower projection from the block which moves between them, the adjusting slide for moving the retaining members inward and outward being arranged beneath same and engaging inwardly directed projections thereon. A separate member is also provided to facilitate adjustment by hand, mounted directly in trigger guard.

Patent 1,114,611 20 Oct 1914
Heinemann, Karl Berlin, Ger.
Automatic gun.
Improvement in Maxim type guns in which lock or breech block is moved by means of lock lever secured to lock crank mounted in slide block reciprocated by barrel recoil. Cams of lock arranged to control opening movement of lock within-in breech casing and in position for engagement with a stop bearing on handle block. Rocking lock lever located outside breech casing and position of rest and breech closing position of latter are such that any pressure or shocks always act in direction of longitudinal axis of barrel so that they cannot impair accuracy of aiming. Buffer spring dampens the shocks.

Patent 1,118,330 24 Nov 1914
Carl, John H. Gilroy, Calif.
Automatic firearm.
Relates to demountable recoil loading firearm. Provides novel arrangement of means for locking barrel on stock wherein the bolt retracting spring also serves to hold locking pin for the barrel in locking position; improved detent for barrel; improved means for holding locking pin from rotation so it may assist in forming detent for barrel.

Patent 1,132,044 16 Mar 1915
Stamm, Hans St. Gallen, Switzerland
Self-loading firearm.
Relates to self loading arms having a sliding barrel and with springs for returning barrel and breech action into forward position, breech action being locked and unlocked by means of a rotary lug riding in curved guide groove of stationary breech case. Previous unlocking methods inadequate for military guns or for pointed projectiles with increased powder charges. Patent provides for compulsory unlocking and relocking of breech bolt by guide groove so that unlocking is effected shortly before end of recoil of barrel. Gradual and positive loosening and ejection of cartridge.

Patent 1,262,169 9 Apr 1918
Buckham, George T. Westminster, Eng.
Automatic gun.
Relates to guns in which the lock is operated by toggle levers comprising a crank and a side lever. The cover of the gun mechanism casing is provided with a tripping piece against which the tumbler comes during the rearward travel of the lock, to displace the tumbler and cock the striker; tumbler has an arm by which it can be displaced by the side lever to cock the striker in the usual manner when lock is operated by hand with cover open.

Patent 1,290,850 7 Jan 1919
Sturgeon, John C. Erie, Pa.
Gas-operated automatic firearm.
Vertically moving breech bolt locking mechanism engaged and actuated by a supplemental piston communicating with and operating bolt-locking mechanism. Rotatable cartridge supply device. Barrel cooling mechanism consisting of thin corrugated strips of metal, secured longitudinally to barrel with a shell and conical disks.

Patent 1,315,329 9 Sep 1919
Redpath, Robert Coventry, Eng.
Automatic gun.
Simple and reliable mechanism for locking and unlocking sliding breech block. Combination of barrel, a rearward extension thereof, breech block adapted to slide axially along extension, locking block capable of sliding transversely within breech block and adapted to lock it to said extension, longitudinal shaft, means for rotating shaft and means for disengaging locking block from extension.

Patent 1,350,543 24 Aug 1920
Brauning, Karl August Zaandam, Netherlands
Automatic firearm.
Improvement on Patent 1,070,579 (1913) in which breech bolt carries a pair of locking levers operated by projections on slide which disconnect bolt from barrel on rearward movement of slide. Device which, when actuated, serves to retract slide and effect loosening of empty cartridge and disengage locking levers.

Patent 1,352,412 7 Sep 1920
Payne, Oscar V. Cleveland, Ohio
Gun.
Gun in which breech closure or bolt is locked in closed position during high breech pressure and is automatically unlocked directly in response to breech pressure when pressure decreases to a safe value. This method of locking incorporated in a breech closure adapted to reciprocate into and out of closed position and to rotate into and out of locked position, in which a single spring reciprocates closure into locked position.

Patent 1,352,413 7 Sep 1920
Payne, Oscar V. Cleveland, Ohio
Gun.
Relates to semi-automatic firearms of small caliber, applying procedure whereby breech closure is locked in closed position during high breech pressure and automatically unlocked directly in response to breech pressure acting upon breech closure when pressure decreases to a safe value, improved safety mechanism, etc.

Patent 1,363,809 28 Dec 1920
Payne, Oscar V. Cleveland, Ohio
Firearm.
To provide lock for interlocking breech block and firing member so that gun cannot be fired before breech block is locked and so that firing member is moved into firing position simultaneously with locking of breech block and so that gun is fired the instant breech block is locked. Improved means for taking up recoil of breech action.

Patent 1,387,369 9 Aug 1921
Duffek, Josef Steyr, Austria
Gun-lock for automatic firearms.
The back portion of the press-lever, actuated by trigger and operating hammer, is provided with a projection which slides in a guide of the firearm-casing on pressing trigger. Guide terminates in a depression into which projection of lever enters whereby latter releases striker causing it to jump forward and fire cartridge. Lever preferably jointed to trigger by a link to shorten backward movement of trigger.

Patent 1,396,949 — 15 Nov 1921
Eickhoff, Theodore H. — Cleveland, Ohio
Automatic gun.
Improvements in lock mechanism and associated firing and recoil mechanism for automatic and semiautomatic firearms. Lock adapted to reciprocate longitudinally as breech is opened and closed and to be rotated into and out of locking engagement with lock means upon receiver.

Patent 1,427,855 — 5 Sep 1922
Russell, Herbert O., Los Angeles, Calif., and Paulus, Charles L., Dayton, Ohio
Lock mechanism for machine guns.
Means whereby force necessary to trip the trigger of a machine gun is decreased to such an extent as to permit trigger to be operated by trigger motor of an electrical synchronizing gear.

Patent 1,432,182 — 17 Oct 1922
Hammond, Grant — New Haven, Conn.
Firearm.
Gun having solid locked breech at instant of firing; minimum amount of "kick": barrel, sights, receiver and handle all maintained rigidly secured together for accuracy. Improved mounting for bolt return spring.

Patent 1,457,961 — 5 Jun 1923
Browning, John M. — Ogden, Utah
Firearm.
Provision of means whereby retractive movement of an inertia-block and a cooperative breeck-block in a receiver are sufficiently retarded to insure the expulsion of the gases arising from an explosion, forwardly through the front of the barrel. Efficient plunger mechanism which acts properly in connection with the inertia-block of the arm. Also effective hammer, trigger and cocking mechanisms.

Patent 1,477,115 — 11 Dec 1923
Gast, Carl — Barmen, Ger.
Double-barreled machine gun with recoiling barrels.
Combines 2 systems of recoiling breech and firing mechanism, one system associated with each barrel, connections between the 2 systems whereby recoil of one produces advance of the other system, and means operating automatically during the advance of each system to cock the firing mechanism thereof. Also breech locking mechanism comprising rotary locking disks mounted in each breech slide to engage projecting cheeks of breech block and lock same against breech end of barrel, with stops to permit free movement of cheeks past disks.

Patent 1,550,760 — 25 Aug 1925
Swebilius, Carl G. — New Haven, Conn.
Automatic firearm.
Prevents unlocking of breech bolt between pulling of trigger and the explosion of the cartridge. Attained by spring actuated lever, one end of which engages a reciprocating portion of breech mechanism whereby latter is maintained in locked position.

Patent 1,637,233 — 26 Jul 1927
Norman, George — Small Heath, Eng.
Small arm.
Improved means for effecting rotary locking movement of the breech bolt. Opening in receiver is covered when bolt is in forward or closed position. Dispenses with open slots or gaps in receiver or breech body usually employed to control reciprocating movement and effect rotary movement of breech bolt.

Patent 1,725,272 — 20 Aug 1929
Heinemann, Karl — Dusseldorf, Ger.
Automatic firearm.
To prevent premature opening of the breech of arms having toggle-joint breech, locking device is required to lock joint in stretched position. Invention provides that lock for toggle joint to be released, on firing, by a control device actuated directly by force of the driving gases. Arm may then be rigidly mounted in a frame without preventing thereby the automatic release of the joint at the proper time.

Patent 1,770,135 — 8 Jul 1930
Herlach, Fritz — Dusseldorf, Ger.
Automatic firearm with sliding barrel and locked breech.
Provides locking device between the two parts of the breech piece, which after the head portion of the breech has been unlocked from the barrel, is automatically inserted and prevents any relative rotation between the two parts of the breech and spring from exerting any outward force. Guiding members of breech piece can now slide unhindered in the guiding groove of the casing without being stressed by spring.

Patent 1,801,072 — 14 Apr 1931
Browning, Jonathan E. — Ogden, Utah
Automatic firearm.
Strong and positive lock between breech bolt and barrel extension which lock is adapted to be easily released by movement of breech bolt. Common accelerator to effect unlocking of breech bolt from barrel extension and accelerate rearward movement of bolt. Improved locking means for preventing movement of barrel extension. Improved safety device, etc.

Patent 2,013,312 — 3 Sep 1935
Larsson, Carl A. and Higson, Percy R.
Westminster, Eng.
Machine gun. (Cl. 89–3)
Improved construction of lock enabling greater speeds of firing from barrel recoiling guns than heretofore possible. Reduces weight of vertically moving parts on Vickers type of lock and supports and actuates various parts in a balanced manner to minimize friction.

Patent 2,035,539 — 31 Mar 1936
Dicke, Allen E. — Upper Montclair, N. J.
Repeating firearm. (Cl. 42–3)
Self loading infantry rifle. Stores part of the energy of explosion of cartridge to reload arm, while holding action completely closed until gas pressure in chamber has been entirely dissipated.

Patent 2,069,432 — 2 Feb 1937
Watanabe, Saburo — Tokyo, Japan
Automatic device for automatic firearms. (Cl. 42–3)
Improved unlocking system for blowback weapons. Crank and pin system.

Patent 2,070,355 — 9 Feb 1937
Chevallier, Arnold L. and Sanders, Thomas F.
London, Eng.
Recoil operated small arm. (Cl. 42–4)
Novel means for locking bolt and for releasing it at appropriate time so as to allow residual gases to act directly on bolt and cause it to execute movements necessary for reloading. Makes use of inertia member moving forward relative to the gun on recoil and actuating a locking member, moving the latter from normal position, where it provides solid abutment for bolt, to a position in which it will allow bolt to travel backward past it.

Patent 2,144,951 24 Jan 1939
Williams, David M. Godwin, N. C.
Firearm. (Cl. 42–3)
Contemplates mechanism whereby operation is performed by use of power derived from the deformation of a part of the cartridge shell under firing pressure. Comprises locked breech with automatic operating mechanism so designed that the breech remains locked for a substantial interval after firing. Breech mechanism locked by a separate slidable locking and breech block actuating member.

Patent 2,145,136 24 Jan 1939
Sanders, Thomas F. Slough, Eng.
Recoil-operated firearm. (Cl. 89–3)
Arrangement for unlocking breech bolt after a shot has been fired and retaining locking mechanism in open position until bolt has returned to locking position ready for fresh firing. Avoids unnecessary friction.

Patent 2,159,127 23 May 1939
Birkigt, Marc Bois-Colombes, France
Automatic firearm. (Cl. 42–3)
Relates to light guns mounted in aircraft which include a breech structure movable at the rear of the gun tube, under opposed actions of recoil and of a counterspring. Employs cooperating inclined surfaces on breech block pawl and firing pin carrier and cooperating stops carried by said pawl and fixed breech casing.

Patent 2,182,907 12 Dec 1939
Vollmer, Heinrich Biberach-Riss, Ger.
Automatic firearm. (Cl 42–3)
Brake mechanism for automatic arm, which includes a plunger operating in a pneumatic brake cylinder, is associated with a pawl which is connected with the plunger and is adapted to engage reciprocating part of firearm mechanism so that plunger retards the movement preceding the discharge of a shot, the pawl being, however, automatically disengaged from the reciprocating part when the required retardation has been effected.

Patent 2,270,683 20 Jan 1942
Janecek, Frantisek Prague, Czechoslovakia
Automatic firearm. (Cl. 42–3)
Improvement of locking device of an automatic firearm with fixed barrel and with a locking operated by inertia of recoil parts. Actuator inserted between breech block and recoil locking block, arranged to be able of angular displacement and in its locked position bearing against a fixed support in receiver. Permits control within a wide range of amount of energy transmitted onto breech block mechanism.

Patent 2,335,854 7 Dec 1943
Green, Samuel G. Gray, Ga.
Backplate latch mechanism for machine guns. (Cl. 89 1)
Improved latch for Browning machine gun. All parts secured to back plate without modification of latter while locking member is arranged to have translatory motion transversely of line of travel of internal gun and not subject to an unlocking force arising from forces of inertia.

Patent 2,344,109 14 Mar 1944
Rossmanith, Wolfgang Solothurn, Switz.
Automatic gun having sliding barrel. (Cl. 42–4)
Arresting device controlled positively by the driving lever, which insures that barrel is held reliably in position necessary for locking with breech block by an automatic checking action between driving lever and the arresting device. Driving lever is arranged to actuate a separately mounted arresting lever by means of a control cam surface.

Patent 2,370,363 27 Feb 1945
Lippert, Hans J. Zurich, Switz.
Automatic firearm. (Cl. 89–3)
Employs novel locking system to effect locking in same way as in mass-locking method without mechanical locking means, while permitting the application of small, rapidly movable breech block masses with recuperator springs of low tension. Unites breech block mass with mass of barrel through a hydraulic resistance which permits relative movement between breech block and barrel during action of gas pressure forces in order to absorb such forces.

Patent 2,409,569 15 Oct 1946
Johnson, Melvin M., Jr. Brookline, Mass.
Automatic firearm. (Cl. 42–3)
Construction in which work imposed on slide for controlling movement of locking lugs is greatly reduced, in which unlocking and opening movement of bolt is controlled largely by breech pressure acting directly on bolt through head of cartridge case, etc. Abutting surfaces of locking lugs and receiver abutments are inclined to direction of breech pressure so that breech pressure tends to produce unlocking movement of lugs.

Patent 2,409,733 22 Oct 1946
Browning, Val A. Ogden, Utah
Repeating firearm. (Cl. 42–4)
Improved arrangement for operating the locking block which will permit reduction in weight of the inertia member which lightens weight of gun. Relates to self-loading, recoil-operated type wherein barrel and breech block are locked together by locking block with which is associated an inertia member adapted to unlock locking block from barrel during recoil.

Patent 2,499,090 28 Feb 1950
Browning, Val A. Ogden, Utah
Inertia operated pivoted bolt lock. (Cl. 89–182)
Unlocking of breech block from barrel is caused to occur automatically during recoil stroke of barrel through action of various forces at play with result that barrel and block are unlocked at proper moment regardless of character or intensity of charge used. Effected without use of abutments or stops.

Patent 2,527,895 31 Oct 1950
Tassan, Gian M. Milan, Italy
Sliding lock for breech bolts of automatic shotguns. (Cl. 89–187)
Comprises a locking member slidable along guides consisting preferably of plane surfaces in breech block body and slidable with respect to breech block bolt along other guides of plane surfaces inclined to aforementioned surfaces. Locking bolt lifts locking member when breech block brings locking member opposite a recess in breech body; firing pin is mounted on a locking bolt as safety arrangement.

Lubrication

Patent 1,334,052 16 Mar 1920
Putnam, Burleigh Pasadena, Calif.
Machine-gun.
Stationary breech block across the face of which the cartridges are passed and a movable barrel which reciprocates

to successively receive the cartridges and fire the same. Rearward movement of barrel caused by a coiled spring which elastically moves barrel rearwardly, breech opens and receives cartridge. Gas pressure when cartridge is fired moves barrel forwardly, thereby uncovering fired shell and operating carrier to bring next cartridge into position. Object of invention is to provide improved means for lubricating cartridges as they are being fed into firing position by wick located adjacent to path of holder or clip.

Patent 1,350,645 — 24 Aug 1920
Eickhoff, Theodore H. — Cleveland, Ohio
Apparatus for lubricating ammunition.
Invention utilized to introduce a lubricant, such as a powder, or a fluid, gaseous or liquid, into the firing chamber or other part of the apparatus for the purpose of lubrication. Lubricates contacting surfaces just prior to time of firing or of inserting cartridge into firing chamber. Utilizes force of an explosion to effect lubrication.

Patent 1,481,930 — 29 Jan 1924
Schneider, Eugene — Paris, France
Apparatus for lubricating the bore of firearms during firing.
Lubricant contained in the actual projectile in front of the driving band. Reservoir of lubricant in internal cavity of nose attached to front end of projectile. Outlet orifices provided in periphery of projectile allow lubricant to flow out by the action of inertia immediately the gun is fired.

Patent 1,656,960 — 24 Jan 1928
Soncini, Cesare — Brescia, Italy
Device for lubricating automatic firearms.
Lubricating system based on use of a reservoir or box from which lubricant flows by gravity under the effects of the vibrations incident to firing, through passages whose inlet can be varied by a regulating element accessible from the outside. Element may be locked in the position desired.

Mounting

Patent 120,588 — 7 Nov 1871
Kinne, George O. — Hartford, Conn.
Improvement in operating machine guns.
To give Gatling and similar guns reciprocating motion in a nearly horizontal plane while in the act of discharging projectiles. Block carrying bearings for trunnions is mounted on a center pin and fitted to spindle which works plungers for discharging gun so that rotary motion of spindle which effects discharge of gun is used to obtain desired reciprocating motion while gun is firing.

Patent 145,563 — 25 Oct 1873
Gatling, Richard J. — Hartford, Conn.
Improvement in traversing mechanisms for machine guns.
Grooved cylinder, in combination with a guide pin, for controlling the line of fire and sweep of Gatling gun.

Patent 198,367 — 18 Dec 1877
Farrington, DeWitt C. — Lowell, Mass.
Improvement in traverse mechanisms for machine-guns.
Provides automatic and adjustable traverse readily adjusted to desired sweep of the gun and will operate automatically as gun is discharged; consists in adjustable eccentric, connected with main shaft by suitable gearing.

Patent 253,924 — 21 Feb 1882
Hotchkiss, Benjamin B. — New York, N. Y.
Machine gun.
Peculiar structure of shoulder pieces for cannon and similar guns trained from shoulder; improved training mechanism for mechanically elevating and depressing cannon; improved means for controlling firing-pin of machine guns. (Basic gun in Patent 211,849)

Patent 1,319,510 — 21 Oct 1919
Birkigt, Marc — Bois Colombes, France
Combined gun and engine for aerial machines.
Comprises a gun in which engine of plane forms the gun carriage. Barrel of gun is a good sliding fit in the interior of the hollow propeller shaft, which is driven by crank shaft of engine through a speed reducing device. Recoil cylinder connected to breech of gun is secured to the casing of the engine. Laying of gun effected simply by steering plane.

Patent 1,320,711 — 4 Nov 1919
Rasmussen, Ernest J. — U. S. Army
Attachment for machine-guns.
Means for automatically controlling the lateral sweep or horizontal swing of gun on swivel base. Bullets may be automatically placed in uniform laterally spaced relation at any given range. Applicable to any machine gun in general use.

Patent 1,364,525 — 4 Jan 1921
Scarff, Frederick W. — London, Eng.
Machine gun mounting.
Mounting on airplanes or other vehicles comprising an elevating arm or bracket upon which gun is mounted and which is carried by a horizontally rotatable member. Single control lever adapted to effect release of a rotatable ring from a fixed ring and elevating arm from its retaining device.

Patent 1,413,936 — 25 Apr 1922
Rauchfuss, Kurt v. and Jaeschke, Ernest — Hamburg, Ger.
Lateral dispersion device for machine guns.
Device in which machine gun is automatically and intermittently trained by the recoil to both sides and reversed, in reaching limit of lateral movement. Attained by action of 2 pressure rods acting on two ratchet wheels connected to a worm engaging with a toothed slide bar and drives alternately in opposite directions.

Patent 1,444,768 — 6 Feb 1923
Wright, Robert L. — Los Angeles, Calif.
Machine gun.
Means for placing together and mounting all makes of individual machine guns, machine rifles, machine cannons and other firearms so that one man can point, fire and operate a plurality of them both simultaneously and separately.

Patent 1,551,809 — 1 Sep 1925
Dodge, William W., Jr. — Asheville, N. C.
Machine gun.
Improvements in machine guns, particularly those mounted in rotatable gangs to turn on an axis approximately parallel with the bores of the guns to produce intense cones of fire. Necessary power derived from the propelling charges fired in one or more of the guns. Provides ports through which parts of the powder gases are discharged in directions approximately tangential to rotary path of guns. Adjusted for fire either convergent, parallel or divergent. Applied to Lewis guns.

Patent 1,628,068 10 May 1927
Scarff, Frederick W. London, Eng.
Gun mounting for use on aircraft.
Improvement in gun mountings of ring type for use on aircraft, to avoid restriction of "over-the-side" or downward fire of gun. Elevating arm can be adjusted with respect to rotatable ring of mounting so that increased downward angle of fire is attained.

Patent 1,757,244 6 May 1930
Green, Samuel G. Gray, Ga.
Mount for guns.
Mount for rapid-fire guns in which a recoiling cradle carrying the rigid frame of the gun is so arranged with respect to its support that the center of thrust is transmitted intermediate the point of application to the support and the support trunnion and substantially coincident with recoiling cradle.

Patent 2,230,328 4 Feb 1941
Krum, Alfred, Dusseldorf, and Herlach, Heinrich, Berlin, Ger.
Automatic gun. (Cl. 89–37)
Relates to mountings for automatic guns comprising a casing with 2 parts which are adapted to be moved pivotally relatively to each other about an axis parallel to axis of bore, to facilitate removing or exchanging the barrel. Front bearings of gun mounting swing out laterally about a common axis. Releasable catches permit freeing of barrel by a single manipulation and swinging movement.

Patent 2,346,172 11 Apr 1944
Lennon, Robert J., E. Moline, Ill., and Green, Samuel G., Gray, Ga.
Gun elevating mechanism. (Cl. 89–41)
Cradle for use with machine gun tripods or like. Permits high elevation of gun, rapid traverse and elevation, means for limiting travel of elevating screw.

Multi-Barrel and Battery Guns

Patent 62,281 19 Feb 1867
Mejia, Enrique A. Mexico City, Mex.
Improvement in many-barreled guns.
New devices for loading and discharging a series of 2 or more parallel barrels, connected on a suitable frame for use by hand in a portable manner. Arrangement of series of double cams operated by hand trigger or winch handle by which all charges are exploded in rapid succession by movement of handle or trigger.

Patent 110,233 20 Dec 1870
Hedrick, James H. Wythe County, Va.
Improvement in repeating cannons.
Strong and compact frame within which cylinder revolves containing chambers for cartridges, in front of which are ranged a number of barrels incased in watertight inclosures, replaceable by other barrels; also a magazine with grooves capable of holding many cartridges, with rammers to force cartridges into chambers of cylinder. Worked by crank and connecting rod at rate of 300 to 500 per minute.

Patent 113,996 25 Apr 1871
Fields, William Wilmington, Del.
Improvement in battery-guns.
Consists in surrounding or covering guns with a hinged spring armor, so as to protect operators, the devices by which breech piece is lowered and raised, and general construction and arrangement of parts. Barrels vary in number from 10 to 50. Device for feeding or loading all barrels at once consists of plate having corresponding groove for each barrel.

Patent 125,563 9 Apr 1872
Gatling, Richard J. Hartford, Conn.
Improvement in revolving-battery guns.
Improvements on "Gatling revolving battery gun" (Patents 47,631 and 112,138—1865 and 1871) reduces length of lock and breech case. Detaining device provided with a transverse groove to receive the knobs on the rear end of lock hammers or firing pins and prevent them from moving forward with the locks themselves.

Patent 129,976 30 Jul 1872
Miles, William A. Salisbury, Conn.
Improvement in machine guns.
Relates to novel battery gun with sliding barrels. Reciprocating barrels, arranged side by side, and connected with rotary cams or other mechanisms or levers whereby they are successively or jointly moved back and forward. In backward movement they close over cartridges that have dropped behind them upon sliding supports. When fully back, motion is arrested and cartridges exploded. Then move forward to allow empty shells to drop down behind them. Also loading mechanism composed of reciprocating carriers to convey cartridges from receiver to upper sides of barrels.

Patent 130,098 30 Jul 1872
Wood, Marshall Lewisburg, W. Va.
Improvement in machine guns.
Combines toggle for reciprocating the breech bolt with hand mechanism for operating it. Combines series of cartridge carriers with the several barrels so they fire all barrels simultaneously. Peculiar construction of cartridge carrier with zigzag chamber, which is made to feed by a vibratory movement thereof. Rod and cam-slotted levers combined with carrier rods to vibrate all carriers at same time.

Patent 143,729 14 Oct 1873
Stensland, Cornelius Negaunee, Mich.
Improvement in machine guns.
Novel construction of intermittently rotating cartridge cylinder in multi-barrel field battery gun and means for loading its lines of chambers in rapid succession with cartridges from a magazine, exploding the cartridges and expelling empty cases. Use of diametrically opposite rows of loading chambers and equal number of rows of needles arranged at right angles to loading chambers.

Patent 145,224 2 Dec. 1873
Miltimore, Alonzo E. U. S. Army
Improvement in battery-guns.
Combines long range gun with revolving short range barrels, thus combining with gun of Gatling type advantages of long-range, large-caliber gun. Central barrel with series of complete barrels of smaller caliber revolving around it.

Patent 169,686 9 Nov. 1875
Farwell, Willard B. New York, N. Y.
Improvement in machine guns.
Relates to multi-barrel machine gun (Patents 137,428 and 154,596). Different mechanism for loading and firing cartridges, whereby firing and loading parts are brought entirely within the cylindrical breech chambers that constitute rearward extensions of the barrels. New traversing mechanism for vibrating gun during firing process. Uses telescopic tubing.

Patent 173,751 22 Feb 1876
Bailey, Fortune L. Indianapolis, Ind.
Improvement in machine guns.
Detachable spring-actuated reciprocating hammers secured to fixed casing of a machine gun and combined with its revolving barrels and shaft and with spiral cams formed on said shaft. Hammers alternately cocked as each barrel approaches line of sight and released to explode cartridge the instant barrel is in line for firing, movement being repeated on approach of every alternate barrel.

Patent 173,752 22 Feb 1876
Bailey, Fortune L. Indianapolis, Ind.
Improvement in machine guns.
Machine gun with barrels moving longitudinally in a revolving frame and governed in movements by fixed guide or cam so that each, when brought into proper alignment for firing, shall close back over a cartridge, brought into position by belt; after firing, belt moves forward with cartridge shell being left upon belt. Also series of pivoted spring-actuated hammers, 1 for each barrel, each cocked and released in turn for striking cartridge by means of fixed cam on inner face of casing covering hammers; also combination of cartridge holders with belt passing over a drum in breech of gun.

Patent 174,130 29 Feb 1876
Gardner, William Toledo, Ohio
Improvement in machine guns.
Relates to gun with any number of barrels, in sets of two. Operation of loading and firing carried on by means of mechanism put in motion by any convenient prime mover. Hopper feed with reciprocating feed plate slotted to feed cartridges alternately to chambers.

Patent 174,872 14 Mar 1876
Taylor, James P. Elizabethton, Tenn.
Improvement in machine guns.
Relates to gun in which a series of barrels are mounted either horizontally or in arc of a cylinder and discharged in succession by revolving cams or rotating spirally grooved cylinder. Fluted feed valves deliver cartridges from hopper to barrels and discharge the empty shell on return stroke.

Patent 174,873 14 Mar 1876
Taylor, James P. Elizabethton, Tenn.
Improvement in machine guns.
Machine gun with a set or series of barrels arranged in arc of a cylinder, in combination with a revolving cam-cylinder, constructed with 2 grooves, one for imparting longitudinal reciprocating movement to a series of plungers, and the other for retracting the firing pins carried by plungers (or sliding locks). Cartridges fed through a hopper consisting of a series of guiding grooves.

Patent 177,030 2 May 1876
Taylor, James P. Elizabethton, Tenn.
Improvement in machine guns.
Improvement in multi-barrel machine guns. New movement for operating sliding plungers by which cartridges are introduced into firing chambers and empty shells are discharged. Cartridges introduced from case or box to hopper by means of hinged hopper-cap.

Patent 179,450 4 Jul 1876
Farrington, DeWitt C. Lowell, Mass.
Improvement in machine guns.
Adjustable device for oscillating barrels of machine gun, by which range or sweep can be varied at will. Opening or mouth-piece of feed case reduced to correspond to size and form of cartridge, so that cartridge must leave case in a horizontal position.

Patent 181,093 15 Aug 1876
Miltimore, Alonzo E. U. S. Army
Improvement in battery-guns.
Combination, with a central gun of large caliber, of a series of smaller stationary guns. Uses revolving cartridge cylinder, constructed with cams or grooves, which cause lock to feed the cartridge in place in its appropriate gun barrel, explode same, withdraw and eject empty shell.

Patent 182,729 26 Sep 1876
Wilder, Elihu Manchester, N. H.
Improvement in machine guns.
Relates to battery gun where loaded cartridges are supplied from hopper and forced into breeches of separate barrels and fired from them by a rotary apparatus.

Patent 208,203 17 Sep 1878
Schultze, Frederick E. New York, N. Y.
Improvement in machine guns.
To construct mounted rifle-battery so as to deliver fire either in a right line or in horizontal radiating lines, at pleasure of operator. Barrels of different guns separated sufficiently to prevent them from being heated during firing. Fired successively, not simultaneously. 20,000 shots per hour from battery of 21 guns.

Patent 211,849 4 Feb 1879
Hotchkiss, Benjamin B. New York, N. Y.
Improvement in machine-guns.
Relates to multi-barrel guns rotated step by step, loaded with cartridges, discharged and extracted by crank action. (Improvements of Patent 130,501) Provides guns of this class with instrumentalities whereby they may be trained and fired while supported from shoulder of gunner. Mounted on universal pivot. Automatic change of elevation for each barrel discharged.

Patent 225,462 16 Mar 1880
Coloney, Myron St. Louis, Mo.
Machine gun.
Battery gun with horizontal range of barrels and a reciprocating breech slide containing 2 sets of chambers, chambers in each set corresponding in number with barrels, so that one is in position for loading when other is being fired. For magazine loading cartridges have peculiar construction, having a shoulder between ball and shell to limit insertion of cartridge from the front. Barrels automatically discharged in rapid succession by pulling trigger of first one.

Patent 245,710 16 Aug 1881
Gardner, William Hartford, Conn.
Machine gun.
Improvements on Patents 174,130 and 216,266. Mechanism adapted to guns which have a series of barrels. Slide employed to feed cartridges into barrels. Positive action of extractors. Improved sighting devices.

Patent 264,897 26 Sep 1882
Pederson, Sivert Menomonee, Wis.
Machine-gun.
Relates to cylinder guns. Consists of cylinder provided with ammunition chambers in its periphery and adapted to be revolved with means for loading and capping said chambers while cylinder is being revolved, and firing charges through series of barrels corresponding to any desired number of said chambers.

Patent 282,553 — 7 Aug 1883
McLean, James H. — St. Louis, Mo.
Machine gun.
Horizontal range of barrels, interposed magazines or hoppers, horizontally moving chambered breech slide. Cartridge shell provided with a serpentine groove to permit expansion in firing.

Patent 298,493 — 13 May 1884
Nordenfelt, Thorsten — Westminster, Eng.
Machine gun.
Simplification and improvement of "Nordenfelt gun"—having barrels arranged side by side in horizontal plane in fore part of a rectangular frame. Arrangements for fixing barrels in their places; arrangement of cocking mechanisms; other modifications.

Patent 303,879 — 19 Aug 1884
Nordenfelt, Thorsten — Westminster, Eng.
Machine-gun.
Improvement in machine guns. Barrels arranged side by side in frame with breech block behind them. Latter in 2 parts, fore part being stationary with trough-like cavities opposite breeches of barrels. Hind part has similar cavities and receives transverse movement to and fro. Cartridges supplied automatically from magazine or hopper into fore part of breech block. Plungers in hind part thrust them into barrels and fire them. Plungers have extractors to withdraw cases which fall through holes in recesses. Actuated by hand-lever.

Patent 311,551 — 3 Feb 1885
Whitney, James S. — Lowell, Mass.
Machine-gun.
Relates to means of so revolving barrels of battery machine gun that 1 barrel may be loaded, 1 fired and the discharged shell extracted from a 3rd barrel simultaneously, and that barrels, while firing, loading and extracting are taking place, shall be at rest and absolutely prevented from moving. Crank-operated.

Patent 340,725 — 27 Apr 1886
Nordenfelt, Thorsten — Westminster, Eng.
Machine-gun.
Improvements in guns in which barrels are arranged side by side in frame, fed with cartridges thrust forward by reciprocating plungers, then cases withdrawn. Uses divided action block, rear part of which moves laterally and carries hammers and lock mechanism. In invention fore part of action block is also movable laterally, called "cartridge-carrier". When plungers retire from recesses in this part, it makes lateral movement and places trough-like recesses beneath the chambers of magazine. Cartridges then fall in and carrier then returns and brings cartridges in line with barrels.

Patent 390,114 — 25 Sep 1888
Burton, Bethel — London, Eng.
Automatic machine gun.
Relates to guns having 2 or more barrels where recoil of exploded charge of one loads and fires the other, and vice versa; where more than one pair of barrels are used, each pair works independently of the other. Invention comprises: all movements of actions and barrels are positive; recoil of barrel automatically actuates other; use of any number of pairs of barrels; minimum heating of barrels, avoiding use of water jackets; regulation of recoil by means of valve; self-acting brace, which permits bolt and barrel to travel together, delays opening of breech; hopper and revolving feed, or pannier.

Patent 431,515 — 1 Jul 1890
Greer, John William — Austin, Tex.
Machine gun.
Relates to series or battery of guns and has for object operating of any one of the guns by recoil of another and in succession. Guns arranged at suitable intervals on periphery of rotatable wheel, recoil of each gun bringing into operative position and operate gun nearest muzzle; automatic mechanism and movable breech for feeding cartridges; automatic mechanism and balls released thereby for passing through guns and cleaning them.

Patent 458,268 — 25 Aug 1891
Cook, Thomas R. — Noblesville, Ind.
Machine gun.
Multi-barrel gun fed with revolving cartridge cylinders by means of a cam wheel. Sufficient supply of loaded cartridge cylinders kept on hand at all times to replace exhausted ones instantly.

Patent 476,590 — 7 Jun 1892
Archbold, Israel N. — Ridge Farm, Ill.
Machine-gun.
Improvements in revolving cannon or machine guns and loading devices therefor. Revolving integral breech block having flanges at its ends and an open annular groove between them, 1 or more barrels extending from one flange and a suitable firing mechanism in one flange, and a stationary shoe or pressure-plate within groove at point of firing, said groove adapted to receive ammunition and pass it under the shoe.

Patent 520,559 — 29 May 1894
Burgess, Andrew — Buffalo, N. Y.
Inertia-piece, releasing second barrel by recoil of first.
Double barrel in which 2nd barrel may be fired by shock of firing 1st barrel; also to render one cartridge feeder inactive when one barrel only is fired; also to lock breech mechanism in such manner that it may be unlocked by shock of firing; improved feeding mechanism.

Patent 563,701 — 7 Jul 1896
Wilder, Elihu — Cambridge, Mass.
Machine gun.
Improvements on Patent 182,729 (1876) wherein cartridges are supplied from hopper and forced directly into breech end of separate barrels and fired by needles operated by rotary apparatus. Improved extracting and ejecting means. Flexible adjustment of mount. Sweep through any angle desired.

Patent 636,974 — 14 Nov 1899
Garland, Frank M. — New Haven, Conn.
Automatic operating mechanism for machine-guns.
Relates to 2-barrel gun the firing of one of which loads and fires the other (Patent 623,003). In this modification loading of one barrel is accomplished by forward movement of the other barrel. Combines barrels, frames connected with barrels, breech-blocks movable backwardly with barrels, a catch for retaining each breech-block while corresponding barrel is moved forwardly, and a coupling moving with each barrel frame for drawing forwardly the breech-block of the opposite barrel.

Patent 674,811 — 21 May 1901
McAllister, Albert H. — New Albany, Miss.
Machine-gun.
One or more horizontal rows of normally parallel barrels, a plane firing-plate provided with corresponding rows of perforations to serve as cartridge chambers and arranged to advance step by step across rear ends of barrels to bring rows of chambers successively in alignment with barrels, means for loading, firing and ejecting cartridges.

Patent 861,467 — 30 Jul 1907
Jusselin, Leon — Moreauville, La.
Machine gun.
To provide cannon embodying numerous barrels adapted to be brought successively into operative alinement with suitable trigger mechanism. Includes element designed to lift the trigger of trigger mechanism and also serve as breech to hold cartridge against displacement incident to concussion of explosion.

Patent 1,090,124 — 10 Mar 1914
Caldwell, Thomas F. — Richmond, Australia
Quick-firing machine gun.
Consists of a body provided with 2 forwardly projecting barrels of like construction. Breech ends of barrels screw into blocks formed on front end of a stout body upon both sides of which are situated independent mechanisms for feeding and firing cartridges and for extracting and ejecting. Will operate barrels alternately or simultaneously.

Patent 1,277,307 — 27 Aug 1918
Gregg, Clarence — Pitt Bridge, Tex.
Machine gun.
Improved multi-barrel gun to permit simultaneous discharge of a plurality of cartridges, and project bullets to effectually sweep path of travel thereof. Novel magazine for feeding cartridges into breech portions of various barrels of gun, magazine being raised in step by step fashion and cartridges being carried to position in alinement with bores of barrels.

Patent 1,328,230 — 13 Jan 1920
Johnston, James S. — Utica, N. Y.
Machine gun.
Rapid fire machine gun that can be fired very rapidly without fouling or overheating. Provided with a plurality of revoluble barrels and with revoluble feeding drums which feed cartridges into position to be exploded by the firing pins and thence projected through the barrels as same come into alinement with cartridge receiving chambers of feeding drums.

Patent 1,386,872 — 9 Aug 1921
Hudson, Robert F. — Richmond, Va.
Machine-gun.
Improved multi-barrel gun. Provides means for positive delivery of cartridge to breech of barrel, retaining it in position during firing operation and removal from breech after firing, even if unexploded. Firing mechanisms preferably arranged in pairs using a plurality of barrels. "Snapped cartridge" removed from barrel as rapidly as exploded shell.

Patent 1,401,768 — 27 Dec 1921
Floricke, Albert E. — New York, N. Y.
Machine-gun.
Production of multiple machine guns capable of being fired simultaneously a plurality of times without reloading. Means for supplying revolving cartridge carriers to all of the several guns at one operation.

Patent 1,424,751 — 8 Aug 1922
Bangerter, Friedrich — New York, N. Y.
Automatic rapid-fire machine gun.
Multi-barreled machine gun continuously fired either by hand or automatically. Rotatable means for supporting series of barrels, traveling magazine comprising series of explosion chambers alining with barrels.

Patent 1,446,635 — 27 Feb 1923
Berthier, André V. P. M. — Neuilly-sur-Seine, France
Firearm.
Relates to automatic arms used on aircraft. In a multi-barrel explosion-operated machine gun, a plurality of independently operable operating mechanisms, a controlling handle for the gun, and unitary mechanical means apart from said handle for rendering said operating mechanisms jointly operative so positioned that it can be operated by hand grasping the controlling handle.

Patent 1,487,695 — 18 Mar 1924
Schneider, Eugene — Paris, France
Multibarrel gun.
Conjugation of barrels in pairs or in groups each containing an even number of barrels. Portion of energy due to the recoil of one barrel or group of barrels is utilized in a suitable recuperator for running-out the other barrel or group of barrels in the conjugation or vice versa. Maintains approximately constant position of the center of gravity of the whole of the movable parts of the gun during firing. Part of energy of recoil utilized for effecting automatic operation of breech mechanism, loading devices, and firing mechanism.

Patent 1,535,619 — 28 Apr 1925
Methlin, Nicolas E. — Paris, France
Multibarrel gun.
Improvement on Patent 1,487,695 (1924). Arrangement as a branch from the connecting duct between the two recuperator brakes, a hydraulic, hydro-pneumatic or other shock-absorber, which is also capable of assuring at all times a plenum of liquid in the two conjugated recuperator brakes, and in their connecting duct, so as to maintain constant conditions of the recoil and returning to battery position of the barrels.

Patent 2,410,848 — 12 Nov 1946
Waltke, Edwin H. — Los Angeles, Calif.
Multiple barrel machine gun. (Cl. 89–2)
Multi-barrel gas-operated machine gun especially adaptable as aircraft gun or a/a gun. Movement of breech block prevented should one or more of cartridges not be exploded. Gas from each barrel is made to operate its own piston and each piston connected with others so they can move only in unison.

Muzzle Attachments

Patent 525,151 — 28 Aug 1894
Mason, William — New Haven, Conn.
Gas-operated gun.
Consists in gas-deflector attached to forward end of gun-barrel and projecting beyond the same and adapted to deflect the gases issuing from mouth of barrel backward, a slide mounted on gun-barrel in position to be impinged on and moved rearward by gases deflected and an operating rod connected with said slide at its forward end and at rear end with feeding and firing mechanism of gun.

Patent 692,819 — 11 Feb 1902
Bissell, Joseph E. — Pittsburgh, Pa.
Means for effecting noiseless discharge of guns.
Arrangement whereby sudden expansion of gases at muzzle of gun is prevented, insuring noiseless discharge. Interposes movable piston between explosive and projectile which serves to prevent or retard escape of gases. Liquid, such as water, interposed between projectile and piston as non-compressible medium.

Patent 809,821 — 9 Jan 1906
Lauber, Otto — Essen, Ger.
Recoil gun.
Relates to recoil guns provided with means for securing the brake-cyclinder to the gun-barrel and for incasing the recuperator spring; object of invention being to provide improved means for introducing brake fluid into brake-cylinder.

Patent 812,326 — 13 Feb 1906
Browning, John M. — Ogden, Utah
Recoil-brake for automatic guns.
To adjust brake mechanism of an automatic gun to the character of the cartridge employed, so that the shock of recoil and the shock of return of barrel to firing position may both be adapted to conditions of use with different cartridges. Improvement on Patent 689,283 (1901).

Patent 870,497 — 5 Nov 1907
Dawson, Arthur T. and Ramsay, James
Westminster, Eng.
Muzzle attachment for automatic guns.
Apparatus for attaching to Maxim muzzle for enabling gases of discharge to actuate or assist in actuating breech mechanism. Overcomes fouling of barrel by providing abundant freedom for the escape of gases from gas space between disks and from sleeve. Sleeve made with large radial openings and little metal between contiguous openings.

Patent 880,386 — 25 Feb 1908
Maxim, Hiram P. — Hartford, Conn.
Silent firearm.
Means whereby emission of gases after ignition may be stopped and direction and amount of flow controlled or regulated as desired. Sliding valve mounted upon firearm arranged to receive pressure of the gases of the explosive to close the bore of firearm.

Patent 953,943 — 5 Apr 1910
Childress, George F. — Wills Point, Tex.
Gun-muffler.
Sound of discharge eliminated by means of a plurality of hollow apertured spheres arranged in a suitable casing fixed on end of the gun muzzle through which spheres and casing the bore of the gun is extended. Gases undergo whirling motion in each sphere before passing to next one thus reducing pressure and velocity.

Patent 956,717 — 3 May 1910
Moore, Robert A. — Chicago, Ill.
Silencer for firearms.
Device which not only prevents discharge from being audible but of such construction that gases of explosion shall be caused to sweep through and out of device in such a manner that device shall be kept both clean and cool.

Patent 958,934 — 24 May 1910
Maxim, Hiram P. — Hartford, Conn.
Silent firearm.
Improvement in silencers such as in Patent 916,885 (1909). Prevents escape of small pencil or core of gas resulting from small angle of divergence of gases as they pass through silencing device. Means provided for deflecting these gases which follow the projectile. Further promotes rotary or whirling movement of gases and enables device to be applied even to a sporting rifle without disturbing front sight.

Patent 958,935 — 24 May 1910
Maxim, Hiram P. — Hartford, Conn.
Silent firearm.
Improved silencer capable of withstanding impact of gases while minimum of weight is secured. Accurate alignment of opening through successive diaphragms for passage of projectile.

Patent 959,400 — 24 May 1910
Stinson, James H. — Cooke, Mont.
Gun-muffler.
Means to arrest forward movement of escaping powder gases and give the same a backward curling motion at successive points, whereby they escape gradually and produce a but slightly audible sound. Casing attached to muzzle having therein a series of dished disks or heads, arranged in spaced relation with concave sides facing rearwardly and a sectional barrel forming a continuation of rifle barrel.

Patent 984,750 — 21 Feb 1911
Craven, Harry — Pittsfield, Ill.
Gun silencer.
Muzzle provided with a valve which is supported upon a spring and which normally closes muzzle of gun, spring being so arranged that as projectile passes out, spring will be raised, lifting valve and permitting escape of projectile, then closing valve. Gas thus confined within barrel. Plurality of perforations permits gradual escape of gas.

Patent 1,000,702 — 15 Aug 1911
Thurler, Eugene — Fribourg, Switzerland
Device for the suppression of the report of firearms.
Uses expansion chambers having shape of conical sleeves which are mounted in a casing the rear end of which is perforated or formed of wire gauze for ⅔ of its length. Inner casing is further inclosed in one or more mantles which are alternately perforated at front or rear end. Gases are thus quickly deviated from trajectory of projectile.

Patent 1,017,003 — 13 Feb 1912
Kenney, Charles H. — New London, Conn.
Silencer for firearms.
Comprises a ring having a tapered opening and openings leading therefrom, a plurality of disks forward of such ring each having a plurality of openings near the periphery extending in a line parallel with the bore of the arm. and an expansion chamber in front of said disks having a central bore and concentric openings.

Patent 1,018,720 — 27 Feb 1912
Maxim, Hiram P. — Hartford, Conn.
Silencing device for firearms.
Improvement on Patent 880,386 (1908). Safety device to prevent firing of gun whenever bore is obstructed in any way by silencer. Provided by interconnection between silencing device and some part of operating mechanism. Device for

checking movement of silencing device without parts being battered to pieces. Provision of other features to meet various conditions arising during operation.

Patent 1,021,742 26 Mar 1912
Moore, Robert A. New York, N. Y.
Silencer for firearms.
Utilizes principle of the mechanical cutting off of passage of gases to the open air to the extent merely of employing a peculiar baffle which operated on gases in such a way as to cause a certain proportion of same to be deflected across projectile path or opening and thus form gaseous barrier to temporarily prevent any of remaining gases from issuing into atmosphere by direct movement through projectile opening. Casing divided into a plurality of chambers with longitudinally removable tubular baffle.

Patent 1,066,898 8 Jul 1913
Gray, Willis R. Oakton, Va.
Silencer for firearms.
Causes gradual release of exploded gases at or beyond muzzle. Gases diverted into suitable number of expansion chambers wherein gases are gradually reduced in pressure.

Patent 1,080,154 2 Dec 1913
Moore, Herbert P. Norwalk, Ohio
Silencer for firearms.
Spring plunger within expansion chamber that recedes under pressure of explosion gases while projectile is passing out of silencer and that operates to push gases out of silencer following projectile. Device also serves as recoil absorber and eliminates kick usually accompanying firing of gun.

Patent 1,111,202 22 Sep 1914
Westfall, Walter E. Maryville, Mo.
Silencer construction for firearms.
Constructed so as not to obstruct line of vision between sights. Tubular silencer casing telescoping with gun barrel and spaced therefrom to form an annular chamber and yielding check means arranged in said casing to deflect exhaust gases into chamber.

Patent 1,140,578 25 May 1915
Coulombe, Joseph C. Northfield, Vt.
Noiseless gun.
Muffling device where expanding gases are allowed to exhaust, to the air, through more or less confined media, such as tubes of pipes or a gun barrel. Muffles or reduces noise of explosion, without interfering with passage of projectile. Reduces recoil orinarily caused by explosion so the accuracy and economy of firing are increased.

Patent 1,143,814 22 Jun 1915
De Vries, Peter J. Sheldon, Iowa
Gun muffler.
An elongated shell having at one end means for securing it on end of barrel and at other end an outlet for bullet, with rearward sleeve around said outlet extending some distance into the shell, said shell also having laterally disposed spiral ducts for escape of the powder gas.

Patent 1,155,061 28 Sep 1915
Heinemann, August A. K. Berlin, Ger.
Machine gun.
Muzzle attachment adapted during firing a shot to be acted upon in downward direction by the driving gases leaving the muzzle in order to steady the latter. Counteracts bucking of muzzle. Forms a baffle device for the propelling gases underneath the muzzle.

Patent 1,171,742 8 Feb 1916
Prather, Andrew T. Rodeo, N. Mex.
Attaching means for gun-silencers.
Silencer secured to muzzle in a manner that will direct all explosive gases through silencer thereby preventing any escape of gases rearwardly between fastening means and barrel.

Patent 1,207,264 5 Dec 1916
Bailey, Oliver J. Florence, Mass.
Silencer for firearms.
Structure adapted to be releasably mounted on muzzle of a firearm and adapted to diminish explosion regardless of impact of gases as they escape from barrel of firearm. Plurality of diaphragms designed to divert gases from the trajectory so they may expand and be ejected from rear of casing in which explosion occurs. Provides ejecting tube designed to break up the hot gases as they pass through the tube.

Patent 1,229,675 12 Jun 1917
Thompson, Eugene W. New London, Conn.
Gun-silencer and recoil-reducer.
Improved silencer with series of air chambers and perforations for permitting escape of gases slowly through said chambers and perforations. At same time recoil is reduced owing to the chambers terminating near or adjacent where projectile leaves the shell.

Patent 1,242,843 9 Oct 1917
Northover, Harry R. Winnipeg, Canada
Flash-absorber attachment for machine guns.
Improved flash-absorbing device, which when attached to muzzle of barrel, not only conceals flash or flame of discharge, but also serves to muffle or deaden the report. Does not affect working of gun or rate of fire.

Patent 1,445,583 13 Feb 1923
Green, Samuel G. U. S. Army
Attachment for gas-operated guns.
Improved means for securing a muzzle block of reduced caliber against the muzzle end of a barrel to effect choke of discharge gas and thereby cause automatic operation of gun when firing blank ammunition. Improved means for securing an auxiliary barrel within a main barrel to permit firing of subcaliber and shot ammunition.

Patent 1,446,388 20 Feb 1923
Ludorf, Ernst Bern, Switzerland.
Machine gun.
Means to damp the recoil in such a manner that initial speed of projectiles leaving muzzle is same in vertical or horizontal position of gun. Fluid brake of improved light and compact design. Means to feed projectiles positively into gun.

Patent 1,462,158 17 Jul 1923
Wildner, Franz Buschullersdorf, Czechoslovakia
Silencer for firearms.
Improved silencer which deadens sound and renders fire and smoke invisible. Perforated external tube with closed ends and having shorter internal perforated tube with closed front end therein and coil spring intervening between front ends of tubes. Fixed on barrel muzzle.

Patent 1,469,918 9 Oct 1923
De Maine, Ernest M. Alexandria, Va.
Recoil-controlling device.
Means whereby the rapidly expanding gases of the exploded ammunition charge are utilized to coact with provided instrumentalities to exert a pressure upon the gun in a direc-

tion opposite to the direction of recoil. To create a gas pressure exterior of the gun body to counteract the pressure of the exploding charge within the gun barrel.

Patent 1,482,805 — 5 Feb 1924
Maxim, Hiram P. — Hartford, Conn.
Silencer for guns.
Improved silencer of increased effectiveness in checking powder gases and causing them to discharge gradually into atmosphere without noise. Baffle member comprises sheet metal disc provided with a cylindrical peripheral flange and centrally apertured with opposite edges offset in opposite direction.

Patent 1,525,846 — 10 Feb 1925
Wurtzebach, Lorenz E. — Lead, S. D.
Silencing device for firearms.
Silencer adapted for use in connection with rifles and not to interfere with aiming operation or balance of rifle. Cylindrical casing secured to muzzle and provided with a longitudinally movable core therein.

Patent 1,538,243 — 19 May 1925
Gorton, Walter T. — U. S. Army
Combined barrel support and flash hider for guns.
Provides a structure which will act as a support for the muzzle end of the gun barrel and increase the recoil of the barrel and also serve as a flash hider which will direct the escaping gases forwardly and prevent lateral divergence thereof.

Patent 1,557,820 — 20 Oct 1925
Fletcher, Wallace R. — Dayton, Ohio
Blast tube for machine guns.
Tube to convey blast or flash from the muzzle of the gun forward through any section or past any material or equipment which it is necessary to protect against fire or blast effect. Applied to Vickers gun.

Patent 2,101,063 — 7 Dec 1937
Green, Samuel G. — Gray, Ga.
Muzzle attachment for guns. (Cl. 89–14)
Adapter mounted on gun barrel and carrying sleeve and attachment which conducts the explosion gases to atmosphere and serves to check recoil, silence the report and eliminate smoke and flash.

Patent 2,101,848 — 14 Dec 1937
Green, Samuel G. — Gray, Ga.
Stabilizer for guns. (Cl. 89 14)
Stabilizer having novel mounting serving to conduct heat from muzzle of gun barrel. Serves to check recoil, silence report, eliminate flash and blast.

Patent 2,101,849 — 14 Dec 1937
Green, Samuel G. — Gray, Ga.
Muzzle attachment for guns. (Cl. 89–14)
Provides gas receiving casing having a simple arrangement for cooling the gases before their discharge into the atmosphere.

Patent 2,128,936 — 6 Sep 1938
Green, Samuel G. — Gray, Ga.
Muzzle attachment for guns. (Cl. 89–14)
Attachment to check recoil, silence report, eliminate smoke, and reduce flash. Provides a gas-receiving casing with a water jacket which may be conveniently in fluid communication with the main water jacket of the gun.

Patent 2,150,161 — 14 Mar 1939
Green, Samuel G. — Gray, Ga.
Muzzle attachment for guns. (Cl. 89–14)
Inexpensive attachment which may be readily disassembled for cleaning and replacement and will reduce the pressure progressively so as to eliminate a blasting effect.

Patent 2,184,595 — 26 Dec 1939
Hughes, Robert H. S. — Baltimore, Md.
Recoil control of firearms. (Cl. 89–14)
Device for minimizing recoil in guns adapted to fire projectiles. Comprises a metal body having a gas chamber therein and having a cylindrical bore adapted to receive muzzle end of barrel. Device has seal port at forward end of chamber and an internal shoulder to close forward part of chamber against lateral escape of gases.

Patent 2,218,877 — 22 Oct 1940
Ernesti, Walter and Herlach, Heinrich — Berlin, Ger.
Gun which fires during forward movement of the gun. (Cl. 89–27)
Mounted so as to be capable of moving longitudinally as a whole on carriage and for firing during forward or running out movement—in order to reduce the recoil force of guns. Firing lever is arranged bodily movable against the action of a resilient loading member in the direction in which it is moved to effect firing by the cam plate on carriage. Spring serves to hold lever in position of rest. Permits firing of different kinds of ammo. regardless of varying recoil forces.

Patent 2,229,390 — 21 Jan 1941
Roemer, William C. — New Haven, Conn.
Braking device for automatic firearms. (Cl. 42–75)
Braking device to permit use of shells having both heavy and light loads without causing jamming, etc. Has progressive increase in braking effect from minimum to maximum during recoil movement of the barrel member of such firearms.

Patent 2,291,867 — 4 Aug 1942
Birkigt, Marc — Bois-Colombes, France
Firearm of the recoiling type. (Cl. 89–37.5)
Relates to recoil-operated aircraft cannon. Includes muzzle brake, in addition to recoil absorbing means, the action of the brake capable of balancing at least approximately the residual live force of said movable parts existing when barrel is nearing end of its recoil stroke. Also braking means, preferably pneumatic, for slowing down the movement of the barrel at end of its return stroke.

Patent 2,315,207 — 30 Mar 1943
Janecek, Frantisek — Prague-Nusle, Czechoslovakia
Firearm. (Cl. 42–76)
An attachment fixed to the muzzle of the barrel and constructed so that a projectile of large caliber is altered to a ballistically more advantageous projectile of smaller caliber. Contains knives so fixed that they cut the rotating bands so they will be thrown off by centrifugal force and leave a smooth surfaced projectile with better ballistic characteristics.

Patent 2,339,777 — 25 Jan 1944
Green, Samuel G. — Gray, Ga.
Flash hider. (Cl. 89–14)
Means for effectively hiding from gunner the lateral flash from barrel and for improving the hiding from the enemy of the lateral flash. Tubular member surrounds muzzle portion of barrel and extending beyond muzzle. Flared mouth for cooling gases by expansion. Gases escape through a series of ports spaced peripherally about the member.

Patent 2,351,037 13 Jun 1944
Green, Samuel G. Gray, Ga.
Stabilizer for guns. (Cl. 89-14)
Muzzle attachment for checking recoil, silencing report, eliminating flash and smoke. Stabilizer in which velocity component of gases is reduced at a more rapid rate than pressure component so that energy values are about equal when gases are discharged into atmosphere.

Patent 2,375,617 8 May 1945
Bourne, Roland B. W. Hartford, Conn.
Gun silencer. (Cl. 181-47)
Provides gas discharge delaying means by giving the gases a more vigorous whirl and of longer duration than previous devices.

Patent 2,402,632 25 Jun 1946
Ivanovic, Nicholas Philadelphia, Pa.
Blast deflector and gun installation. (Cl. 89-14.1)
Blast deflector so mounted as to minimize drag on the airfoil. Incorporates means for sealing gun gases from the gun mechanism and allows for more efficient cooling.

Power-Driven Guns

Patent 430,206 17 Jun 1890
Garland, Frank M. New Haven, Conn.
Machine-gun.
Positive-feeding automatic magazine gun having stationary barrels, in which operations of loading and firing are automatically performed without clogging mechanism with stuck shell and to arrange mechanism to prevent it becoming foul from firing and so that balls have as great velocity whether fired rapidly or slowly; feeds and explodes cartridges, the shells of which need not be extracted. 2 barrels; crank operated.

Patent 502,185 25 Jul 1893
Gatling, Richard J. Hartford, Conn.
Machine gun.
Provision of Gatling gun which can be readily changed so as to be fired with great rapidity either by hand or by power. Power furnished by electric motor. Comprises a revolving shaft, an armature, a group of barrels and a mortised cylinder holding reciprocal locks, a casing inclosing a field magnet adjacent to armature and a cylindrical cam in the path of the locks.

Patent 1,216,938 20 Feb 1917
Brotherston, Alexander M. Moncton, N. B., Can.
Machine gun.
Consists of a barrel breech and a support, to which are applied an electric motor operated by current derived from a storage battery carried on the gun. Motor is connected to mechanism in such a manner that it will simultaneously operate a cartridge carrier and breech mechanism and if desired an oscillating device so gun will swing steadily back and forth through a given angle, thus maintaining a fan-shaped zone of fire.

Patent 1,352,319 7 Sep 1920
Smith, David J., Jr. Washington, D. C.
Motor-operated gun.
To provide on airplane a plurality of guns mounted for revolution in a horizontal plane and mechanism whereby guns will be fired automatically as guns revolve within control of gunner or aviator. Means whereby power may be transmitted from aircraft engine for rotating and actuating guns.

Rate Control

Patent 669,236 5 Mar 1901
Garland, Frank M. New Haven, Conn.
Automatic machine-gun.
Relates to machine guns in which mechanism is actuated by recoil of barrel. Includes variable means for regulating and controlling speed of movement thereof, so that cartridge may be pushed home and the gun loaded at any desired speed. Barrel is mounted in a case and connected with a piston which is movable within a fluid chamber, the flow of fluid therein being controlled so that barrel will recoil at a predetermined speed.

Patent 783,770 28 Feb 1905
Young, Franklin K., Boston, Mass., and Sheriff, James E., Brooklyn, N. Y.
Firearm.
Mechanism by which gun can be made semi- or full-automatic, as desired. After explosion rearward movement of a secondary bolt carrying the firing pin unlocks the bolt. It travels a certain distance before unlocking bolt to give time for projectile to move some distance before bolt is unlocked. Mechanism for locking bolt after each forward movement.

Patent 854,557 21 May 1907
Benét, Laurence V. and Mercié, Henri A. Paris, France
Firing gear.
Apparatus by which gas operated gun is caused to fire continuously and automatically or automatically in single shots, under absolute control of operator. A detent cooperating with piston of breech mechanism is placed under control of a trigger pulled by hand, and a device operated from exterior permits either single shot or automatic fire.

Patent 905,071 24 Nov 1908
Heinemann, Karl Berlin, Ger.
Trigger mechanism of machine guns.
Device for regulating number of shots fired in unit time by a machine gun, while shooting is in progress, e. g., if constructed to 400 rpm, it can be regulated to fire only 200 rpm. Movable trip combined with firing mechanism, said trip being actuated by forward movement of parts subject to recoil, and a delay action device arranged to retard movement of the trip to reduce the normal speed of firing.

Patent 926,052 22 Jun 1909
Dawson, Arthur T. and Buckham, George T. London, Eng.
Automatic gun.
Relates to change fire mechanism of Maxim rifle caliber type guns. Firing mechanism comprises trigger lever to which is hinged a trigger pawl so arranged with respect to a tripping piece that by setting latter into one of several positions by means of an external indicator, can be fired single shot or automatic or set at safety.

Patent 1,308,016 24 Jun 1919
Clark, William R. Seattle, Wash.
Gas-operated gun.
Devices for regulating effective pressure of gases so as to vary speed of gun mechanisms in continuous firing. Provides improved breech locking and releasing appliances. Means to prevent barrel from becoming unduly heated, by longitudinal air-cooling passages.

Patent 1,318,214 — 7 Oct 1919
Logan, Humphrey T. — London, Eng.
Machine gun and the like.
Means whereby rate of automatic firing can be reduced or varied from the maximum downward to any desired extent while yet maintaining automatic action. Relates to guns with reciprocating member, such as Lewis. Uses dashpot device for retarding rate of fire, combined with "piston rod" means for automatically locking latter back when hand trigger is still in the firing position.

Patent 1,411,473 — 4 Apr 1922
Brauning, Karl A. — Herstal, Belgium
Automatic firearm.
Device by means of which it is possible to perform with an automatic firearm a semi-automatic fire, in which several operations are performed by hand, in order to diminish rapidity of fire without imposing on shooter fatiguing efforts. Device locks recoil spring in such a position that it acts no more upon movements of the bolt except as a buffer.

Patent 1,464,276 — 7 Aug 1923
Vinçon, Gustavo — Turin, Italy
Automatic firearm.
Pneumatic retarding device for automatic firearms by the aid of which speed of firing can be varied within wide limits. Characterized by a gripper for holding striker pivoted to a piston working in a cylinder the base of which has ports in it which regulate admission of air to chamber of cylinder during suction stroke of piston.

Patent 1,511,262 — 14 Oct 1924
Browning, John M. — Ogden, Utah
Automatic firearm.
Means for retarding rate of firing by preventing return of firing mechanism to battery after recoil until after a desired lapse of time. Applied to machine rifle (Patent 1,293,022). Retarding mechanism insures that firing mechanism shall be cocked on recoil thereof and not released until retarding mechanism is moved to inoperative position as regulated by ratchet pawl and escapement wheel.

Patent 1,532,305 — 7 Apr 1925
Darne, Regis — St. Etienne, France
Device for regulating the rate of fire in automatic firearms.
Device for altering rate of fire without altering admission of gas or the mass of the moving parts. Comprises fixed casing, a member having a reciprocating movement in said casing during actuation of firearm, spindle rotatably mounted in casing, and an arm fixed to spindle so as to rock therewith.

Patent 1,741,432 — 31 Dec 1929
Pfeiffer, Christian — Hartford, Conn.
Speed regulator for machine guns.
Regulator adapted to form a permanent part of the firearm. Provision made to change effective length of regulating lever to vary the retarding effect. Same brake serving to absorb recoil of barrel and barrel extension also used to effect retarding of breech bolt.

Patent 1,741,534 — 31 Dec 1929
Pfeiffer, Christian — Hartford, Conn.
Speed regulator for machine guns.
Regulating device similar in purpose to that in Patent 1,741,432 (1929). Adapted to be readily attached to or removed from gun without necessitating any major changes in structure of gun itself.

Patent 1,749,137 — 4 Mar 1930
Hudson, Robert F. — Richmond, Va.
Machine gun.
Provision of gun which may be operated as a single shot mechanically operated gun or automatically for intermittent or continuous fire. Gas and spring actuated means employed to operate breech block. Provision of adjustable means to regulate at will the speed of operation. May be made in various sizes without changing general construction.

Patent 1,771,132 — 22 Jul 1930
Mascarucci, Giuseppe — Turin, Italy
Device for reducing the rate of fire of automatic firearms.
Escapement wheel is provided with a diametral controlling cam disposed upon path of a recoiling part of mechanism so as to be struck eccentrically by recoiling part during its travel, for purpose of producing a partial rotation of wheel. Oscillating anchor actuated by wheel determines by inertia a braking action upon movement of recoiling part.

Patent 1,803,946 — 5 May 1931
Revelli, Bethel A. — Turin, Italy
Automatic firearm actuated by compressed air.
Simplified construction while obtaining a regular action and greatly reduced recoil and firing speed which can be reduced at will down to a few rounds per minute. Breech acts as compression cylinder and obturator acts as a piston compressor, discharge value and admission valve for air thus allowing different pressures to be obtained.

Patent 2,342,824 — 29 Feb 1944
Swebilius, Carl G. — Hamden, Conn.
Self-loading repeating firearm. (Cl. 42–3)
Gas-operated repeating firearm, capable of firing selectively or continuously. Single manual control member for safe, semi-automatic and full automatic. Safety automatically restored to operation when breech bolt is manually drawn back.

Patent 2,376,726 — 22 May 1945
Rossmanith, Wolfgang. — Solothurn, Switz.
Automatic shoulder firearm adapted to be used in a carriage. (Cl. 89–27)
Firearm may be used selectively as semi-automatic firearm upon firing from shoulder or fully automatic mounted in a carriage. Arrangement for adjusting trigger mechanism of firearm to single or continuous firing.

Patent 2,384,854 — 18 Sep 1945
Simpson, Clarence E. — Springfield, Mass.
Firing rate reducer. (Cl. 89–27)
Firing rate reducing mechanism in automatic firearms so as to permit extended automatic firing without excessive heating. Entirely contained within trigger guard group of firearm. Accomplished by a method involving 3 distinct stops of moving bolt parts during breech opening and closing part of operation cycle.

Patent 2,409,251 — 15 Oct 1946
Cantley, Joseph C., Beverly, and Pym, Arthur F.
Topsfield, Mass.
Automatic firearm. (Cl. 89–3)
Mechanism for insuring approximately constant rate of fire in automatic guns. Power-driven member having a substantially uniform velocity-curve, a member operative in response to recoil and counter-recoil movement of parts of the gun, resistor unit, for opposing recoil and counter-recoil movement of said parts, a valve for controlling flow

of fluid in said housing and mechanism for controlling valve to cause velocity curve of gun-operated member to approximate curve of power-driven member.

Patent 2,451,624 — 19 Oct 1948
Loomis, Crawford C. and Lowe, Kenneth J. Ilion, N. Y.
Inertia rate of fire retarders. (Cl. 89-130)
Relates to automatically loading firearms. To modify time-displacement characteristics of automatically operating parts in manner to improve certainty of firing. Operating cycle provided that insures that cartridges will have adequate period of time in which to feed to loading position. Provides spring mounted inertia weight which resists any force tending to disturb its condition of motion.

Patent 2,461,670 — 15 Feb 1949
Williams, David M. New Haven, Conn.
Automatic sear-releasing mechanism for firearms. (Cl. 89-140)
Self-loading firearm which may be utilized for full or semi-automatic firing. Rate of fire may be kept at relatively low rate or rapid.

Recoil Operation

Patent 317,161 — 5 May 1885
Maxim, Hiram S. London, Eng.
Machine-gun.
(Improvement on Patent 321,513)
Improvements in mechanism for effecting operations of feeding, firing, extracting and ejecting shells. Cartridges fed by uniformly and intermittently moving belt. Explosion of cartridge automatically performs all operations.

Patent 321,513 — 7 Jul 1885
Maxim, Hiram S. London, Eng.
Machine-gun.
To produce a gun which shall be entirely automatic in its action and continue, when once set into operation, to discharge at predetermined intervals so long as it has a supply of cartridges. Operation dependent upon recoil or force of the explosion of the cartridges. Barrel moves on stationary frame following explosion of a cartridge. Device feeds loaded cartridge and mechanism for placing cartridges in barrel, exploding same and extracting and ejecting empty shells by force of recoil. (Basic Maxim patent)

Patent 429,819 — 10 Jun 1890
Skoda, Emil Ritter v. Pilsen, A.-H.
Automatic quick-firing gun.
Combination, with the gun, of a support in which said gun is movable longitudinally and with which the gun is adapted to revolve on horizontal journals, of a power-accumulator for accumulating power exerted by recoil of gun, and of mechanism for operating breech-block either by power of the recoil or by accumulated power due to such recoil; also devices for automatically controlling and operating firing mechanism by said power, etc.

Patent 430,210 — 17 Jun 1890
Maxim, Hiram S. London, Eng.
Automatic gun.
Improvements in firearms by which action or operation is rendered automatic. Rotation of crank shaft automatically effected by recoil of gun. 2 variant sear devices. Feed system consists in feed wheel operating in combination with belt containing cartridges. Empty shells extracted, then carried around by feedwheel until they fall through openings in frame. Device for regulating speed of firing. Baffle plates for arresting smoke and pipe for conducting it away from chamber.

Patent 430,211 — 17 Jun 1890
Maxim, Hiram S. London, Eng.
Automatic machine-gun.
Improvement in Maxim guns based on recoil energy. Applicable to various weapons, from sporting arms to heavy guns. When breech is closed, breech-block is securely locked to barrel until movable parts have terminated recoil movement, and then automatically disengaged from said barrel. Backward and subsequent forward movement of barrel effects extraction of shell; forward movement of breech block effects insertion and discharge of fresh cartridge. Cartridge feed device presents cartridges in position to be thrust in breech. Plurality of barrels and breech mechanisms combined for operating independently or simultaneously or successively.

Patent 436,899 — 23 Sep 1890
Maxim, Hiram S. London, Eng.
Automatic gun.
Mechanism for effecting operation of Maxim recoil operated guns. Arrangement of hydraulic or hydropneumatic cylinders and pistons by which energy of the recoil of barrel is stored and rendered available for returning barrel to original or firing position, by which also force of forward or return movement of barrel is utilized to continue backward movement of breech-block after it is unlocked from barrel, and energy of said movement is stored and rendered available to return breech block to normal and forward position. Also improved feeding mechanism.

Patent 447,836 — 10 Mar 1891
Maxim, Hiram S. London, Eng.
Automatic gun.
Adapts improvements of recoil automatic operation to short guns and pistols. Combination of outer frame, stock to which it is secured, a barrel and inner frame fixed on barrel and arranged to slide in outer frame, breech block adapted to slide in inner frame and springs placed in stock for returning breech block and barrel after recoil. Breech mechanism operated by recoil of barrel to reload same after discharge. Hammer cocked by movement of breech mechanism; and trigger engaging therewith to prevent automatic discharge of gun. Tubular magazine attached to barrel.

Patent 447,837 — 10 Mar 1891
Maxim, Hiram S. London, Eng.
Automatic machine gun.
Application of Maxim recoil principles to operate heavier types of guns of an automatic means. Breech block is shortened to save space and lighten gun because of longer and heavier shells. Vertical hopper and feeder beneath which frame slides so that when breech is closed, cartridge drops into frame.

Patent 448,841 — 24 Mar 1891
Skoda, Emil Ritter von Pilsen, A.-H.
Quick firing gun.
Combination with barrel and breech mechanism of a power accumulator connected with this device and adapted to store the power of recoil and give same up for purpose of returning gun into normal position, introducing a charge into said gun, firing mechanism and means for cooling gun.

Patent 453,702 9 Jun 1891
Maxim, Hiram S. London, Eng.
Automatic breech-loading gun.
Main distinguishing feature of recoil-operated gun in this patent is a transversely-movable breech-block, moved by action of explosion of cartridge in a direction transverse to axis of barrel to open and close breech. Permits breech to be kept closed for longer period after explosion than other types of guns, so there will be no escape of gas during or after extraction. Combines with fixed support and longitudinally moving barrel breech block movable at right angles to axis of barrel, breech mechanism connected therewith and carried by barrel and fixed stop engaging with mechanism on forward movement of same after recoil.

Patent 454,374 16 Jun 1891
Nordenfelt, Thorsten Westminster, Eng.
Gun.
Combination of gun, the breech-block locked in the breech of the gun during recoil, and means for automatically rotating breech-block to unlock and withdraw it from breech opening by forward movement of gun and for moving breech-block laterally away from breech opening. Mechanism also capable of being operated by hand.

Patent 454,993 30 Jun 1891
Catlin, Robert M. Tuscarora, Nev.
Recoil-operated magazine-gun.
Relates to magazine gun in which energy of recoil of gun when fired is utilized to extract shell, introduce new cartridge and cock hammer. Barrel mortised vertically at breech with magazine beneath barrel with carrier at rear end to transfer cartridges into position to be introduced into barrel and at same time effect empty shell. Barrel has limited longitudinal movement with relation to stock, with spring at rear end of barrel which is compressed by force of recoil and operates to prepare weapon for next discharge. Trigger mechanism permits successive firing automatically.

Patent 468,127 2 Feb 1892
Bergman, Oscar W. Gothenburg, Sweden
Breech-loading fire-arm.
Machine gun or other breech loading arm adapted to be operated either by hand or by recoil. Combination of block pivoted to the shell of gun and provided on its side with a cam-groove, a pin on said block being loosely pivoted and adapted to reciprocate in direction of its length, a longitudinally reciprocating carrier, and a stud secured to carrier and adapted to reciprocate in said cam-groove.

Patent 472,377 5 Apr 1892
Mallen, Rafael Mexico City, Mex.
Recoil-operated magazine-gun.
In a magazine fire-arm, a locking brace provided with a hammer and secured on a shaft in stock so as to turn with said shaft, in combination with operating lever, also secured to shaft, and a sliding breech-piece provided with arms pivoted to and connecting said brace and breech-piece whereby when brace and arms are forced down by lever, sliding piece is forced back to uncover firing-chamber. Loading follows and pull of trigger sets action again in motion.

Patent 519,151 1 May 1894
Darche, Paul Paris, France
Recoil-operated firearm.
Combination of a receiver, movable barrel, cartridge magazine under barrel and spring coiled around magazine and adapted to be tensioned by backward movement of barrel during recoil, to return barrel, with a movable breech block, a 2nd spring bearing at one end against receiver and at other end against movable breech-block and adapted to be tensioned by recoil of movable block to return said breech-block, and means for temporarily retaining breech block after barrel has returned, whereby breech is opened.

Patent 520,752 29 May 1894
Burgess, Andrew Owego, N. Y.
Recoil-operated firearm.
Support or non-recoil portion, barrel and connections constituting recoil portion, breech piece and a lever connected to breech piece actuated by recoil portion to open breech by the direct recoil movement. Also improved magazine feed and other arrangements.

Patent 520,753 29 May 1894
Burgess, Andrew Owego, N. Y.
Recoil-operated magazine-gun.
To produce fire-arm which shall operate easily and rapidly and may load by recoil action; also to improve loading and feeding devices of magazine fire arms. Unlocking of recoil portion from non-recoil portion of gun is effected by 1st backward movement of shell in chamber of gun on firing and is not dependent on recoil of main part of gun.

Patent 547,454 8 Oct 1895
Schmeisser, Louis Mannheim, Ger.
Recoil-operated firearm.
Relates to a firearm in which closing of breech, loading and cocking of hammer is effected by the gas pressure resulting from the explosion. Operates on principle of the power of resistance of bodies. Counterpressure opposed to gases in front of cartridge is considerably less than that opposed at rear. Thus backward motion is slower and final recoil is reduced to a minimum.

Patent 551,779 24 Dec 1895
Maxim, Hiram S., Bexley, Eng., and Silverman, Louis, Crayford, Eng.
Automatic machine gun.
Improvement in "Maxim" guns of that class where breech mechanism is operated by means of a crank which is turned in one direction by force of recoil and in other direction by reaction of a spring. Consists in improved arrangement of spring and connection of same with crank. Also improved feed and extracting mechanism to avoid obstruction to action by an empty cartridge case after extraction.

Patent 557,359 31 Mar 1896
Burgess, Andrew Buffalo, N. Y.
Automatic magazine-firearm.
Connects reciprocating barrel or breech-piece to a movable recoil receiving piece or butt-plate, which operates through recoil to open breech; also devices for locking breech part and barrel part together and unlocking them; devices for cocking hammer and feeding cartridges and means for loading magazine.

Patent 557,360 31 Mar 1896
Burgess, Andrew Buffalo, N. Y.
Magazine firearm.
Various improvements in cartridge-feeder and connecting parts, coupling of handle to breech mechanism, construction and attachment of fore-arm and its tip to barrel and magazine, coupling barrel to and releasing it from frame, construction of carrier and its spring, and the recoil or "shock" unlocking mechanism. In breech-loading and magazine firearms.

Patent 571,260 10 Nov 1896
Borchardt, Hugo Berlin, Ger.
Recoil magazine-pistol.
To provide repeating firearm, furnished with a magazine containing a number of cartridges and inclosed in butt, which by recoil of fired cartridge opens the breech, extracts and ejects, cocks firing-pin, shoves cartridge into barrel and closes barrel. Recoil used directly for opening breech against momentum of parts and balanced so hand holding arm feels no shock. Springs compressed by recoil react to push forward bolt and cartridge until latter is driven into barrel. Butt stands out at right angles to direction of barrel at under side.

Patent 580,924 20 Apr 1897
Browning, John M. Ogden, Utah
Firearm.
Relates to automatic breech-loading firearms in which the several operations are automatically effected by or through energy of recoil of breech block or bolt carrier. Improved means to prevent release of hammer until breech is fully closed; or after single discharge until trigger has been released. Breech block or bolt carrier automatically locked in closed position. Barrel is caused to have double movement to attain these objects.

Patent 584,153 8 Jun 1897
Carr, Howard San Francisco, Calif.
Recoil-operated firearm.
Improved magazine gun having longitudinally movable barrel and employing in breech movement a pair of links connecting breech-bolt and barrel, so that bolt moves with barrel during recoil movement of latter, while on return movement of barrel links are actuated to retract bolt and open breech, the breech bolt being released and returned to position at proper time in operation of gun.

Patent 584,479 15 Jun 1897
Mauser, Paul Oberndorf, Ger.
Recoil-operated firearm.
Improved magazine repeating firearm with movable barrel in which recoil caused by shot is used to unlock and open breech to eject empty case and cock firing mechanism as well as to compress a number of springs so as to load fresh cartridge, relock breech and lock bolt and advancing movement of barrel.

Patent 584,631 15 Jun 1897
Fosbery, George V. London, Eng.
Recoil-operated firearm.
Relates to weapons in which cartridges are in revolving chambered cylinder. Object to construct so that discharge of one cartridge will automatically cause hammer to be cocked and fresh cartridge brought into position for firing. Cylinder, barrel and breech mechanism mounted on handle of weapon so that on discharge, all recoil and slide together on stock and recock hammer by bringing a projection thereon against fixed piece attached to stock. Sliding portion returned to normal position by spring reaction.

Patent 591,155 5 Oct 1897
Burgess, William S. Brookline, Mass.
Recoil-operated gun.
Improvement in machine guns in which charges are delivered successively to loading chamber from magazine, recoil being used to reset parts and load gun preparatory to discharge of next shot. Barrel longitudinally movable in supporting frame, barrel retracting spring, spring controlled firing pin carried by breech-block, cocking mechanism, automatically operated by return of breech block, releasing device of said mechanism; and other actuating mechanisms.

Patent 591,525 12 Oct 1897
Burgess, Andrew Buffalo, N. Y.
Recoil-operated firearm.
Relates to automatic or self-operating firearms. Simplified and cheap construction, improved means of locking and unlocking breech mechanism; improved construction of magazine and its connection to barrel; etc.

Patent 593,228 9 Nov 1897
Maxim, Hiram S. London, Eng.
Automatic gun.
Improvement in automatic guns to provide means whereby all operations required in working of gun, except pulling trigger, may be effected automatically. Provides cartridge carrier into which cartridges are received one by one from magazine, recoil energy causing carrier to bring cartridge into alignment with barrel and deliver it into chamber. Successive cartridges are automatically thrown (not pushed) from magazine into carrier and then into barrel.

Patent 616,260 20 Dec 1898
Roth, Georges Vienna, A.-H.
Automatic firearm.
Automatic quick-firing magazine gun, in which the recoil, after firing, moves back, barrel, receiver and breech bolt simultaneously in their closed position to a distance exceeding length of a cartridge, in which position they are held by a stop lug actuated by trigger and by a stop piece abutting against hammer as long as trigger is held back. This retention occurs under all circumstances and discharge of gases is always forward.

Patent 623,003 11 Apr 1899
Garland, Frank M. New Haven, Conn.
Automatic machine-gun.
Machine gun having 2 barrels so arranged that the recoils incident to the explosions of the cartridges that are supplied by a belt are utilized to feed the cartridges and load and fire the opposite barrels alternately. Cartridges, which are temporarily held by spring clips to reverse sides of flexible belt, are by a positive feed intermittently elevated into case enclosing mechanisms through opening in bottom. Recoil causes backward movement of barrel and breech-block, and this is transmitted by connected pistons to pistons connected with other barrel and breech-block.

Patent 634,913 17 Oct 1899
Roth, Georg and Krnka, Karl Vienna, A.-H.
Recoil-operated firearm.
Relates to guns having sliding barrel utilizing recoil for ejection and reloading. Breech-block and barrel coupled in such manner that block will not be uncoupled until backward movement of both, due to recoil, has taken place and while barrel is performing its forward movement. Prevents gases of combustion from firing out at rear when breech is opened.

Patent 636,977 14 Nov 1899
Garland, Frank M. New Haven, Conn.
Automatic machine-gun.
Relates to automatic machine gun in which barrel moves backwardly when cartridge is fired and after compressing the operating-spring is drawn forward by the spring, while

breech-block moves farther backward for extracting exploded shell and permitting feeding of another cartridge into position for loading in barrel, when breech-block is thrown forward, block being released for this purpose when cartridge is properly fed.

Patent 638,045 — 28 Nov 1899
Dawson, Arthur T. and Silverman, Louis — London, Eng.
Recoil mechanism for automatic machine-guns.
Provides means whereby guns of larger caliber and adapted to fire heavier charges than heretofore may be operated on same plan as ordinary rapid-fire machine guns. (1½ inches or more.) Combines with barrel which slides endwise on recoiling in a frame or cradle, a spiral spring placed around barrel in the water-jacket and with the breech mechanism, a hydraulic buffer, so placed within gun casing at rear of crank and so arranged that it can be readily replenished with liquid without removing it from the gun.

Patent 639,421 — 19 Dec 1899
Mauser, Paul — Oberndorf, Ger.
Recoil-operated firearm.
Firearm that can be fired normally at prearranged low rate of fire and changeable to be converted into a rapid-fire, automatic or self-loading firearm. A safety catch which places automatic catch out of action when single fire is desired is employed. When automatic catch is used, recoil of explosion permits automatic operation.

Patent 642,018 — 23 Jan 1900
Ternstron, Ernst — Paris, France
Automatic machine-gun.
Improvements in automatic machine guns in which firing can be done by hand in which all movements of different pieces are effected by reciprocation of system of recoil, either by explosion of charge of cartridge in automatic firing or by crank handle when hand fired. Rocking movement of locking-levers to prevent movable bolt from moving relative to breech-piece in closed position obtained by resistance plate acting on projections of said levers. Extractor is combined with a locking lever. Movement of drum feed controlled by a piece movable longitudinally having a spring buffer.

Patent 643,118 — 13 Feb 1900
Garland, Frank M. — New Haven, Conn.
Automatic machine-gun.
Relates to recoil-operated machine guns. Object to provide light gun with positive mechanisms to fire without becoming disabled by breakage of pieces or fouling and clogging of moving parts. Longitudinally-movable barrel, casing encircling barrel, fluid chamber in casing and surrounding part of barrel, cylinder surrounded by fluid chamber and surrounding part of barrel, said cylinder open at both ends to chamber in casing, piston mounted on barrel and movable in cylinder, a valve concentric with barrel located at one end of cylinder and adjustable means for restricting valve movement.

Patent 659,507 — 9 Oct 1900
Browning, John M. — Ogden, Utah
Recoil-operated firearm.
Improvement in automatic portable firearms in which recoil following explosion of cartridge in barrel operates breech mechanism. Consists in improved housing for recoiling parts for protection of parts and user. Tube-like extension into which barrel is screwed and located within and housed by upper portion of gun frame or receiver.

Patent 671,062 — 2 Apr 1901
Anderson, Edward W. — Witton, Eng.
Automatic gun.
To provide automatic or machine gun of few and simple parts with projectiles discharged from single barrel, operations being performed automatically by energy of the recoil of the barrel and adjacent parts. Rifled barrel mounted to slide in an axial direction through bushing carried on main frame of gun. Water-jacketed. Receiver attached to breech end of barrel and carries bolt and firing mechanism. Cartridges are belt fed and automatically withdrawn by a lever operated by reciprocation of receiver.

Patent 678,937 — 23 Jul 1901
Browning, John M. — Ogden, Utah
Automatic gun.
Belt-operated automatic gun light enough for manual transportation. All operations of loading and firing after first cartridge are effected by recoil. Barrel and barrel extension move back in casing under the influence of recoil, and the bolt moves in the same line, part of the time with the barrel, being locked thereto by a vertically-moving locking-block, and part of time the bolt has an independent movement in the same line as the barrel movement.

Patent 681,439 — 27 Aug 1901
Carr, Howard — San Francisco, Calif.
Magazine-gun.
Recoil-operated machine or field gun, employing breech-movement of Patent 584,153 (1897), with improvements in construction and arrangement of parts by which recoil is utilized in performing breech operations. Novel magazine construction and means for feeding cartridges therefrom to barrel.

Patent 684,055 — 8 Oct 1901
Gabbett-Fairfax, Hugh W. — Leamington, Eng.
Automatic firearm.
Relates to automatic weapons of kind in which barrel and breech block or bolt recoil together against resistance of springs and in which barrel remains held retracted while barrel advances towards firing position and opens breech, bolt then being released to advance under spring action and inserting fresh cartridge. Improvements in bolt, feeding, cartridge lifter, etc.

Patent 689,283 — 17 Dec 1901
Browning, John M. — Ogden, Utah
Automatic firearm.
Improvement in automatic portable firearms in which recoil is used to operate breech mechanism. Simplifies and improves Patent 659,507 (1900). Handle located directly on breech-bolt for manual opening. Uses safety cartridge stop. Also collar brake to reduce shock of recoil upon rear end of frame.

Patent 690,739 — 7 Jan 1902
Kjellman, Rudolf H. and Andersson, G. L.
Stockholm, Sweden
Automatic firearm.
Relates to hand automatic firearms having recoiling barrel and receiver, latter located in fixed frame. Consists in construction whereby when breech is closed the actuating lever occupies such a position that breech-bolt may be drawn back or out by hand without disturbing said lever; cartridge lifter provided with spring-buffer which when cartridges are exhausted automatically drives rearward the partially advanced breech bolt, to allow recharging of mag-

azine; means for retaining receiver in place after recoil until breech-bolt has time to move rearward to full extent.

Patent 690,799 — 7 Jan 1902
Vickers, Albert — Westminster, Eng.
Automatic gun.
Relates to automatic guns of class in which breech mechanism is operated by crank turned about its axis in one direction by force of recoil and in other direction by reaction of spring, particularly "5-motion feed" principles of Maxim gun. Permits lock to be assembled without use of tools; crank and connecting rod arranged to occupy position of alinement with each other when breech is closed; improved joint of toggle links and lifting levers for elevating cartridge carrier; etc.

Patent 690,955 — 14 Jan 1902
Horne, George A. — Syracuse, N. Y.
Recoil-operated firearm.
Improvements in recoil-operated guns: Combination with lock-frame, reciprocating barrel extension and barrel, and the breech-block adapted to reciprocate with respect to barrel extension, of a latch pivoted to frame and adapted to engage said breech-block, a cartridge-lifter, pivotally mounted in frame and having a cam part engaged by barrel extension, a vertical trip-pin, etc. so that upward movement of lifter will lift latch and release breech-block.

Patent 695,784 — 18 Mar 1902
Bennett, Thomas G. and Mason, Wm.
New Haven, Conn.
Automatic firearm.
Improvement in recoil-operated firearm using box-magazine, constructed with particular reference to reducing friction of recoiling parts to a minimum. Means connected to barrel and barrel extension and receiver to cause barrel and extension to recoil and return in a circular path.

Patent 698,472 — 29 Apr 1902
Driggs, Louis L. — Washington, D. C.
Automatic gun.
Improvements in automatic revolving guns in which there are a plurality of barrels and in which each barrel recoils as it fires and exerts a part of the energy of recoil in moving other barrels toward firing position. Locking features on barrel and breech-block to avoid danger to moving parts from hanging fire.

Patent 728,739 — 19 May 1903
Mannlicher, Ferdinand von. — Vienna, A.-H.
Automatic firearm.
Relates to weapons having a movable barrel, a breech-bolt closure and a tumbler locking-bolt. Unlocking of breech bolt effected in positive manner while barrel moves back without breech-bolt having to cooperate for this purpose, whereupon bolt is moved back into open position by reason of its momentum. Also device to prevent firing pin from striking against percussion cap of cartridge before bolt is completely closed and locked. Also device to prevent release of hammer so long as bolt is not closed and locked.

Patent 730,801 — 9 Jun 1903
Schouboe, Jens T. S. — Rungsted, Denmark
Recoil-firearm.
In combination with a breech block arranged to turn about a pivot at its rear end and having backward and forward movement, a lug thereon, a lug on the casing to guide former lug in its movements. Also cartridge feeder with means for guiding cartridge into chambe .

Patent 730,870 — 16 Jun 1903
Browning, John M. — Ogden, Utah
Recoil-operated firearm.
Employs recoiling receiver, and non-recoiling receiver, former located on latter so as to slide back and forth thereon. All of recoiling parts of action mechanism are connected directly or indirectly with recoiling receiver, while non-recoiling parts are fixed to non-recoiling receiver.

Patent 733,681 — 14 Jul 1903
Schouboe, Jens T. S. — Rungsted, Denmark
Automatic firearm.
Refers to recoil mechanism in self-loading firearms with fixed barrels characterized thereby that breech block is in one piece with a U-shaped receiver, which during backward and forward movement of breech block completely covers lock mechanism and at same time, together with a closing-piece, forms the connection between main parts of the gun.

Patent 738,140 — 1 Sep 1903
Friberg, Holsten — Stockholm, Sweden
Automatic firearm.
Small arm operated by recoil. Magazine is stationary, while barrel and barrel extension, which are connected together rigidly, reciprocate under influences of recoil and recoil spring. Barrel extension slides in keeper-bearings in metal frame set in stock, breech-bolt slides in barrel extension and firing pin slides in breech-bolt. Lever acts to drive back breech bolt to greater extent than barrel extension and also to drive back and cock firing-pin.

Patent 747,585 — 22 Dec 1903
Browning, John M. — Ogden, Utah
Automatic firearm.
Recoil operated firearm in which energy is stored during opening movement of breech-bolt in a spring to actuate return movement of breech-bolt. Detachable barrel rigidly held above frame near sighting line of arm. Breech slide, movable abutment for reaction spring and breech-bolt combined in integral whole and mounted on top of frame from front. Gases prevented from blowing rearward. Firing mechanism completely inclosed except trigger. Other safety devices.

Patent 753,414 — 1 Mar 1904
Luger, Georg — Charlottenburg, Ger.
Recoil-loading small-arm.
Improvements in recoil firearms provided with movable barrels and toggle-actuated or knee-jointed breech blocks. Includes safety devices to prevent firing accidentally. Improved breech mechanism, breech closing-spring, disassembly, automatic arresting arrangement for keeping breech open after contents of magazine have been exhausted.

Patent 753,700 — 1 Mar 1904
Halle, Clifford R. S. J. — London, Eng.
Automatic firearm.
Utilizes recoil to recock, extract and draw out shell and place new cartridge in position. Lever connects movable barrel and recess in block on frame.

Patent 755,482 — 22 Mar 1904
Halle, Clifford R. S. J. — Hampton Wick, Eng.
Recoil-operated firearm.
Positive action of breech-bolt in lieu of ordinary system generally employed of bringing recoiling barrel to sudden stop and leaving kinetic energy of free breech-bolt to compress a spiral spring independently of barrel, which has to be locked in its backward position during flight and return of bolt. Utilizes full power of recoiling barrel.

Patent 783,123 21 Feb 1905
Mauser, Paul Oberndorf, Ger.
Recoil-operated small-arms.
Construction of breech-loading rifle, in which after weapon has been fired both barrel and breech bolt coupled together perform complete receding movement jointly until breech bolt has reached end of its course. Quiet and steady ejection. Before reaching end of path barrel and bolt are disconnected by recoil automatically at end position so that barrel may immediately advance while bolt is retained until barrel has reached forward position, whereupon bolt goes forward by spring action to be locked with barrel.

Patent 785,085 21 Mar 1905
Burton, Bethel Brooklyn, N. Y.
Automatic firearm.
Improvement in recoil-operated magazine firearm. Fixed stop positively determining backward or withdrawn position of bolt—to prevent injury to actuating springs of bolt. Lever mechanism for facilitating manual retraction of bolt in opposition to force of actuating springs when charging magazine. Device for positively locking firing pin in its cocked position.

Patent 794,652 11 Jul 1905
Young, Franklin K., Boston, Mass., and Sheriff, James E., New York, N. Y.
Ordnance and firearm.
Construction of rapid-fire ordnance so as to reduce or entirely overcome vibration of barrel. Operating mechanism constructed so that operating force acts in alinement with bore and breech mechanism acts in alinement with or parallel with line of fire or has rotary movement of balanced parts concentric with line of fire; absorbing rearward effect of pressure from zero to maximum in a rearwardly movable member which is brought to rest gradually.

Patent 797,420 15 Aug 1905
Febiger, Henry B. Philadelphia, Pa.
Firearm.
Improvement in explosion or recoil firearms, consisting in rigid barrel and movable chamber adapted to receive the cartridge, means for locking and releasing breech block.

Patent 804,694 14 Nov 1905
Whiting, William J. Wandsworth, Eng.
Automatic firearm.
Relates to recoil operated automatic firearms. A firearm having a breech-slide movable rearwardly by recoil, a spring-actuated lever for moving the breech-slide forward, a magazine having a movable follower and means operable by said follower when magazine is empty, for engaging the lever to hold the breech-slide in open position.

Patent 804,748 14 Nov 1905
Mannlicher, Ferdinand von Vienna, A.-H.
Small-arm having automatic breech-action.
Improvement in weapon described in Patent 728,739 (1903) to simplify construction and facilitate assembly and disassembly for use as military gun.

Patent 804,984 21 Nov 1905
Searle, Elbert H. Philadelphia, Pa.
Recoil-operated firearm.
Relates to magazine firearms being either semi- or full-automatic by recoil action. New features of assembly of arm and relation and construction of its various parts.

Patent 808,003 19 Dec 1905
Browning, John M. Ogden, Utah
Firearm.
Relates to recoil operated firearms. Provides simple and strong means of attachment between barrel and stationary frame of the arm. Also means to positively limit rearward movement of the barrel with breech-block, arrest movements of barrel as soon as same is unlocked from breech-block. Means for securing breech-block on frame of arm by positively limiting movements of breech-block on frame and for causing breech-block to be engaged by the reaction block.

Patent 814,547 6 Mar 1906
Kjellman, Rudolf H. Stockholm, Sweden
Automatic firearm.
Improvement in straight pull recoil operated automatic firearms. Barrel and breech-bolt recoil together for a certain distance against resistance of recoil-spring; then bolt is unlocked from barrel and continues recoil against resistance of a return spring. Means for locking bolt in its retracted position and releasing barrel, means for ejecting case as barrel advances to forward position, means for enabling barrel to release bolt as barrel advances and means for introducing cartridge into barrel as bolt moves forward.

Patent 830,511 11 Sep 1906
Lehmann, Hermann Magdeburg, Ger.
Automatic gun.
Improvements in recoiling guns. Combination with a part moving automatically upon firing and a breech-block, of a swinging lever moved by said part in one direction, a slide controlling opening and closing movements of breech-block, movable and mounted independently of breech-block and operated by swinging lever and spring moving slide in other direction.

Patent 854,771 28 May 1907
Strasburg, Charles A. Cridersville, Ohio
Automatic firearm.
Relates to automatic arms of type in which a spring is adapted to be placed under tension by recoil of the breech block and subsequently to exert its force for closing block after supply of new cartridge. Recoil movement of breech block expands suitable spring which will restore breech block to its former position after carrier supplies new cartridge to barrel.

Patent 867,960 15 Oct 1907
Farquhar, Moubray G., Aboyne, Scotland, and Hill, A. H., Birmingham, Eng.
Automatic rifle.
Relates to recoil-operated rifles, and consists in means whereby recoil energy opens and closes breech, ejects and reloads. Energy obtained from recoil is conserved until all pressure on barrel has been relieved and breech may be safely unlocked.

Patent 870,719 12 Nov 1907
Freeman, Charles Los Angeles, Calif.
Automatic firearm.
Relates to firearm having a frame, a breech-bolt slidably mounted on frame and being recessed for the greater part of its length, a locking block pivoted therein and having a vertical locking movement against frame, a firing pin mounted in locking block and extending forwardly through breech-bolt, a momentum-block coacting with firing pin to withdraw it from contact with breech block before unlocking movement begins. Improved trigger mechanism; means for

protecting external manual operating device from accidental interference.

Patent 922,173 18 May 1909
Lovelace, Charles D. Fort Worth, Tex.
Automatic gun.
Relates to recoil operated guns for feeding and ejection. A butt stock, a receiver, a barrel recoilably mounted in said receiver, breech block adapted to move rearwardly with said barrel, means for moving breech block forward after recoil with barrel, a cartridge magazine in stock and means operable by said breech block moving means whereby cartridges may be conducted into receiver from said magazine.

Patent 930,305 3 Aug 1909
Maudry, Julius Vienna, A.-H.
Firearm.
Relates to recoil-loaders provided with rotating barrel retreating only a short distance and with a cylinder breech mechanism with locking lugs on both sides. Barrel when in loading position is secured by means of an automatically acting part in that position in which its locking to breech block can be effected after completion of unlocking movement. Locking pin pressed into engagement with recess on outside of barrel by spring. Intermediate piece mounted on incline in handle of breech block transmits blow of hammer to firing pin. Trigger mechanism comprises sliding catch forced against operating lever by a spring.

Patent 936,369 12 Oct 1909
Searle, Elbert H. Philadelphia, Pa.
Gun.
Relates to semi-automatic, recoil-actuated magazine guns. Improved means for connecting barrel and breech bolt to frame; automatic interlocking of barrel and breech bolt at time of firing; improved grip; improved means for securing firing pin, safety lock, follower-operated lock, magazine and mounting.

Patent 960,880 7 Jun 1910
Frommer, Rudolf Budapest, A.-H.
Automatic firearm.
Improvement in Patent 802,279 in which barrel and breech block slide back in closed condition on recoil and block is held in backward position by 2 catches while barrel moves forward again. Good working order of the 2 catches insured by invention. So connected with one another and with their controlling springs outside the firearm that they can be inserted with ease into firearm in connected condition; also removed without affecting correct setting of springs.

Patent 971,061 27 Sep 1910
Mauser, Paul Oberndorf, Ger.
Recoil-loader with fixed barrel.
In a recoil-operated breech-loading firearm, combination of a breech-block, locking levers for said breech-block, and a cam plate freely mounted upon firearm and operating by inertia to actuate said locking levers to unlock breech-block upon recoil of the firearm.

Patent 981,210 10 Jan 1911
Menteyne, Paul M. and Degaille, Pierre Paris, France
Automatic firearm.
Applied to recoil operated cannon, machine guns, muskets and pistols. Comprises barrel, movable rearwardly by the recoil, a spring for returning barrel to normal position, a breech block having sliding movement on barrel, a firing pin sliding in breech block, spring for returning firing pin to normal position, a locking block and means for operating the latter by movement of firing pin.

Patent 984,263 14 Feb 1911
Browning, John M. Ogden, Utah
Recoil-operated firearm.
Improved recoil-operated firearm with respect to: means to effect rotation of bolt within carrier; extraction of empty shells; safety device to lock trigger in position of full cock and prevent rearward movement of bolt carrier; means for transferring cartridges from magazine into chamber of barrel.

Patent 984,519 14 Feb 1911
Browning, John M. Ogden, Utah
Firearm.
Recoil-operated magazine firearm. Improved strength and durability; safety device for breech slide; readily detachable barrel in forward direction only; means of attachment and connection between barrel and frame which shall leave barrel free to recoil a limited distance interlocked with breech bolt; automatic lock to insure against accidental firing when trigger is pulled after magazine is withdrawn but cartridge is still in chamber.

Patent 1,001,250 22 Aug 1911
Chevallier, A. L. and Eastwick, James London, Eng.
Automatic small-arm.
To provide automatic small arm in which the opening and closing of breech with attendant operations of extracting and ejecting and inserting a new cartridge shall be effected by energy of the recoil, this being utilized by means of a heavy cover or inertia block.

Patent 1,063,882 3 Jun 1913
Jones, Edward Perry-Bar, Eng.
Gun.
Employment in an automatic machine gun having recoil-operated reciprocating barrel of an arrangement whereby force of recoil of a gun acting on a bolt and nut device preferably of multithreads and high pitch causes the same to effect storage of energy. Improved cartridge feeding system to breech by carrier to which shells are attached by clip.

Patent 1,096,324 12 May 1914
Stamm, Hans St. Gallen, Switzerland
Automatic-loading firearm.
Relates to long-recoil, straight-pull breech, automatic loading firearms. Adapted for use with pointed bullet ammunition. Barrel as well as breech are under separate spring pressures and unbolting or unlocking of breech is performed in 2 stages: barrel and breech recoil until barrel strikes a rigid stop while bolt operating sleeve is flung farther back, causing breech bolt to be turned and partly unbolted, loosening discharged shell. On counter recoil bolt operating sleeve is temporarily arrested by a lock: resulting action includes complete unlocking of breech, ejection and positioning new round.

Patent 1,128,180 9 Feb 1915
Orman, Benjamin Belvedere, Eng.
Automatic firearm.
Relates to firearms in which barrel and bolt recoil together for short distance, then are unlocked, barrel returning to firing position while bolt continues to recoil, thus opening breech for ejection and cocking. Bolt constructed so that during recoil of barrel rearward movement of the body of the bolt is accelerated so that said body will move faster than the stem so that stem is turned in proper direction to unlock it from barrel.

Patent 1,159,417 9 Nov 1915
Revelli, Bethel A. Rome, Italy
Automatic firearm.
Firearm having a barrel and means permitting said barrel to recoil for a short distance after discharge, a recuperating spring for partially advancing recoiled breech bolt, means for arresting action of said spring before bolt is fully closed and a cylindrical sliding and rotating breech bolt whose initial forward movement is effected by action of said spring, and final and complete movement forward is effected solely by momentum acquired during initial movement of breech bolt.

Patent 1,176,254 21 Mar 1916
Smith, Morris F. Utica, N. Y.
Firearm.
Improved recoil-operated firearm. Means for postponing opening movement of element movable to open or close breech until suitable time after discharge to allow projectile to clear barrel. The force remaining is force of recoil for opening breech. Improved safety feature when gun is not in use.

Patent 1,190,351 11 Jul 1916
Winks, John O. San Francisco, Calif.
Automatic firearm.
Provide an automatic firearm (recoil operated) in which cartridge is locked in barrel at time of firing. Novel means for conveying cartridge from magazine to barrel; improved trigger and firing mechanism; improved means for allowing insertion of loaded cartridges into magazine.

Patent 1,293,021 4 Feb 1919
Browning, John M. Ogden, Utah
Automatic machine-gun.
Improved recoil-operated machine gun in which barrel and breech closing part recoil together, while interlocked, a limited distance, are then unlocked, the movement of the barrel arrested and breech closing part alone continues recoil, all parts being returned to firing position by reaction spring.

Patent 1,346,012 6 Jul 1912
Gabbett-Fairfax, Hugh W. London, Eng.
Automatic firearm.
Relates to recoil-operated firearm. Provides means for allowing sufficient time to elapse between firing of weapon and unlocking of breech without using a longer recoil than is actually necessary. Piston attached to barrel, breech or sliding carriage attached thereto, so arranged that effort of recoil will compress a volume of air in a cylinder from which, at any desired point in recoil, a quantity of compressed air is taken to uncouple breech mechanism from barrel, force former to desired length of travel and return barrel to rest.

Patent 1,355,378 12 Oct 1920
Bardelli, Arturo Milan, Italy
Automatic firearm.
Arrangement attaining the reduction of the recoil and absolute tightness of the gun, the breech block being opened only after bullet has left barrel.

Patent 1,360,873 30 Nov 1920
Bjorgum, Nils Christiania, Norway
Automatic hand-gun.
Automatic magazine gun of recoil loading type with short recoiling barrel and breech mechanism consisting of a slider with rectilinear movement and having at forward end a locking head with rotatory movement. Slider and trigger device combined with a safety lever pivoted on rear end.

Patent 1,398,452 29 Nov 1921
Wagnon, Ira W. Casa Grande, Ariz.
Automatic rifle.
Improved magazine-fed, recoil-operated and air-cooled rifle wherein motive power for operation of mechanism is furnished by recoil of bolt incident to the explosion, and wherein recoil springs are eliminated.

Patent 1,424,773 8 Aug 1922
Payne, Oscar V. Cleveland, O.
Firearm.
Improvement on Patent 1,347,756 (1920). Improved recoil system adapted to resist both rotary and longitudinal movement of bolt or breech closure. Means for transmitting to a recoil spring greater compressive strength without additional length of recoil of the breech closure.

Patent 1,452,123 17 Apr 1923
McCrudden, John C. R. Hurstville, Australia
Machine gun.
Relates to recoil-operated machine guns having axially moving breech block with key locking means. Improvements: rapid recharging; means for regulating rate of fire and varying it; carrying away heat from barrel and chamber; protection against fouling; convertible to single fire or automatic; means for smothering flash and muffling explosion report; etc.

Patent 1,453,439 1 May 1923
Cedillo, Nicasio Houston, Tex.
Recoil-operated firearm.
Machine gun comprising a casing, a barrel carrier, a breech bolt slidably carried by barrel carrier and having a central firing pin, an extractor carried by upper part of said breech bolt, an ejector carried by lower part to have limited sliding movement and a contact device carried by barrel carrier coacting with a lug on ejector to project latter beyond the breech bolt.

Patent 1,525,065 3 Feb 1925
Browning, John M. Ogden, Utah
Automatic firearm.
Automatic recoil-operated gun adapted to fire large caliber projectiles (37 mm or larger) but mobile and adapted to be mounted on aircraft. Novel feed and breech block actuating means. Simplicity of construction.

Patent 1,525,066 3 Feb 1925
Browning, John M. Ogden, Utah
Automatic firearm.
Relates to recoil operated guns. Novel means for pushing cartridges into chamber of barrel and for supporting and guiding said cartridges before and during such movement, means for extracting empty shell, etc. Means for locking together breech block and lock frame; means for positioning, supporting and guiding transversely moving feeder.

Patent 1,618,510 22 Feb 1927
Browning, John M. Ogden, Utah
Automatic firearm.
Automatic recoil-operated weapon with simplified mechanism, reducing number of parts and aiding assembly and disassembly. Embodied in pistol, but adaptable to other firearms.

Patent 1,628,226 — 10 May 1927
Browning, John M. (deceased)
Automatic firearm.
Improvement on recoil operated machine gun (Patent 1,293,021–1919). Adapts gun to fire modern service cartridges greatly increased in caliber, length, weight and size. Provides composite brake or buffer in rear of heaviest recoiling members of breech mechanism (spring actuated recoil cushion). Also cushioning devices in rear of breech closing block for absorbing excess recoil energy.

Patent 1,637,400 — 2 Aug 1927
Kiraly, Paul von and Lovasz, Josef — Budapest, Hungary
Automatic arm.
Relates to automatic arms having a barrel arranged for short recoil which movement is transmitted to the breech bolt and involves an improved transmission of the recoil momentum of the barrel to the breech bolt, then an increased delay in opening of bolt and means for dislodging spent shell by means of a front blow.

Patent 1,648,469 — 8 Nov 1927
Adamson, Keith F., Fort Bragg, N. C., and Stambaugh, Henry J., Troy, N. Y.
Automatic gun.
Designed for 37 mm shells. Automatic gun of the sliding breech block type in which extraction takes place during an early stage of recoil and ejection during a later stage. Rammer energized during recoil and swung into ramming position. Magazine given partial rotation during counter-recoil. Means to prevent firing of last round from magazine until latter is replenished.

Patent 1,651,128 — 29 Nov 1927
Jervey, Thomas M. — Washington, D. C.
Automatic gun.
Relates to 37 mm gun. Novel means for positioning charge, associated with which is novel rammer for forcing charge home to prevent jamming. Operation by recoil. May be operated manually as well as automatically.

Patent 1,698,228 — 8 Jan 1929
Harring, Harry K. — Washington, D. C.
Machine gun.
Gun having a movable frame arranged at rear of barrel and a bolt mounted in same frame, said pieces being adapted to be moved rearwardly by recoil a predetermined distance and bolt then moved rearwardly to permit ejection and reloading. Improved operating means for breech block controlled by movement of frame.

Patent 1,747,546 — 18 Feb 1930
Janecek, Frantisek — Prague, Czechoslovakia
Machine gun.
Provides machine guns of type having recoiling barrel and drum magazine with a loading mechanism in which magazine is operated by spring means strained by the barrel on recoil. Strain of spring means is transmitted to magazine by a bent lever and sliding element. Cartridges fed out of magazine by spring and lever device.

Patent 1,773,441 — 19 Aug 1930
Soncini, Cesare — Brescia, Italy
Machine gun and other automatic firearm.
Relates to recoil operated firearms in which a lever is provided for amplifying such recoil motion for parts of mechanism. Lever located in upper part of breech casing and bifurcated, the 2 prongs acting symmetrically on head of breech bolt on either side of axis of gun. 2 reaction springs absorb energy of recoil. Frame of breech held firm during movement of lever regardless of inclination of weapon.

Patent 1,931,262 — 17 Oct 1933
Loomis, Crawford C. — Ilion, N. Y.
Firearm. (Cl. 42–4)
Improvement in auto-loading Browning (Patent 659,507—1900) recoil-operated firearm, with cartridges stored in tubular magazine under barrel. Improved carrier locking device and means for retaining cartridges in magazine during displacement of carrier from its normal position. Improved cartridge stopping means associated with breech block. Friction device for checking speed of recoil of barrel.

Patent 1,946,388 — 6 Feb 1934
Chevallier, Arnold L. — Llangarron, Eng.
Recoil-operated small arm. (Cl. 42–4)
Weapon comprising a member adapted to move back under effect of recoil to carry out re-loading is provided with means for using initial force of recoil to hold said member in firing position in a positive manner supported by inertia of a second member and for releasing first member only when recoil pressure has subsided. Inertia member constructed as a cover over mechanism.

Patent 2,017,283 — 15 Oct 1935
Laloux, Rene — Brussels, Belgium
Automatic repeating gun. (Cl. 42–3)
Recoil operated shoulder arm. Recoil of barrel takes place above the magazine, which is disposed in almost same plane as edge of the barrel when gun is in position of rest. Shortens necessary breech-chamber length. Return of bolt, displaced when gun is fired, by recoil of barrel above the magazine takes place only when barrel is returned to its initial position.

Patent 2,048,395 — 21 Jul 1936
Larsson, Carl A. and Higson, Percy R., Westminster, Eng.
Machine gun. (Cl. 89–3)
Relates to barrel-recoiling type of machine gun in which lock is connected by a rod to a spring controlled crank pivoted to recoil plates connected to the barrel. Accelerated return of recoiling parts to firing position.

Patent 2,049,776 — 4 Aug 1936
Hyde, George J. — Brooklyn, N. Y.
Gun. (Cl. 42–3)
To balance the gun so that reaction due to the recoil of the breech block will be greatly minimized. Provides breech mechanism which will coact with frame of gun in such a way as to assist in balancing of gun and reduction of the effect of the recoil action of the breech block.

Patent 2,213,953 — 10 Sep 1940
Conlon, Thomas A. — Silver Spring, Md.
Automatic gun. (Cl. 89–3)
Automatic 37 mm gun having a long recoil and a high muzzle velocity. Arrangement for positive feeding of a long and heavy cartridge, novel breech locking mechanism, and means for manually unlocking breech bolt for initial loading and correcting stoppages.

Patent 2,215,470 — 24 Sep 1940
Johnson, Melvin M., Jr. — Brookline, Mass.
Automatic firearm. (Cl. 89–3)
Relates to firearms of type (in Patent 2,094,156) (1937) in which barrel has short recoil movement, bolt has locking lugs interlocking with abutments on barrel, etc. To provide firearms of this type capable of firing high power ammunition

in which barrel does not pound heavily on receiver at end of recoil. To prevent firing until breech-closing mechanism is in firing position.

Patent 2,328,108 31 Aug 1943
Swebilius, Carl G. Hamden, Conn.
Recoil-operated self-loading firearm. (Cl. 42–4)
Improved reciprocating barrel firearm whereby relatively short axial movement of barrel-unit imparts a relatively long axial movement to breech bolt of firearm. Actuation of mechanism accomplished with a minimum of recoil shock.

Patent 2,362,613 14 Nov 1944
Browning, Val A. Ogden, Utah
Machine gun. (Cl. 89–3)
To provide machine gun of recoil-operated belt-feed type wherein barrel structure may be readily and quickly mounted or dismounted from breech casing. Permits utilization of air cooling means in conjunction with barrel, thus eliminating water cooling. Gun may also be properly breeched without stripping any of the breech casing.

Patent 2,370,835 6 Mar 1945
Bell, Davitt S. and Wilkander, Oscar R. Pittsburgh, Pa.
Automatic gun. (Cl. 89–44)
Improved recoil mechanism for automatic guns which does not slow down firing rate; not affected by temperature changes; does not require periodical lubrication. Improved trigger mechanism placed on mount which controls firing despite axial vibration at a rapid rate due to recoil forces. Applied to Browning M2 gun. Comprises a ring spring formed of interfitting elastic rings having complemental tapered friction surfaces.

Patent 2,372,652 3 Apr 1945
Balleisen, Charles E. U. S. Army
Firearm. (Cl. 89–3)
Improvement in Browning gun with means for assuring minimum amount of failure due to extraction difficulties. Means for assuring that breech bolt and cartridge are in farthermost rear locked positions with respect to barrel before firing. Uses springs of low strength sufficient to overcome the inertia and friction of the parts to be moved to rearmost position.

Patent 2,377,692 5 Jun 1945
Johnson, Melvin M., Jr. Brookline, Mass.
Firearm. (Cl. 42–4)
Relates to firearms having reciprocating bolt which rotates into and out of locking position at forward end of stroke and in which unlocking of bolt is effected by short recoil movement of barrel. To provide means for preventing rebound when reaching forward position without interfering materially with the recoil of the bolt when gun is fired.

Patent 2,389,960 27 Nov 1945
Dobremysl, Josef London, Eng.
Automatic gun. (Cl. 89–3)
Relates to short-recoil belt-fed automatic guns. Characterized by a combination of means retaining barrel in recoil position until action slide has reached its rearmost position in which it is retained by a sear mechanism and means on trigger mechanism controlled by barrel and rendering sear mechanism inoperative against releasing carrier until barrel returns to fore position. Of advantage when applied to guns of large caliber.

Patent 2,465,196 22 Mar 1949
Browning, Val A. Ogden, Utah
Self-loading recoil-operated firearm. (Cl. 89–177)
Provides easy and quick takedown for removal of barrel; improved design of parts; buffer means for softening shock incident to stopping forward movement of barrel without causing vibration; friction brake to retard velocity of recoiling barrel and forward velocity of barrel returning to battery.

Patent 2,466,902 12 Apr 1949
Lochhead, John L. Springfield, Mass.
Inertia operating member for automatic firearms. (Cl. 89–182)
Automatic firearm having fixed barrel with improved mechanical means, as distinguished from gas-operated means, responsive to recoil action of firearm when fired, to automatically actuate breech block operating mechanism. Inertia weight for operating breech block, weight being adapted to use initial recoil force of firearm to hold breech block in locked position and after force of recoil has spent itself to unlock block and move it rearward in receiver.

Recoilless Guns

Patent 891,778 23 Jun 1908
Mertens, Ludwig London, Eng.
Non-recoiling firearm.
Mechanism applied to firearms whereby recoil imparted by firing of a charge is absorbed partly by stopping forward movement of certain masses and partly by stressing of a spring or other suitable device, to avoid direct effect of the recoil on casing or body of weapon. Recoil preventing mechanism in which effect of recoil is manifested only in the reaction of a spring during period from firing to final return of parts into position for another shot. Cartridge chamber constructed so that case or shell is not distorted by gases generated at time of a discharge.

Patent 1,108,714 25 Aug 1914
Davis, Cleland USN
Aeroplane gun.
Apparatus adapted for firing projectiles from flying machines, comprising a tube open at both ends, a gun mounted in said tube and adapted to contain a projectile and a propelling charge. When discharged projectile goes in one direction and gun expelled in opposite direction. Recoilless principle.

Patent 1,108,715 25 Aug 1914
Davis, Cleland USN
Apparatus for firing projectiles from aeroplanes.
Recoilless gun for aircraft. Apparatus comprises gun barrel open at both ends to atmosphere, a projectile, a propelling charge for said projectile, and a recoil weight in rear of said charge and adapted to be expelled from gun into air when propelling charge is fired, for neutralizing backward thrust.

Patent 1,108,716 25 Aug 1914
Davis, Cleland USN
Apparatus for firing projectiles from aircraft.
Improvements in recoilless guns (Patents 1,108,714 and 1,108,715). So arranged that a compensating mass whose inertia is preferably substantially the same as that of projectile flies through open breech in opposite direction to projectile. Loading apparatus reduced to simple form, for convenient operation on aircraft. Electric firing apparatus. Telescopic sighting arrangement.

Patent 1,108,717 25 Aug 1914
Davis, Cleland USN
Fixed ammunition for use on aircraft.
To provide fixed ammunition intended to be fired from a gun with bore open at both ends and so arranged that when projectile flies toward muzzle of gun, a compensating mass will be projected rearward through breech of gun, thereby eliminating all shock of recoil. Radial pressure of powder gases will be balanced by opposite sides of the bore. May be conveniently mounted on a light mount or aircraft.

Patent 1,373,381 29 Mar 1921
Cooke, Charles J. Hong Kong, China
Non-recoil gun for aeroplanes.
Provision of a gun open at both ends, operating to fire a charge comprising a shell, associated with a propelling charge and a reaction mass adapted to be discharged from rear end of gun at higher initial velocity than projectile.

Patent 1,380,358 7 Jun 1921
Cooke, Charles J. Washington, D. C.
Non-recoil gun.
Improved non-recoil gun adapted to fire shell in one direction and utilize escaping gases to counterbalance the recoil. Characterized by a diverging deflector at rear end in direct communication with firing chamber of gun, designed to utilize expansion of gases as they pass through deflector for dissipating recoil forces resulting from explosion. Additional muzzle deflectors at forward end of guns.

Patent 1,394,490 18 Oct 1921
Giles, Julian A. Derby, Conn.
Non-recoil gun.
Improvement on "Davis non-recoil gun" (Patent 1,108,716—1914). Simplified percussion firing mechanism combined with a one motion breech mechanism adapted for positive action and easy manipulation. Diminishes power necessary to swing rear barrel of gun from open to closed position and vice versa, simplified locking and unlocking of front and rear barrels, and positive safety lock for firing mechanism.

Patent 1,395,630 1 Nov 1921
Davis, Cleland Englewood Cliffs, N. J.
Non-recoil gun.
Improvement on Patent 1,108,715 (1914) and Patent 1,108,716. Provides gun body made with a single continuous tube provided with a hinged door at one side and near central portion thereof, through which loading of projectile, propelling charge and counterweight is effected, together with means for firmly holding said door in place and for preventing escape of gas when propelling charge is ignited.

Patent 1,434,044 31 Oct 1922
Cooke, Charles J. Hong Kong, China
Ordnance.
Guns of non-recoil type, open at both ends carried on aircraft or mobile carriages that cannot stand shock of recoil. Equipped with muzzle deflectors arranged and adapted to assist in dissipating recoil forces which result from explosion in ordinary guns. Means for readily separating front and rear sections of non-recoil gun to facilitate loading and extracting.

Patent 1,446,000 20 Feb 1923
Davis, Cleland USN
Armament for aircraft.
Mounting of large caliber non-recoil guns on aircraft as patented in Patents 1,108,715 and 1,108,716 (1914). Guns operated as single firers and take up space and weight otherwise utilized as gun crew and ammunition area.

Patent 2,405,414 6 Aug 1946
Eksergian, Carolus L. Detroit, Mich.
Recoilless gun mechanism. (Cl. 89–1)
Relates to recoilless guns of type wherein a plurality of vanes are disposed in a gas discharge passage for counteracting tendency toward rotation of gun incident to rifling of gun barrel. Provides improved vane arrangement in gas discharge chamber.

Patent 2,456,812 21 Dec 1948
Blacker, Latham V. S. Fittleworth, Eng.
Recoilless gun. (Cl. 89–1.7)
Recoil forces generated upon discharge of a propellant cartridge are largely absorbed and utilized for recocking gun. Means for accurately locating a projectile in position in a gun so that a moving striker can enter a narrow tube in tail of projectile and discharge a propellant charge at end of tube.

Patent 2,480,328 30 Aug 1949
Johnston, Hal C. Dayton, Ohio
Firing mechanism for recoilless shoulder mounted guns. (Cl. 42–69)
May be cocked and reloaded by another person without throwing the carrier off balance. Improved safety means for preventing premature or accidental firing, particularly before loader is in safe position.

Rotary Chamber Guns

Patent 34,024 24 Dec 1861
De Brame, J. A. New York, N. Y.
Improvement in revolving ordnance.
Improvement to reduce danger of rupturing operating chamber of cylinder of revolving cannon. Axis pin constitutes central brace to prevent the frame from being sprung by the recoil in firing. Also has provision for sealing space between chamber and barrel.

Patent 34,025 24 Dec 1861
De Brame, J. A. New York, N. Y.
Improvement in breech loading ordnance.
Mode of applying a rotating many-chambered cylinder in combination with a fixed barrel, and certain means of rotating cylinder to bring the several chambers successively in line with the barrel. Axis pin makes tight joint between the open rears of the chambers and a breech formed by the rear end of cylinder frame.

Patent 35,998 29 Jul 1862
Franke, Bernhard New York, N. Y.
Improvement in revolving ordnance.
Barrel of cannon, with wheel containing separate breeches firmly attached to it, rests on carriage. Breeches held in solid horizontal wheel bored for their reception in radial positions. Wheel revolves on shaft and each breech enters in turn cavity at rear of barrel for firing.

Patent 36,148 12 Aug 1862
Hardy, Moses F. Seward, N. Y.
Improvement in revolving ordnance.
Horizontal turn table with series of breech pieces or charge receivers mounted around outer rim of table so as to be successively brought in line with and forced into open rear end of cannon.

Patent 39,850 8 Sep 1863
Ward, H. D. Pittsfield, Mass.
Improvement in double-barreled revolving firearms.
Consists in so applying two barrels, in combination with one cylinder having a single circle of chambers, as to provide either for discharging of two of said chambers, one through each barrel, without rotating cylinder between discharges, or for discharge of the several chambers successively through one of said barrels.

Patent 41,857 8 Mar 1864
Palmer, William New York, N. Y.
Improvement in revolving firearms.
Employs carrier intermittently revolved by automatic mechanism and presenting one loaded chamber at rear of barrel, pausing while charge is fired, then proceeding to present next chamber on line with barrel. Hopper slide by which chambers descend into carrier by gravity. Incorporates gas seal and chamber alignment cam.

Patent 42,379 19 Apr 1864
Joslyn, B. F. Stonington, Conn.
Improvement in revolving fire-arms.
Relates to improvements in revolvers having cylinders made of 2 parts, one fitting into the other, with view to prevent accumulation of dirt between the parts and also to readily load cylinder and remove spent cartridges, by use of piece with radial ribs and recesses for reception of heads of cartridges.

Patent 85,350 29 Dec 1868
Adams, John The Strand, Eng.
Improvement in revolving fire-arms.
Revolver constructed of barrel and cylinder frame forged in one piece and combined with a back piece, to support and contain the handle and lock, and with a lock, hammer, cylinder and ejector rod arranged for insertion in this assembly.

Patent 143,855 21 Oct 1873
Smoot, William S. Ilion, N. Y.
Improvement in revolving fire-arms.
Barrel, bridge-strap, lockframe and upper portion of handle made of a single piece; revolving recoil shield arranged to turn in rear of cylinder far enough to open or close passage through which cartridges are inserted and removed; center pin provided with projecting guide in combination with sliding ejector.

Patent 158,957 19 Jan 1875
Mason, William Hartford, Conn.
Improvement in revolving fire-arms.
Construction of gate trunnion flat upon 2 sides at nearly right angles to each other and combining therewith a spring to bear on trunnion to force and hold gate in either open or closed position; securing ejector tube by means of a boss on barrel and screw transversely through tube into said boss and recess in the frame into which rear end of tube extends; semispherical form for rear end of frame.

Patent 189,360 10 Apr 1877
Jones, Owen Philadelphia, Pa.
Improvement in revolving fire-arms.
Combination, with a relatively fixed extractor-plate, a sliding cylinder and tilting barrel, of an intermediate rack mechanism for uniting barrel and communicating movement of former to latter without lost movement.

Patent 193,620 31 Jul 1877
Schofield, George W. U. S. Army
Improvement in revolving fire-arms.
Provides gas-collar to prevent gas and smoke from fouling base pin; non-corrosive base pin, with short bearings and a gas recess; reliable pivot for cylinder; means through foregoing to prevent clogging of revolving cylinder by fouling, rust or gas or by its losing rear bearing.

Patent 222,167 2 Dec 1879
Wesson, Daniel B. Springfield, Mass.
Improvement in revolving fire-arms.
Object to force cartridge forward a little so that front part of shell will be in rear part of bore of the barrel and when explosion occurs, shell will pack the joint between cylinder and barrel and prevent escape of gas. Consists of reciprocating breech piece, combined with pivoted auxiliary tumbler with limited rotary movement and thumb-piece having movement independent of hammer and arranged to give partial rotary movement to tumbler and reciprocating movement to breech-piece.

Patent 226,923 27 Apr 1880
Nagant, Emile & Nagant, Leon Liége, Belgium
Revolving pistol.
Bow of trigger guard serves as spring vise, forming powerful lever for disassembly and assembly. Space between body of revolver and side plate filled up with piece of wood, metal or other substance. Axial stem of cylinder or cartridge-chamber and extracting rod kept in place by piece placed in head of stem. Pressure of spring forces a projection on this piece to enter a notch in body of revolver. Another projection from same piece enters notch in extracting rod.

Patent 231,653 31 Aug 1880
Coloney, Myron New Haven, Conn.
Machine gun.
Revolving magazine consisting on an annular series of chambers surrounding barrel and revolved intermittently by a pawl to bring a new chamber into position to communicate with a breech slide by which cartridges are conducted to a position in rear of barrel for firing. Same mechanism which moves slide rotates magazine and retracts trigger bolts.

Patent 426,356 22 Apr 1890
Accles, James G. London, Eng.
Machine gun.
Relates to Gatling-type guns, with number of barrels ranged around a cylinder and revolving about its axis. Carries axis of handle for giving motion to barrels through one of trunnions upon which gun is mounted.

Patent 459,874 22 Sep 1891
Krnka, Karel Prague, A.-H.
Revolving magazine fire-arm.
Small arm in which whole strength of gas is used for propulsion of bullet, while in usual revolvers much of it escapes between barrel and cylinder; automatically throws out shells after each shot; provides for firing from a magazine, which is easily replaced when empty; provides for charging single cartridges directly into barrel; need not be charged until immediately before use; provides for fixing breech-bolt in its extreme forward position by a screw-plug, so it can be instantly reopened.

Patent 548,096 15 Oct 1895
Smith, Morris F. Philadelphia, Pa.
Machine gun.
Provided with 2 barrels which act, preferably, alternately. Operating parts for effecting feeding and firing of cartridges are duplicated on the opposite sides of the machine. Has revolving shell feeder. Crank operated.

Patent 560,842 26 May 1896
Cook, Thomas R. Marion, Ind.
Machine gun.
Combination of revolving barrel cylinder, drum cases placed alongside thereof, drums in said cases, and spring wedges whereby they are held in engagement with barrel cylinder. Adapted especially for use at short range.

Patent 688,217 3 Dec 1901
Whiting William J. Handsworth, Eng.
Automatic revolver-firearm.
Simplified construction and rotation of cylinder-rotating mechanism in Webley-Fosbery type revolvers. Dispenses with stepping zigzag channel and use of spring peg over which channel slides. Improved alignment of chambers of cylinder with barrel and hammer.

Patent 747,073 15 Dec 1903
Huntley, Stephen A. Sioux City, Iowa
Automatic firearm.
Relates to firearms employing automatically actuated rotary cartridge cylinder. Prevention of undue wear from shock of recoil and secure positive and certain actuation of cylinder. Additional safeguards against accidental discharge.

Patent 771,019 27 Sep 1904
Kober, Ferdinand Allentown, Pa.
Machine-gun.
Improvements in machine guns having rotatable cylinders. Barrel provided at breech end with an enlarged chamber, a revolving cylinder in chamber, an ejector plate at rear end of cylinder, breech-block hinged sidewise to breech end of barrel, means for rotating cylinder and ejector plate, hammer-and-trigger mechanism located in an extension of breech-block, and means for locking breech-block firmly into breech end of barrel.

Patent 1,377,236 10 May 1921
Watson, Glenn C. Cleveland, Ohio
Automatic rifle.
A plurality of magazine tubes which progressively diverge in a direction from the muzzle toward the breech and so as to gradually approach and assume a circumferential relationship at a point where they come in line with a corresponding number of chambers in a revolving cylinder, which latter is positioned so all of its chambers may successively register behind barrel. Automatic gas operation.

Patent 1,869,738 2 Aug 1932
Davis, Louis, Jr. Galveston, Tex.
Machine gun.
Positive means for loading revolving cylinder of gun. Positive means for ejection from a chamber of cylinder after firing. Firing mechanism with means for preventing premature firing. Means for locking cylinder against rotation during firing. Water cooled embodying drip arrangement whereby circulating water flows around rotating cylinder. Common operating lever actuates all operating parts. Means for automatic swinging of gun in horizontal and vertical planes.

Safety Devices

Patent 427,239 6 May 1890
Murphy, John L. Springfield, Mass.
Machine-gun.
Relates to Gatling-type guns. Provision is made for moving cocking-ring from and back to normal position, thus preventing its usual action, whereby gun is discharged, or permitting it to perform its proper function, at pleasure of operator, thereby providing means for preventing gun from being fired inadvertently, although crank and its connected firing devices be operated in usual manner.

Patent 599,587 22 Feb 1898
Bennett, Thomas G. and Mason, William
New Haven, Conn.
Magazine firearm.
Improvement in type of arm in which action mechanism is actuated by means of sliding supporting and actuating handle which is reciprocated back and forth in a line parallel with axial line of gun barrel, object being to increase safety and reliability of these arms. Use of buffer spring, improved extractor and other features.

Patent 639,414 19 Dec 1899
Luger, Georg Charlottenburg, Ger.
Safety device for firearms.
To simplify manipulation of breech-loading arms with movable barrels. Arrangement of catches adapted to come into action automatically by which both barrel and trigger are locked in position except when being fired. Capable of being thrown out of action, preparatory to firing by firmly grasping firearm without any special movement of the hand.

Patent 662,427 27 Nov 1900
Hepburn, Lewis L. New Haven, Conn.
Safety locking device released by recoil.
Supplemental safety lock to prevent accidents resulting from premature unlocking of breech in case cartridge "hangs fire", in breech-loading firearms. Device is pivoted to frame so that it may tilt or swing and provided with spring causing it normally to swing in rearward direction.

Patent 720,698 17 Feb 1903
Johnson, Thomas C. New Haven, Conn.
Gas-operated firearm.
(Improvement on Patents 681,481, 694,156 and 694,157) Detachable-box magazine take-down gun constructed for use of large cartridges. Timing lever on "balanced breech block" prevents gun from being fired until cartridge has been pushed home in chamber.

Patent 772,700 18 Oct 1904
Dawson, Arthur T. and Silverman, Louis
Westminster, Eng.
Automatic gun.
Improvements in Maxim-type guns. Means for preventing return movement of lock if it fails to accomplish full rearward stroke to prevent projectile of cartridge withdrawn from belt by carrier from striking cap or detonator of succeeding cartridge. Mainspring common to all three levers of lock (sear, cocking-arm and safety sear). Forward end of recoil spring adjustably connected to gun-casing by screw, having at its outer end a cylindrical head carrying ring for actuating same. Improvements in feed block.

Patent 822,851 5 Jun 1906
Burgess, Andrew Owego, N. Y.
Automatic gun.
Automatic gun or pistol controlled as to movement of barrel and breech; also means to bring barrel opening and cocking mechanism into interrelation; improved barrel mount, firing mechanism, magazine, safety mechanism, etc.

Patent 827,488 31 Jul 1906
Whiting, William J. Birmingham, Eng.
Automatic firearm.
Relates to automatic pistols, etc., on recoil principle. Means for indicating whether magazine is empty or when last cartridge has been fed. Special mechanism locks breech block or breech-slide in open position to attain this object.

Patent 842,547 29 Jan 1907
Hermsdorf, Max Essen, Ger.
Barrel-recoil gun with wedge breech-block.
Provides recoil-guns with means for securing breech block in open position against unintentional closing. Crank-shaft journaled in side of gun breech and having internal crank arm which engages in a cam-groove of breech block and an external hand lever through which motion is imparted to shaft. Crank-shaft cannot receive any rotary movement during this reaction.

Patent 863,770 20 Aug 1907
Whiting, William J. Handsworth, Eng.
Automatic firearm.
Relates to recoil-operated automatic pistols and other automatic firearms. Safety device for locking hammer at half-cock when arm is not in use. A detachable barrel and a trigger guard constituting means for locking barrel to body of arm.

Patent 929,491 27 Jul 1909
Reifgraber, Joseph J. St. Louis, Mo.
Automatic firearm.
Improvement on Patents 729,413 and 834,753 on gas-operated pistol. When hammer is down, safety lever cannot be moved to its released position. Trigger lock adapted to prevent pulling of trigger if barrel is in rear of its normal position, and also operates to prevent any forward movement of trigger when barrel is moved rearwardly.

Patent 939,882 9 Nov 1909
Whiting, William J. Handsworth, Eng.
Automatic firearm.
Improved construction of automatic small arms in which barrel is fixed to frame and breech slide, externally mounted on frame, is traversed rearwardly on each discharge by direct action of recoil, and returned by reaction spring. Reciprocating breech slide is combined with firing and safety mechanism so it is impossible for arm to discharge unless handle is firmly grasped in hand with intention of firing.

Patent 987,584 21 Mar 1911
Mauser, Paul Oberndorf, Ger.
Small-arm.
Refers to recoil loader with fixed barrel in which breech mechanism is actuated by the displacement of a slide-like movable part (as in Application 461,670). Present invention refers to providing recoil loader of such construction with a safety device preventing percussion bolt or pin flying forward into firing position before cam slide has adjusted the supporting or locking levers in the locking position.

Patent 1,014,660 16 Jan 1912
Mauser, Paul Oberndorf, Ger.
Automatic gun.
Object is to prevent loading and consequently use of weapon, if the lock, but more particularly the breech mechanism, has been incorrectly put together or if some part has been omitted when mounting the breech. Essential feature is that movable or adjustable parts are arranged on casing of lock in a position so as to exert a locking action on movable part if incorrectly mounted. Invention is applied to a recoil loader of Mauser system M .08 (Patent 918,760)

Patent 1,047,672 17 Dec 1912
Mauser, Paul Oberndorf, Ger.
Safety mechanism for firearms.
Firing pin arrangement comprising locking mechanism which, when breech is being locked, holds firing pin behind the face of breech bolt until latter has reached closed position, so that point of firing pin cannot project beyond the face of the breech bolt and cannot be released until breech is positively locked.

Patent 1,198,382 12 Sep 1916
Huberty, Oliver A. London, Eng.
Mainspring-retainer and automatic safety release.
Relates to readily removable and replaced mainspring of type used in Lewis type automatic gas-operated firearms. Provides against accidental release.

Patent 1,200,872 10 Oct 1916
Rosebush, Waldo E. Appleton, Wis.
Firearm.
Relates to recoil operated, breech loading automatic hand firearm. Device to prevent firing in case a cartridge is not properly seated in breech of barrel or shell is not properly ejected. Use made of a receiver carrying barrel and a frame having at front end a detachable hinge connection with receiver and a fastening device engaging the receiver and frame at rear ends to securely lock the parts together.

Patent 1,291,689 14 Jan 1919
Sheppard, Creedy C. Boston, Mass.
Firearm.
To render mechanism of arm safe against dangerous blowbacks by providing construction whereby breech mechanism will remain locked when subjected to high powder pressure while bullet remains in bore, but will operate to actuate the mechanism under the influence of the comparatively low pressure as bullet leaves bore.

Patent 1,320,578 4 Nov 1919
Savage, Arthur J. San Diego, Calif.
Firearm.
Relates to semi-automatic firearms operated by recoil action. Equipped with safety device whereby firing pin may be definitely spaced or removed or retracted from cartridge and locked positively in such position, until release is effected. Means for assembling barrel with breech block for convenience in assembling and disconnecting.

Patent 1,354,825 5 Oct 1920
Green, Samuel G. U. S. Army
Attachment for preventing the feeding of ball-cartridges to a gun.
Permits use of blank cartridges during maneuvers and for saluting purposes and renders chance of an accident due to feeding of ball cartridge extremely remote. Also provides forward stop for blank cartridges.

Patent 1,371,527 15 Mar 1921
Thompson, Walter Brooklyn, N. Y.
Means for preventing the jamming of machine-guns.
Displacement of percussion cap from its seat prevented by positively anchoring the cap against displacement, preferably by upsetting the material of the cartridge base into an anchoring formation relative to positioned cap.

Patent 1,395,292 1 Nov 1921
Pedersen, John D. Jackson, Wyo.
Firearm.
Improved firing train mechanism and grip safety device applicable to automatic and auto-loading firearms. Grip or handle contained safety device is arranged to prevent firing of firearm by locking hammer and the trigger sear when device is in normal or safety position. Locking of main slide of firearm effected in forward position by means of combined slide detainer and controller which engages a face on main slide.

Patent 1,452,465 17 Apr 1923
Johnston, Millard L. Utica, N. Y.
Actuator for machine guns.
Locks firearm in a secure manner against accidental explosion until cartridge has been moved into its chamber in barrel. Employs a dog having a depending projection to hold the hammer from striking the end of the firing pin until breech bolt has pushed cartridge home into its chamber in barrel.

Patent 1,516,835 25 Nov 1924
Frommer, Rudolf v. Budapest, Hungary
Automatic firearm.
Means to disconnect sear from trigger lever to prevent accidental repeated firing of automatic pistol.

Patent 1,579,742 6 Apr 1926
Frommer, Rudolf v. Budapest, Hungary
Automatic firearm.
Automatic safety device is locked by one of the parts of the firearm which is influenced by the movements of the breech bolt, namely interrupter of the pull-off mechanism of the gun.

Patent 1,730,269 1 Oct 1929
Darne, Regis St. Etienne, France
Automatic firearm.
Arrangement preventing firing sear from operating when arm is not loaded. Arrangement stabilizing cartridge seized in lifting carrier, in spite of shock imparted to breech bolt at end of rear stroke. Firing mechanism mounted outside movable parts of firearms insuring instantaneous discharge with a view of firing through field of propeller in aircraft.

Patent 1,925,776 5 Sep 1933
Scotti, Alfredo and others Brescia, Italy
Direct interlocking device for the breech block and the firing pin of automatic firearms. (Cl. 42-3)
Provides means adapted to prevent firing pin from detonating cartridge before breech block reaches the position where the breech is completely closed and the breech block from receding before the gas pressure produced by the explosion is sufficiently reduced. Breech block itself houses firing pin which is pressed forward by the restoring spring without necessity for the trigger spring.

Patent 1,930,864 17 Oct 1933
Schmeisser, Hugo Suhl, Ger.
Automatic firearm. (Cl. 42-1)
Relates to firearms in which barrel is adapted to slide lengthwise and a closing spring is accommodated in neck of stock. Provides a firing and safety mechanism in connection with cartridge-delivering mechanism to simplify and make more practical for use. Pin carrying hammer spring is pivotally connected with hammer and when hammer is cocked the pin projects from trigger guard to indicate gun is ready to fire.

Patent 2,016,646 8 Oct 1935
Mancini, Niccolo Florence, Italy
Automatic firearm. (Cl. 42-4)
Firing or safety mechanism intended for machine guns with recoil barrel and double armed block lever. Special structure of trigger, which in combination with peculiar conformation of firing pin is designed to prevent casual discharge of arm when unguarded. Trigger holds breech block open on cessation of firing, preventing cartridge from remaining within the barrel.

Patent 2,115,041 26 Apr 1938
Obregon, Alejandro Mexico City, Mex.
Automatic loading firearm. (Cl. 42-4)
Recoil-operated pistol comprising a combined safety and retention mechanism made in one piece and adapted to act as a safety device, a retention device to hold breech slide when last cartridge is fired, device for holding pivot pins in assembled position and to hold main frame and breech slide in their assembled positions for firing.

Patent 2,169,083 8 Aug 1939
Swartz, William L. Wethersfield, Conn.
Automatic firearm. (Cl. 42-69)
Firearm including a reciprocal bolt and mechanism for preventing doubling, i. e., firing more than a single shot upon a single operation of the trigger, with means on bolt to render the preventing means operative or inoperative.

Patent 2,335,688 30 Nov 1943
Moore, Frederick T. Hartford, Conn.
Firing mechanism for automatic firearms. (Cl. 89-3)
Relatively simple but positively certain mechanism to avoid misfiring in Browning recoil operated automatic firearm to avoid misfiring by assuring releasing movement of sear by the trigger lever only when breech block is in its full breech closing position. Trigger lever moves away from sear release if trigger is pulled and breech block is not in full closing position.

Patent 2,339,027 11 Jan 1944
Mossberg, Harold F. New Haven, Conn.
Firearm. (Cl. 42-16)
Improvements in loading and firing means of relatively small caliber firearms. Recoil operated bolt adapted to cooperate with a swingable loading platform to insure that latter is in fully closed position when gun is fired. Means to catch the bolt as it is retracted by recoil to prevent accidental firing.

Patent 2,345,127 28 Mar 1944
Kehne, Karl Berlin, Ger.
Gun having sliding and interchangeable barrel. (Cl. 42-75)
Improved safety device which locks breech mechanism when barrel is imperfectly coupled with gun. At rear end of longitudinal groove there is connected a guide groove which affords positive guidance to barrel over entire course

of its assembling movement. Guide groove so shaped that gun cannot be cocked if barrel has not been completely coupled.

Patent 2,355,768 15 Aug 1944
Williams, David M. New Haven, Conn.
Gas-operated self-loading firearm. (Cl. 42–3)
Gas-operated repeating firearm construction in which stock is effectively shielded from hot gases and residues which may escape past actuating piston. Action slide has transverse wall extending laterally across rear end of piston chamber and flange-like side wall extending forwardly from transverse wall and enveloping bottom and sides of piston chamber structure to shield stock.

Patent 2,356,615 22 Aug 1914
Revelli, Gino Rome, Italy
Firing mechanism for automatic guns. (Cl. 42–69)
Means for preventing inadvertent discharge of gun even though trigger may be maintained in an actuated position. Provides pivotal pawl which normally maintains firing pin in a retracted position including means for pivoting pawl upon actuation of trigger and means for further pivoting pawl to release same from trigger linkage so it may retain striker in retracted position even though trigger is not released.

Patent 2,377,338 5 Jun 1945
Garand, John C. Springfield, Mass.
Firearm. (Cl. 42–3)
To secure greater leverage to more firmly clamp receiver and trigger guard and hold stock therebetween, an element of the clamp is associated with trigger guard. Hammer held by auxiliary sear and is arranged to be cocked by a trigger guard as well as to insure that trigger guard is in locked position. Safety locks hammer in cocked position and also trigger against movement. Latch holds operating rod in retracted position when new clip is being inserted.

Patent 2,390,061 4 Dec 1945
Eklund, Hans E. Malmo, Sweden.
Disconnector means in self-charging firearms. (Cl. 42–3)
Disconnector members to prevent release of hammer when cocked and to prevent trigger, whenever pulled, from locking in position of release a sear released by trigger and locking hammer in cocked position. Provides single disconnector device to perform both functions.

Patent 2,495,383 24 Jan 1950
Mulno, Lester F. Worcester, Mass.
Safety device for firearms. (Cl. 89–145)
Extremely easily operable device for holding a breech bolt of a firearm in open condition so that firearm may not be accidentally fired. Pivoted hook movable into path of action bar so as to engage it at rearmost position. Hand operated member engages hook and holds same out of path of action bar against action of spring.

Patent 2,495,800 31 Jan 1950
Young, Lautt F. Corpus Christi, Tex.
Gun clearing device. (Cl. 89–1)
Device mountable on gun chargers of well known types that is operable remotely to clear the gun of rounds and allow gun cooling to prevent accidental discharge of gun after prolonged firing. Avoids "cook offs". Utilizes solenoid that is remotely controlled to actuate a lever means adapted to be pivoted into path of gun bolt stud to prevent stud from returning to battery position subsequent to recoil. Prevents firing of first round subsequent to closing operation of gun clearing switch by which live round is ejected.

Patent 2,529,359 7 Nov 1950
Stevens, Harry A. Hartford, Conn.
Safety device for automatic pistols. (Cl. 89–148)
Relates to pistols of barrel recoiling type with magazine within grip handle. Safety feature enables pistol to be gripped in usual manner while safety devices remain in safety positions and hammer locking safety device moved to firing position while pistol is held in firing position. Recoil slide may be manually retracted to unload cartridges from magazine and chamber while safety device is in locking position.

Sear Mechanisms

Patent 225,466 16 Mar 1880
Coloney, Myron New Haven, Conn.
Machine gun.
Movement of locking bolt serves to release the firing pin, so as to effect discharge; applicable to small arms and battery guns. Series of firing pins, trigger bolts and connecting levers effects automatically the successive discharge of a range of barrels.

Patent 693,106 11 Feb 1902
Burgess, Andrew Owego, N. Y.
Automatic gun.
Improvement in automatic weapons. Combination of longitudinally-reciprocating barrel, a connection to the hammer, a plurality of sears engaging said hammer connection, an abutment carried by barrel by which one of sears is detached and a trigger and connections whereby other sear may be disengaged.

Patent 1,382,317 21 Jun 1921
Pomeroy, Edward S. Springfield, Mass.
Automatic pistol.
Improved operative connection between hammer and sear and means for pressing the sear into position to hold the hammer cocked. Detachable stop for limiting forward movement of housing slide normally connected to breech block.

Patent 1,441,807 9 Jan 1923
Horan, Timothy F. Ilion, N. Y.
Firearm.
Gas operated automatic firearm. Embodies an actuator, a breech block, a trigger, a main spring and a trigger spring. Has a sear adapted to effect a semiautomatic operation of the gun. Sear is controlled by a sliding bar which can be manipulated to convert the firearm from automatic to semiautomatic as well as act as safety lock.

Patent 1,456,182 22 May 1923
Berthier, Andre V. P. M. Neuilly-sur-Seine, France
Firearm.
Rifle operated by the explosion that may be used either for semi-automatic or automatic firing. Receiver, sear normally in operative position, trigger, intermediate connections between sear and trigger whereby sear is moved to inoperative position when trigger is pulled, a second sear cooperating with other sear in semi-automatic firing, and means for rendering second sear inoperative in automatic firing.

Patent 1,456,625 29 May 1923
Dawson, Arthur T. and Buckham, George T.
Westminster, Eng.
Machine gun.
Improvements in Vickers and similar machine guns. Device for retaining firing spring and side lever axis pin of lock

in their assembled position, stop-piece for crank and resilient bush between crank-handle roller and spindle or spigot of this roller and improved sear and tumbler arrangement.

Patent 1,498,542 — 24 Jun 1924
Gorton, Walter T. — U. S. Army
Machine gun unit.
Design of sear, sear slide and side plates of aircraft machine guns (mounted in pairs) so that trigger motor may be mounted on either side as desired and gun properly fired thereby. (Browning)

Patent 1,530,702 — 24 Mar 1925
Russell, Herbert O. — Los Angeles, Calif.
Sear and sear release for machine guns.
Sear and sear release mechanism for use on bolt of Browning automatic machine gun. Bolt is slightly modified to hold the sear and sear release. Releases firing pin when a comparatively slight pressure is exerted on sear release. Used in connection with an electromagnetical trigger motor the direct action of which exerts the releasing pressure on the sear release.

Patent 1,689,482 — 30 Oct 1928
Green, Samuel G. — Gray, Ga.
Machine-gun unit.
Sear release mechanism applicable for synchronized guns mounted on aircraft. Improved for application to cal. .50 guns. Establishes direct connection with sear thereby avoiding linkage with its lost motion and backlash; means for traveling a minimum distance for assuring clearance when bolt arrives in battery out of time with the trigger. Accessible connection with motor of plane.

Patent 1,924,159 — 29 Aug 1933
Kellotat, William F. — Portland, Oreg.
Automatic firing action for guns. (Cl. 42–3)
Provides full automatic firing action particularly suited for light weapons in which breech block or slide is not locked in battery. Characterized by a sear actuator that is axially displaceable to operate the sear and that is elevated by the breech block when out of battery and depressed by a member on the block as the block arrives in battery.

Patent 2,108,026 — 8 Feb 1938
Sutter, Charles, Suresnes, France, and Boussel, Andre, Courbevoie, France
Automatic firearm. (Cl. 89–27)
Mechanism on recoil-operated automatic arms is subjected to the action of accelerating members consisting of resilient elements (springs, Belleville washers, rubber, etc.) which serve at same time as damping members for the sear when the firing is stopped. Sear carried by a movable member which can be displaced in direction towards which the sear is urged against the action of resilient members.

Patent 2,159,126 — 23 May 1939
Birkigt, Marc — Bois-Colombes, France
Automatic firearm. (Cl. 42–3)
Relates to guns with movable breech system adapted to recoil when shot is fired against action of a counterspring and to be locked when brought back into firing position. Sear adapted to hold movable breech system in rear position thereof, so as to stop the working of the firearm and control the working thereof, cooperated with locking member, carried by movable breech system, which locks said system in forward or firing position.

Patent 2,397,387 — 26 Mar 1946
Trevaskis, Henry — Foleshill, Eng.
Firing mechanism of automatic gun. (Cl. 89–27)
A sear serves to retain breech block in a rearward position against spring load, said sear being displaceable against a sear spring to permit the breech block to advance to its firing position, whence the breech recoils to its rearward initial position. Insures full and positive contact between sear and breech block in an automatic manner.

Patent 2,465,487 — 29 Mar 1949
Sampson, Frederick W. and Hamisch, Paul H.
Dayton, Ohio
Semiautomatic firearm converted to full automatic. (Cl. 89–140)
Improvement in carbine as disclosed in Patent 2,308,283 (1943). Provides means whereby it may be selectively operated as full automatic. Provides selector arm for continuous fire which trips sear.

Synchronizers

Patent 1,298,886 — 1 Apr 1919
Challenger, George H. — Westminster, Eng.
Bullet-deflector for the propellers of aeroplanes and similar aircraft provided with guns.
Means whereby bullets that leave gun while propeller blades are in the line of fire are deflected without impairing efficiency of propeller.

Patent 1,298,887 — 1 Apr 1919
Challenger, George H. and Savage, Harold A.
Westminster and Bexley Heath, Eng.
Automatic gun.
To convert gun of Lewis, Hotchkiss or similar type to operate like one operating like Vickers automatic gun in which when gun is ready for firing, bolt is in its forward position with cartridge in barrel, actuation of trigger or sear then merely releasing striker. Particularly applicable for firing between propeller blades of aircraft and for firing to be controlled by aircraft engine. Striker spring becomes energized during forward movement of striking post.

Patent 1,339,390 — 11 May 1920
Hazelton, George — Battersea, Eng.
Machine-gun.
Relates to Lewis-type guns, employing gas cylinder in connection with a fixed barrel. Improved form of firing mechanism particularly adapted for firing through propeller path by operation of mechanism synchronized with propellers so gun is automatically fired through path without bullet coming in contact with blades of propeller.

Patent 1,372,944 — 29 Mar 1921
Constantinesco, Gogu — Weybridge, Eng.
Method and means for actuating gun-triggers.
Apparatus for actuating gun triggers by liquid wave transmission, particularly for machine guns firing through propellers on aeroplanes at intervals determined by speed of propeller shaft. Cam of generator driven from engine.

Patent 1,444,849 — 13 Feb 1923
Paumier, Emile L. A. — Paris, France
Machine gun.
Allows machine gun or twin machine guns to be operated by a driven shaft. Shaft may be the screw shaft of an aeroplane and in such case fire is regulated so bullets always pass through blades of screws or propellers.

Patent 1,450,653 — 3 Apr 1923
Swebilius, Carl G. — New Haven, Conn.
Automatic gun.
Pertains to firing control mechanisms of automatic firearms. Utilizes impulses of a higher frequency than the firing frequency of an automatic gun to effect the firing of the gun at definite times. Trigger operated by impulses transmitted thereto and providing means on trigger to render it inoperative to effect firing of gun except on operation of trigger next succeeding complete breaching of gun. Utility in connection with guns mounted on planes to shoot between blades for synchronizing.

Patent 1,454,137 — 8 May 1923
Ross, Oscar A. — New York, N. Y.
Synchronized machine gun for airplanes.
Plurality of machine guns mounted on airplane and adapted to fire between blades of propeller, means actuated by motor for firing each one of guns in a given sequence in synchronism with blades between passing of given point by one blade and passing of same by next blade.

Patent 1,466,951 — 4 Sep 1923
Edwards, Daniel G. — Hopkinsville, Ky.
Fire-control means for aircraft machine guns.
Controls fire for shooting through the plane of revolution of propellers and between the blades. Electro-magnetic means for determining firing of gun and a contact device operated in accordance with revolving propeller to control circuits of said magnetic means for governing fire.

Patent 1,471,359 — 23 Oct 1923
Russell, Herbert O., Detroit, Mich. and Paulus, Charles L., Dayton, Ohio
Automatic advance for synchronizing gun control.
Means for automatically timing the firing impulses in the Nelson gun control to compensate for any increase or decrease in rotational speed of engine shaft in order that bullets will pass between blades of the propeller.

Patent 1,486,909 — 18 Mar 1924
Lucas, Owen D. — London, Eng.
Means for controlling the fire of automatic guns carried by aircraft.
Controlling means are of such a character that the moment of application of the electric current for igniting ammunition is determined by the position of the blades of the propeller in conjunction with position of gun mechanism, whilst duration of application of the current is determined in the case of electrically ignited ammunition by time ammunition requires for its explosion.

Patent 1,496,749 — 3 Jun 1924
Sutton, Harry A. — Dayton, Ohio
Synchronizing gun control.
Improved control in which trigger of a machine gun is synchronously operated with the speed of the aircraft engine. Impulse generating unit in which an impulse lever is operated by the impulse cam and in which a bell crank lever is adapted to be moved into and out of position between cam and impulse lever so as to serve as an idler while transmitting impulses to lever.

Patent 1,504,394 — 12 Aug 1924
Sutton, Harry A. and Paulus, Charles L. — Dayton, Ohio
Synchronizing gun control.
Mechanical means for automatically rotating one section of the impulse generator shaft in relation to the other section thereof for automatically timing the firing impulses of the Nelson gun control to compensate for any increase or decrease in rotational speed of engine shaft and propeller in order that bullets will pass between blades of the propeller and not damage same.

Patent 1,504,712 — 12 Aug 1924
Russell, Herbert O., Detroit, Mich., and Paulus, Charles L. Dayton, Ohio
Control for synchronized guns.
Simple means for purpose of starting and stopping fire of a machine gun when operated by a gun control or synchronized gear. Especially adapted for gear in which impulse is transmitted from mechanism to gun by a wire cable within a casing. Starting and stopping of operation accomplished by shortening and lengthening effective length of casing relatively to cable.

Patent 1,528,952 — 10 Mar 1925
Russell, Herbert O., Detroit, Mich., and Paulus, Charles L. Dayton, Ohio
Synchronized gun control.
Control adapted for use upon and in conjunction with the control or joy stick of an airplane. Connected with firing mechanism of a plurality of machine guns so that one or more guns may be fired at a time.

Patent 1,530,700 — 24 Mar 1925
Russell, Herbert O. and Fletcher, Wallace R. Dayton, Ohio
Electrical synchronizer and trigger motor for automatic machine guns.
Electrical device adapted to so time the firing of a machine gun that it may be fired between the rotating blades of an aircraft propeller at any and all speeds thereof. Uses mechanical action of an energized electromagnet to cause a trigger to mechanically strike the sear release or other initial release of gun.

Patent 1,562,424 — 17 Nov 1925
Nelson, Adolph L. — Indianapolis, Ind.
Control mechanism for aircraft guns.
Mechanical construction features of gun and gun control designed to be mounted on airplane engine and to fire between blades of propeller. Transmission of timing impulses from propeller engine to gun by mechanical connection. Also provided for cooperation of this connection with a single shot trigger mechanism.

Patent 1,592,500 — 13 Jul 1926
Paulus, Charles L. and Kauch, Robert — Dayton, Ohio
Machine gun synchronizer.
Relates to aircraft synchronizers operated by intermittent explosion pressure impulses of one of the cylinders of the engine of an aircraft. Consists of a valve tapped into rearmost engine cylinder and normally held closed, to be opened only so long as delivery of pressure impulses is desired and a trigger motor on gun connected through a pressure line with valve, latter being controlled through a cable extending to a lever on the joy stick.

Patent 1,595,993 — 17 Aug 1926
Cecero, Ralph S. — Waterbury, Conn.
Automatic machine gun.
Mechanism whereby gun may be fired between blades of propeller during fight. Mechanism for determining timing of firing. Motor operated mechanism associated with machine gun trigger for positively operating trigger to fire gun. Capable of being operated and controlled by a gunner at any distance from the machine.

Patent 1,803,349 5 May 1931
Pfeiffer, Christian Hartford, Conn.
Automatic firearm.
Applicable to Patent 1,293,021 (1919) (Browning machine gun). Adapted to be used with a synchronizing mechanism and "trigger motor" of known design; so constructed that motor can be applied at either side. Likewise feeding of cartridge belt in either direction.

Patent 1,848,720 8 Mar 1932
Horton, Winthrop S. Farmingdale, N. Y.
Gun synchronizer.
More compact arrangement of machine gun synchronizer unit and improved means for maintaining proper alignment between cam and its follower.

Patent 2,465,749 29 Mar 1949
Rataiczak, Francis I. Dayton, Ohio
Breech bolt mechanism. (Cl. 89–132)
Improved fire control mechanism for use in .60 caliber machine gun (T17E3). Means for synchronizing firing of gun with the operation of an airplane propeller or other moving part. Sear and sear trigger mounted within bolt so as to be movable therewith.

Toggles

Patent 712,972 4 Nov 1902
Schwarzlose, Andreas W. Suhl, Ger.
Automatic firearm.
Toggle-link breech mechanism employed in fixed barrel automatic arms; breech mechanism opened by the gases pressing on bottom of empty cartridge shell.

Patent 804,506 14 Nov 1905
Schwarzlose, Andreas W. Suhl, Ger.
Toggle-link lock for recoil-loading guns.
Improvement on toggle-link locks in which parts of the links lie one within the other when in the locked position; obviates defects in previous links and in more suitable form for hand-firearms.

Patent 839,778 25 Dec 1906
Luger, Georg Charlottenburg, Ger.
Recoil-operated firearm.
Improved spring devices for toggle links which operate breech-bolt, whereby the full efficiency of the spring tension and leverage will be utilized to close the toggle links but will be less effective as a retarding force when the links are opening in consequence of the recoil.

Patent 851,538 23 Apr 1907
Luger, Georg Charlottenburg, Ger.
Recoil-operated firearm.
Relates to means for effecting the raising of the toggle joint in breech-closing mechanism out of the extended or closed position. Cam projections provided on forward link at suitable point in front of middle link pin. Provides retarding action against recoil action.

Patent 1,147,780 27 Jul 1915
Borchardt, Hugo Charlottenburg, Ger.
Toggle breech mechanism for automatic firearms.
Device by which toggle joint can be opened even when it is located in the extended position or below it. This result is attained by the action of an inertia member which on recoil of arm imparts to joint an initial breaking movement, either directly by acting upon the middle hinge or indirectly by acting on one of toggle levers provided with appropriate stops or abutments.

Patent 1,457,477 5 Jun 1923
Walther, Fritz and Georg Zella-Mehlis, Ger.
Automatic firearm.
Improved toggle mechanism for recoiling barrel guns. Bending of toggle joint and opening of breech slide is effected by a lateral cam on rear toggle lever mounted in the breech slide, which cam after the recoil of the receiver abuts on a spring controlled arm mounted on the wall of the receiver.

Patent 1,160,831 16 Nov 1915
Borchardt, Hugo Charlottenburg, Ger.
Automatic firearm with toggle-joint.
Detent for automatic firearms with toggle joint wherein action of detent is rendered dependent on movement of toggle joint (instead of breech bolt). Toggle joint, especially its central point, covers, during 1st opening movement of breech, a distance which is a multiple of that of the breech bolt. Trigger thus is released only when breech is actually completely closed.

Triggers

Patent 782,716 14 Feb 1905
Bennett, Thomas G. New Haven, Conn.
Bolt-gun.
Improvement in rotary-bolt thumb trigger gun described in Patent 632,090 (1899) to simplify construction and increase efficiency and safety. Trigger and sear brought so close together that leverage between them is reduced to minimum.

Patent 817,198 10 Apr 1906
Smith, Morris F. Philadelphia, Pa.
Gas-operated firearm.
Improved means for mounting trigger, breaking connection between trigger and sear, mounting sear, locking sear against movement, locking and operating breech bolt, cushioning breech-bolt, etc.

Patent 818,920 24 Apr 1906
Smith, Morris F. Philadelphia, Pa.
Gas-operated rifle.
Combination, with movable breech bolt, a firing pin and a sear, of a trigger for moving sear out of engagement with firing pin and connections between trigger and breech bolt for moving trigger out of engagement with sear on movement of breech-bolt.

Patent 859,990 16 Jul 1907
Stern, Maurice Philadelphia, Pa.
Revolver.
To provide revolver with trigger spring which is supported by frame and trigger so as to relieve all pressure from the guard heretofore supporting same and thus prevent inaction of trigger spring whenever guard becomes displaced. To provide coiled spring which offers even resistance to movement of trigger. Guard serving as cover for trigger and when removed permits free access to trigger spring. Other improvements.

Patent 987,543 21 Mar 1911
Borchardt, Hugo Charlottenburg, Ger.
Trigger mechanism for automatic firearms.
Trigger rod or sear is not only rotatable but also longitudinally displaceable resiliently relatively to its point of rotation in order that when breech returns after firing and trigger is still pressed, the trigger rod or sear may be able to yield and return to its engaged position when breech moves forward.

Patent 1,087,371 17 Feb 1914
Heinemann, Karl Berlin, Ger.
Machine gun.
Improvement in trigger mechanism of guns of Maxim type. Arranges member of trigger mechanism directly acted upon by gunner so that it is pulled backward by forefinger or medium finger instead of being pushed forward by means of the thumb. Thereby gunner is enabled to firmly grasp handle with palm and thumb.

Patent 1,125,578 19 Jan 1915
Mauser, Paul Oberndorf, Ger.
Automatic firearm.
Improved means for locking and releasing the trigger in arms in which trigger is automatically locked when breech is not closed so that firing is possible only when breech is closed.

Patent 1,230,930 26 Jun 1917
Schouboe, Jens T. S. Holte, Denmark
Trigger mechanism for automatic firearms.
Recoil lever, which, actuated by a spring contracted by the recoil, serves to carry barrel and breech block with the breech parts forward into firing position, is locked after the recoil, when the trigger is let go, so that it cannot carry breech forward into firing position, thus preventing insertion of any cartridge into chamber after firing has ceased.

Patent 1,240,068 11 Sep 1917
Lytton, Edward London, Eng.
Firing mechanism for small arms.
Trigger arrangement having toggle means, which, when maintained at approximately the dead center position, are adapted to hold the firing pin or other operative means at cock and means for throwing the toggle off and over the dead center when the arm is to be fired.

Patent 1,561,756 17 Nov 1925
Tucker, Leonard London, Eng.
Trigger mechanism of machine guns and automatic small arms.
Improved device for converting weapon at will from automatic to single shot. Will not allow more than one shot to be fired at each operation of trigger when device is set to "single fire." Sear is made longitudinally movable and placed under influence of a spring.

Patent 1,596,177 17 Aug 1926
Haubroe, Werner C. L. Copenhagen, Denmark
Trigger mechanism for automatic small firearms.
Trigger mechanism for recoil-operated small arms: Cartridge inserted all the way into chamber will always be fired when barrel and breech block have been moved to foremost position; barrel and breech block will always remain in withdrawn position when trigger is released; safety prevents these pieces from moving forward when gun is secured; pieces prevented from moving forward when safety device is turned into an intermediate position.

Patent 1,738,502 3 Dec 1929
Pfeiffer, Christian and Moore, Frederick T.
Hartford, Conn.
Trigger mechanism for machine guns.
Improvements in Browning machine guns to prevent automatic continuous firing of the gun and to require trigger to be separately moved for the firing of each shot.

Patent 2,050,539 11 Aug 1936
Moore, Frederick T. and Tansley, George H.
Hartford, Conn.
Firing mechanism for machine guns. (Cl. 89–27)
Improvement on Browning machine gun (Patent 1,293,-021—1919). Two separate movable triggers which can be operated simultaneously to fire gun, or successively. If either one of triggers is pressed separately, firing does not occur, but repetitive firing is effected by pressing remaining trigger. On cessation of firing breech bolt automatically retained in rearward or forward position as gunner may elect.

Patent 2,069,244 2 Feb 1937
Green, Samuel G. Gray, Ga.
Trigger mechanism for machine guns. (Cl. 89–27)
Hand trigger mechanism for aircraft guns which may be readily interchanged with a right or left trigger motor without altering the standard equipment of the gun or interfering with its operative parts and which utilizes the attaching means of the trigger motor.

Patent 2,119,536 7 Jun 1938
Green, Samuel G. Gray, Ga.
Trigger for machine guns. (Cl. 42–69)
Trigger capable of automatic or semi-automatic firing which may be readily installed to replace present Browning trigger without altering the gun or modifying its normal action. Made in form of a compound lever and a slide which is moved into inoperative position when it is desired to fire automatically and into operative position for semi-automatic firing.

Patent 2,474,180 21 Jun 1949
Browning, Val A. Ogden, Utah.
Firing mechanism. (Cl. 42 69)
Improved firing or trigger mechanism for firearms. Economy, improved design, simplicity. Trigger has relatively small movement when pulled.

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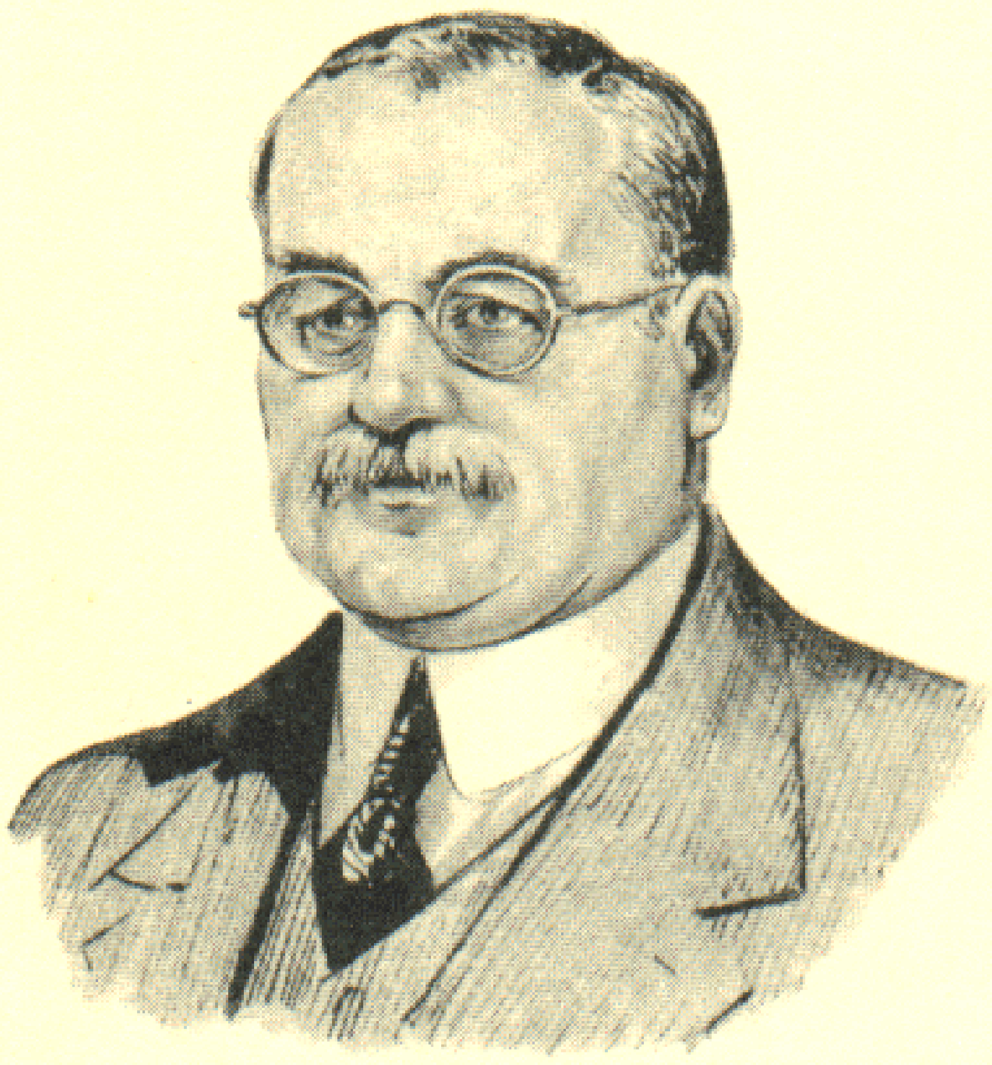
NOTE: Numbers in **boldface** refer to illustrations in Part XI.

U. S. GOVERNMENT PRINTING OFFICE: 1956 O—358375

MENDOZA

NORDENFELT

SHPITALNY



KJELLMAN

REVELLI

SCHOUBOE

BIRKIGT

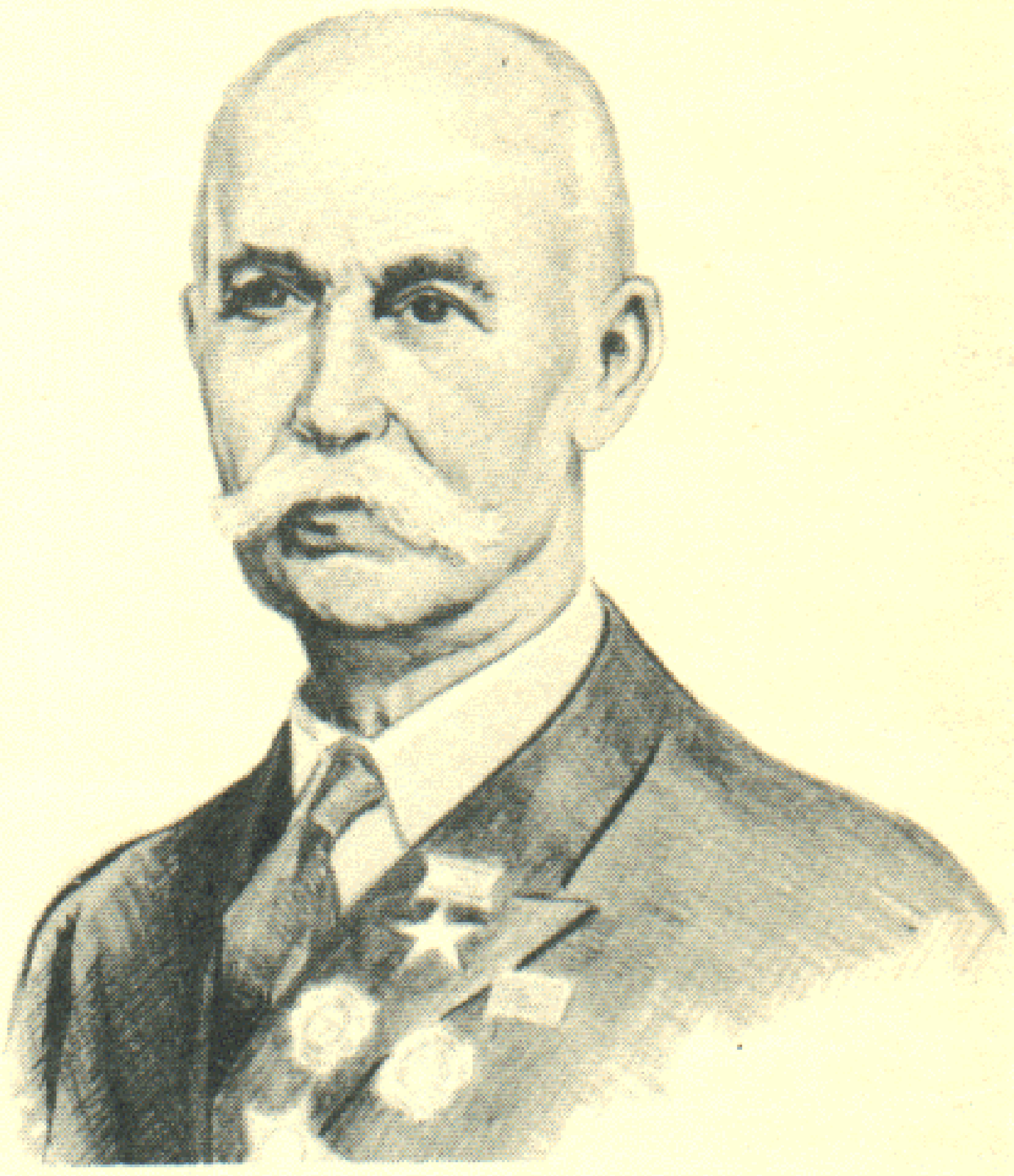
LUGER

WALTHER

MAUSER

von DREYSE

BERTHIER



TOKAREV