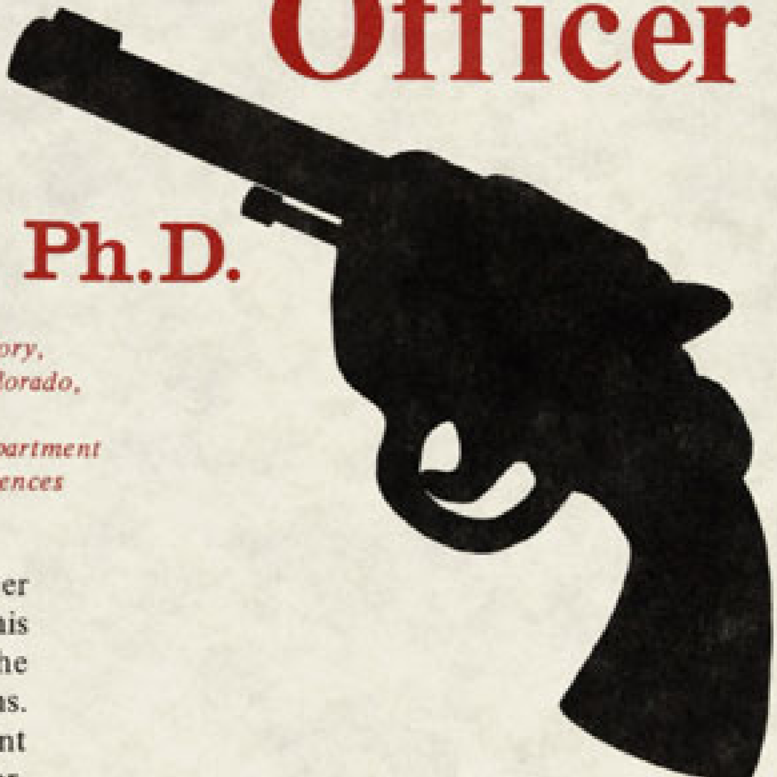
Ballistic Science for the Law Enforcement Officer



CHARLES G. WILBER, Ph.D.

Professor of Zoology and
A Director of the Forensic Science Laboratory,
Colorado State University, Fort Collins, Colorado,
Deputy Coroner, Larimer County,
Special Investigator, Fort Collins Police Department
Fellow, American Academy of Forensic Sciences

The author's thirty-year career has laid the groundwork for this uniquely scientific study of the ballistics of civilian firearms. Written for the law enforcement officer, the college instructor, the investigator, coroner, district attorney, competitive shooter, and the avid hunter, this book explains clearly and understandably the physics and chemistry involved when bullet meets target, the types of wounds or holes produced by various firearms, suggestions of firearms and cartridges to be used for special purposes, and performance information. For readers wishing to perform their own ballistic research, the author includes a description of methods for inexpensively gathering data. All of the latest scientific advances in ballistics are discussed in this professional and informative book.

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CONTRIBUTOR

Irvin K. Owen
Office of University Safety
Indiana University
Bloomington, Indiana

PREFACE

LAW ENFORCEMENT OFFICERS in the United States use, as a proper and necessary part of their profession, a variety of tools that are classified as firearms. Among these essential tools of their occupation are revolvers, pistols, shotguns, rifles, gas grenade launchers. Most progressive police agencies in the United States provide regular, competent tactical training in the use of these instruments by their officers. This book does not pretend to give advice on the tactical use of police firearms.

There is rather widely spread a less than satisfactory understanding among law enforcement personnel of the basic laws of physics and principles that govern the functioning of firearms. These laws and principles are conveniently included under the specialty known as ballistic science. A search of English language publications has failed to reveal any book devoted to ballistic science with particular reference to law enforcement officers. It therefore seemed appropriate and useful to create such a book.

The various chapters of this book have been tried out or tested using as "guinea pigs" my many friends and students in the law enforcement community. Their responses to and criticisms of my lectures, workshops, and classes in which various parts of the material in this book were presented are valuable. It was these reactions that finally persuaded me to put the material together in book form.

During the many years that I have served in a number of universities as a professor, I have had impressed on me the truth of the saying, *"Repetitio est mater studiorum";* repetition is certainly the mother of learning. Readers of this volume will find that concepts, ideas, generalizations are repeated in various ways to fix the impression, as so many teachers' manuals advise. Such repetition is, by many, bemoaned; but experienced teachers understand its worth.

Because firearm safety is so critical for all persons who keep and use such devices, in accord with the *rights* provided to all Americans by the Bill of Rights, I felt it imperative to include at the very beginning of this book the "Ten Commandments" of firearms safety. Police officers should carefully observe these commandments on duty and off duty. They should be prepared to explain these commandments to all citizens within their jurisdiction.

Safety—Ten Commandments

Accidents do not just happen. They are caused by ignorance or disregard of safety rules. The following firearms rules are critically important. Learn and practice them until they become automatic for you, whether on duty or off duty; whether in your home or on a hunting trip.

1. TREAT EVERY GUN WITH THE RESPECT DUE A LOADED GUN.
2. WATCH THAT MUZZLE! Be able to control the direction of the muzzle even if you should stumble.
3. UNLOAD GUNS WHEN NOT IN USE. Take down or have actions open; guns should be carried in case to the shooting area.
4. BE SURE BARREL AND ACTION ARE CLEAR OF OBSTRUCTIONS, and that you have only ammunition of the proper size for the gun you are carrying.
5. BE SURE OF YOUR TARGET BEFORE YOU PULL THE TRIGGER; know identifying features of the game you hunt.
6. NEVER POINT A GUN AT ANYTHING YOU DO NOT WANT TO SHOOT; avoid all horseplay with a firearm.
7. NEVER CLIMB A FENCE OR TREE OR JUMP A DITCH WITH A LOADED GUN; never pull a gun toward you by the muzzle.
8. NEVER SHOOT A BULLET AT A FLAT, HARD SURFACE OR WATER; at target practice be sure your backstop is adequate.
9. STORE GUNS AND AMMUNITION SEPARATELY, beyond the reach of children and careless adults.
10. AVOID ALCOHOLIC BEVERAGES BEFORE OR DURING SHOOTING.

American ballistic scientists will inevitably be forced into the metric system. Useful references are available to make the transition reasonably nontraumatic. Police officers are advised to be familiar with such books as the following:

Christine N. Govoni Vogel, *How to Convert the Metric System into the U. S. System and Vice Versa*, 2nd ed. Chicago. Adams Press, 1973 155 pages.

R. A. Hopkins, *The International (SI) Metric System and How It Works*. Reseda, Polymetric Services, Inc., 1973, 281 pages.

Scientific terms are used in this book. A scientific dictionary such as the following will be helpful:

H. G. Jirrard and D. B. McNeill, *A Dictionary of Scientific Units,* 2nd ed. London, Chapman and Hall, 1964, 204 pages.

Note that British spellings are used in this dictionary.

This book is designed for use by all levels of the law enforcement community. It should also serve as a dynamic text in college level ballistic courses. The material can be used in a single course or could serve as the basis of several shorter courses. Serious firearms users (competitive sport shooters, hunters, game managers, and teachers of firearms subjects) should find the book a useful reference. It is also my suggestion that attorneys, coroners, medical examiners, and judges may find good reason to consult the book for basic information on firearms of the type used by police.

The following women on the staff of the Department of Zoology-Entomology, Colorado State University accepted a burden far beyond the call of duty, and produced the final typescript from my somewhat bizarre drafts; their endeavors are deeply appreciated: Kirby Maxwell, Jamie Marschner, Janelle Simon.

Many other wonderful persons have responded to my requests for help in connection with this book. I wish that I could thank them all individually in an adequate manner.

Dr. David O'Keefe of Corrales, New Mexico dug out and made available to me a treasury of basic but hard-to-come-by references on propellant powder technology.

Commercial firms have been helpful in making available to me tables, art work, and photographs for use as illustrations. My sincere gratitude is due especially to the Remington Arms Corporation for rapid and cooperative help with illustrations.

Finally I acknowledge with thanks and pleasure the heroic efforts of my wife, Clare Marie Wilber, in the proofreading of drafts, galleys and page proofs.

CHARLES G. WILBER

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—1———

INTRODUCTION

A Definition

According to the volume *Ordnance Technical Terminology* published by the U. S. Army Ordnance School (1962), ballistics is a "branch of applied mechanics which deals with the motion and behavior characteristics of missiles. . .and of accompanying phenomena. It can be conveniently divided into three branches: *interior ballistics,* which deals with the motion of the projectile in the bore of the weapon; *exterior ballistics,* which deals with the motion of the projectile while in flight; and *terminal ballistics,* which is concerned with the effect and action of the projectile when it impacts. . ."

A useful reference for weapons terminology and definitions was published by Quick (1973).

Weapon Development

In the development of weapons, historically man has used a variety of devices (throwing sticks, slings, etc.) to increase the velocity of whatever object is being driven toward an enemy. By experience, prescientific man was aware that increased velocity increases the effectiveness of any missile.

"In brief, man took advantage of the physical law of kinetic energy which remains as the fundamental law in the study of missiles and the formation of wounds" (Beyer, 1962). A rough outline of these developments is seen below:

Time Period	*Missile Velocity*
(a) Before Gunpowder	Several hundred feet per second
(b) 14th to 20th Century	Increased to about 2000 feet per second
(c) 1900 to 1918	Up to 4000 feet per second
(d) 1918 to present	Up to 7000 feet per second

The essence of increasing weapons effectiveness has been the development of ever greater missile velocities.

As a general rule of thumb, supported by actual tests, a missile having 58 foot-pounds of energy can produce a casualty in man. Lesser kinetic energies are casualty producing only under unique circumstances.

This book will emphasize again and again the crucial role of kinetic energy in determining bullet effectiveness. Moreover, it will be shown that bullet velocity is by far the single most important factor in determining kinetic energy.

Velocities

Popular gun magazines are filled with articles purporting to show that velocity or kinetic energy mean little in weapon effectiveness. However, for the police officer the effectiveness of his weapons is too serious a matter to permit rhetoric a place in decision making.

The usual police weapon, a handgun, is a sidearm of less than 0.50 caliber. Muzzle velocities are ordinarily no greater than 800 feet per second (ft/sec). (German military pistols produce velocities up to 1200 ft/sec.) Minimal wounds are caused by such weapons unless vital structures in the body are hit: brain, heart, kidney, for example.

The Army .30 caliber carbine is used by some police officers at times. It drives a 110-grain bullet at a muzzle velocity of 1975 ft/sec. One might consider this piece a "supersidearm."

Rifles used for special purposes by police will have muzzle velocities over 2800 ft/sec. The effectiveness of rifles is in a class quite apart from sidearms. Even rifles that are of mediocre effectiveness are more potent than the most effective handguns.

The British have always had a propensity for choosing cartridges that are heavy and are driven at relatively low velocities. In some quarters in the United States that influence is still felt. Some firearms "buffs" would advise peace officers to use in their .38 Special revolvers a cartridge having a 200-grain bullet driven at a low velocity. In fact it is said from time to time by less well-informed persons that high velocities in bullets should be avoided because the slug will pass through the target so rapidly that it cannot cause damage. Such a view reveals a lack of understanding of the basic physics of motion.

Commercial loadings of the 200-grain .38 Special cartridge give test velocities by chronograph, from a two-inch-barrel revolver (snubby), averaging 570 ft/sec; the average muzzle energy is a mere 145 foot-pounds (ft-lbs). At such velocity the perforation of auto safety glass is problematical. The perforation of the sheet steel of an auto body by such a heavy, slow-moving bullet is improbable.

The thesis will be developed in this book that the laws of physics apply to a firearm as they do everywhere else in nature. Viewpoints that are at variance with the basic laws of motion, energy, and work will be shown to be nonproductive in the advancement of ballistic science.

Bullet Comparison

In the day-to-day language of law enforcement the ballistic expert is ordinarily considered to be the specialist who identifies a bullet as having been fired from a given gun. The specialty requires little ballistic science as an essential element, but does require a wealth of information about tool marks and the principles of tool mark identification.

Bullet comparison is properly a specialized part of tool mark identification. In bullet comparison the comparison microscope is used. Formerly this specialized tool was called "ballistic" microscope by vendors. However, at the present time the proper designation of bullet comparison microscope is used.

This volume on ballistic science makes no pretense to consider bullet comparison. A useful introduction to bullet comparison is to be found in Burrard (1962). The three volume classic on firearms identification by Mathews (1973) is mandatory for any bullet comparison work. Details of bullet and cartridge construction may be found in Barnes (1972), Bearse (1966), and White, Munhall, and Bearse (1967).

A new tool, the scanning electron microscope, has already proven to be an instrument of outstanding potential value in bullet identification.

Handguns

Revolvers and pistols, the customary weapons supplied to police, are relatively low-velocity guns. Consequently in dealing with these weapons one is considering low-velocity, low-energy ballistics.

If one turns attention to high-powered rifles, velocities and energies reach levels much greater than is possible with handguns by at least an order of magnitude or more.

These considerations must be kept in mind in any discussion of small arms ballistics. Some observations and principles that derive from rifles may not be extrapolated to handguns without ascertaining that they really apply. Certain ballistic characteristics of pistols and revolvers are related to their low-velocity limitations; these characteristics are not always directly applicable to the ballistics of rifles, and vice versa.

Nonlethal Weapons

The question is frequently asked why nonlethal weapons are not used by police in the United States. A simpler answer is that no such weapons exist and the probability of their development is remote indeed.

Nightsticks (batons) and tear gas devices are used by police officers under appropriate conditions. The so-called beanbags have been touted as harmless stun-gun instruments. However, experienced forensic scientists realize that these projectiles, if they are to be effective must be fired with a force that is great enough to cause severe injury and even death under some circumstances.

The firing of an hypodermic syringe filled with an immobilizing drug at a dangerous aggressor sounds attractive; it is an unrealistic option. Considerable experience is now available about the effects of such immobilizing instruments as a result of extensive trials in the laboratory, in the field, and in zoological gardens using a variety of animal species. The experience does not suggest that these drug dispensers will have any value for police, aside from animal wardens.

For example, bears resemble man in size and general configuration. Piekielek and Burton (1975) used the drug phencyclidine hydrochloride to immobilize bears. Even the effective manual injections of the drug required an average time, from injection to immobility, of 30 minutes; the time range for effect was from 3 to 85 minutes. During a 30-minute period before "knock-down" a person bent on mischief could cause considerable damage.

Moreover, there are unpredictable and ill-understood personal peculiarities with respect to drug responses by people. For example, most people can take reasonable doses of aspirin without difficulty. A small percentage of persons are seriously harmed by even mild doses of aspirin. Similarly with immobilizing drugs, how is one to know that the person in front of him has a lethal sensitivity to the drug being issued? Moreover, the precise dose for desired effect is difficult to determine; it varies with age, sex, size, and physiological condition of the person who will receive the drug.

Because these kinds of weapons seem to hold little promise for police work, they will not be discussed further.

Some Limitations

This book is not concerned with general ballistics as a specialty which would include artillery and rocket science. Rather it attempts to focus on those aspects of ballistic science that are of special concern to peace officers.

In the United States, the revolver is by far the most widely used police service weapon; the self-loading pistol is second in importance, although its use is becoming more widespread. Hence it is that this book emphasizes the ballistics of handguns.

Police use shotguns for special purposes. Consequently it seems appropriate to include some ballistic data on the shotgun. Rifles are used for highly specialized purposes by police, e.g. antisniper activity, some kinds of hostage situations. Brief reference will be made, as appropriate, to rifle ballistics.

The tactical use of a particular weapon is not part of ballistic science.

Therefore one will not find in this book instructions on marksmanship nor procedures for using police weapons "on the street."

Safety precautions are of such an imperative nature that they are repeated in this book, as one would hope to find in all books that deal with firearms.

Examples of Police Weapons (Army, U. S., 1952)

The usual police weapons are either handguns or shoulder guns. Handguns are firearms that are designed to be held in one hand for firing. The contemporary practice of firing handguns with a two-hand hold does not vitiate this classification

Handguns may be either pistols or revolvers. The weapons in this class are sometimes called sidearms because they are carried on the officer's side, usually attached in some manner to his belt, although at times these guns may be carried under the arm in a so-called shoulder holster. These arms are small; "they are for short range and are generally used for defensive purposes only." Figure 1-1 shows several representative handguns in use by the police.

Shoulder arms are those that are braced against the shoulder when they are fired. In this way the shock of recoil is absorbed; increased accuracy in shooting results from the steadier hold. Included in shoulder arms are rifles, carbines, shotguns, and submachine guns. The latter may be fired from the shoulder or it may be fired by bracing it against the side of the body with both hands.

Weapons may be automatic, semiautomatic, or manual. A manual weapon (the usual revolver) requires the user to fire by pulling the trigger each time a cartridge is expended. The weapon is readied for the next shot by cocking the mechanism manually.

A semiautomatic firearm is one that is fired by pulling the trigger for each shot; but one complete cycle then is performed without further effort by the user; the cycle includes cocking, extracting the empty cartridge case, ejecting the case, reloading, and locking the breech. Guns of this sort reduce fatigue experienced in firing and increase the rapidity with which successive shots can be made by the user. "The semiautomatic feature prevents the firing of a continuous burst of fire with the consequent large consumption of ammunition. A semiautomatic gun is a weapon in which the cycle is interrupted at the completion of each full cycle, just before firing." In some weapons a switch permits the user to select automatic or semiautomatic fire at will.

An automatic weapon is one which continues to fire with no interruption as long as the trigger is held down by the user. To keep firing, the weapon need merely be supplied with ammunition from a long belt, or some sort of magazine. As long as the trigger is pressed and cartridges are fed into the

Figure 1-1. Handguns representing types that are available to police officers: (A) Star Model B® self-loading pistol, 9 mm Luger, 9 shot, 5-inch barrel, fixed sights, 37.5 oz. in weight; cartridge shown below gun; (B) Walther PPKS self-loading pistol, .380 or 9 mm short, 7 shot, 3.27-inch barrel, fixed sights, double-action, 23.5 oz. in weight; cartridge shown below gun; (C) Charter Arms Bulldog®, double-action revolver, .44 Special, 5 shot, 3-inch barrel, fixed sights, square notch rear sight, 19 oz. in weight; cartridge shown below gun; (D) U. S. Army Colt caliber .45 self-loading pistol, 5-inch barrel, overall length 8.5 inches, 40 oz. in weight, 7 shot, fixed sights; (E) Colt .357 Magnum Trooper® revolver, 4-inch barrel, 6 shot, 36 oz. in weight, adjustable rear sight, square butt, grooved trigger; and (F) HI-Standard®, derringer, 2-shot, .22 WRM, model DM-100, 3.5 inches over-under barrel, overall length, 5 inches, 11 oz. in weight, hammerless, double-action, top-break, fixed sights.

chamber the gun continues to fire. "Care should be exercised in the use of the term 'automatic firearm,' as it is commonly misapplied to weapons that are really semiautomatic. Outstanding examples of this usage are the so-called automatic pistols and shotguns."

Most state laws make the possession and use of fully automatic weapons illegal. The Federal government imposes a heavy tax on each automatic weapon every time it is transferred from one person or agency to another; this tax is a device to discourage civilian use of such weapons and to give a method of readily convicting persons who deal in such weapons—and juries are prone to decide "guilty" in most tax evasion cases.

The average citizen has no apparent need for fully automatic weapons. Their sporting and target shooting value are nonexistent; they are inherently dangerous.

The use of fully automatic weapons by police is of questionable value except in rare special cases. In such instances, units of the National Guard would probably be called up which would use such military fully automatic weapons as might be justified.

Police Firearms

The usual firearms are described below. The definitions are those given by the U. S. Army Ordnance School.

Revolver

This piece is a firearm with a cylinder having several chambers so arranged as to revolve on an axis and be discharged in succession by the same lock. Pistols are excluded from the classification. The lock is a mechanism for preventing unwanted movement of striking device in cartridge-gun combination before firing and for holding securely in position the cartridge-firing pin and for holding securely in position the cartridge-firing pin combination immediately before firing.

Pistol

(Figure 1-2) This handgun is a short automatic or semiautomatic firearm aimed and fired usually with one hand; it uses the force of the recoil to eject the empty shell and to insert a new round into the firing chamber. In police use the semiautomatic pistol (also called the self-loader) is gaining adoption. Fully automatic pistols are not used in the United States but are favored by some foreign military units.

Rifle

(Figure 1-3) For special purposes, such as antisniper activity, law enforcement officers may use the rifle. This item is a firearm having spiral grooves cut upon the surface of the bore to impart rotary motion to a bullet, thereby

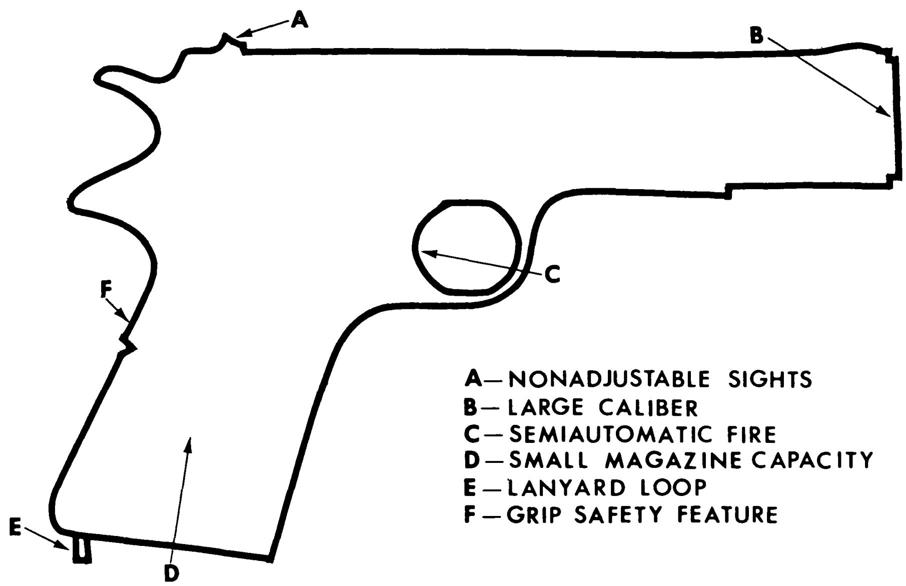

Figure 1-2. General characteristics of a handgun (self-loading pistol).

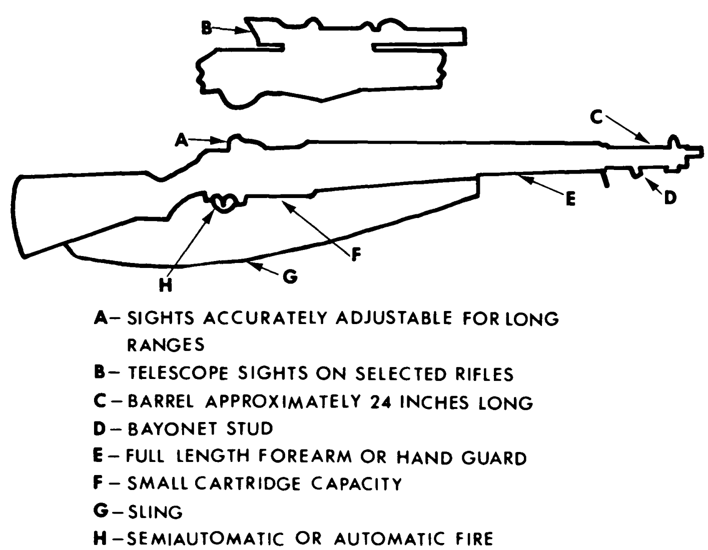

Figure 1-3. General characteristics of a military rifle. Automatic fire, bayonet lug, and full-length forearm are the primary characteristics that distinguish military from civilian rifles. Many police organizations use military rifles for special purposes.

stabilizing projectile and insuring greater accuracy of impact and longer range. A rifle may be designed to fire bullets automatically or semiautomatically; successive rounds may be loaded manually. The operation may be gas, recoil, or manual. A rifle is provided with a stock for firing from the shoulder; it may have a sling as an aid in carrying to insure steadier aiming.

Shotgun

The shotgun is being used more by police as its potential in law enforcement becomes more apparent. This weapon is a smooth-bore shoulder firearm. There are a number of types of shotguns: skeet, trap, field, sporting, riot. The 12-gauge riot shotgun is of particular interest to police. It is a manually operated, slide-action, repeating, hammerless shoulder weapon, having a solid frame. Some are equipped with iron rifle sights, a sling, and sling swivels.

Carbine

This is a firearm of short length and light weight. It is a rifle. In the United States the .30 caliber carbine was first issued in World War II to officers as a personal arm with improved performance over the .45 caliber pistol. Some police agencies use it for special purposes. It is magazine-fed and gas-operated; it is self-loading and may be fired fully automatically or semiautomatically. A civilian model that operates only semiautomatically is available.

Gun Barrel Sizes

During the discussion in this book, reference will be made to gauge and caliber as a measure of how big a gun barrel is. A brief explanation of the sizing of gun barrels will be helpful (Figure 1-4).

The nomenclature of gun barrel size is at first glance confusing. Shotguns are described, with respect to barrel inside diameter, by the term gauge. Originally, gauge meant the interior diameter of a shotgun barrel expressed by the number of spherical lead balls fitting it that would be required to weigh one pound. For example a 12-gauge shotgun has such a diameter of its barrel that twelve leaden balls of that same diameter weigh one pound; similarly, for the 16-gauge shotgun, sixteen leaden balls that fit it weigh one pound; and so on for the 18, 20-gauge, etc. The only exception is the popular boys' .410-bore shotgun which has an inside diameter of barrel measuring .410 inch.

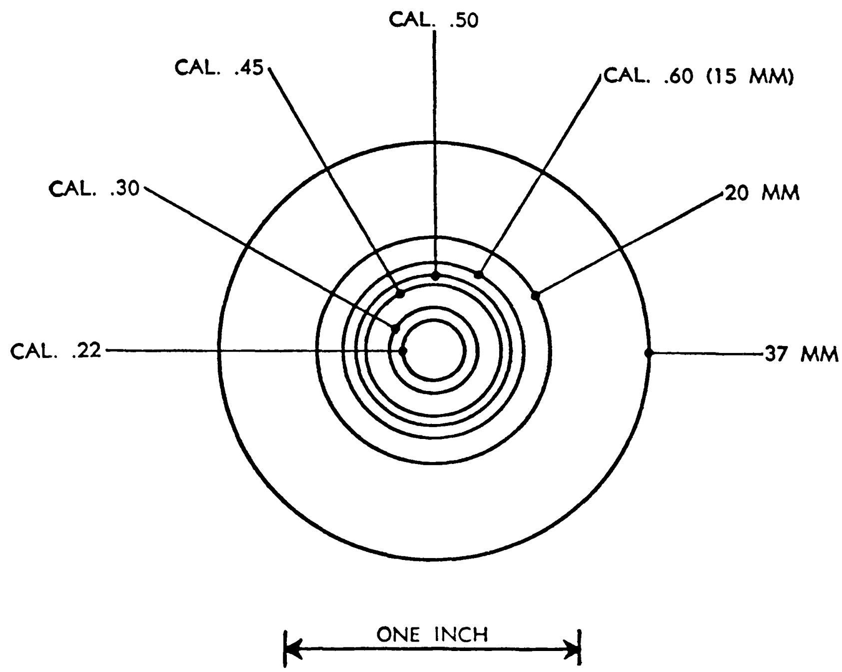

Figure 1-4. Drawing showing the relative bore sizes of small arms.

The diameter of various popular shotgun barrels of different gauges are given below.

Shotgun Size	*Barrel Diameter*	
Gauge	Centimeters	Inches
8	2.12	.835
10	1.97	.775
12	1.85	.729
14	1.76	.693
16	1.68	.662
20	1.56	.615

Rifled arms (handguns, rifles, carbines) have their barrel diameters measured in caliber, expressed either in millimeters or inches. Caliber is usually measured from the surface of one land to the surface of the land directly opposite. Often caliber designation is based on a nominal diameter and represents a close approximation rather than an exact measurement. The following tabulation of calibers likely to be encountered by peace officers will illustrate the sometimes confusing aspects of caliber measurements.

Caliber Designation	*Actual Barrel Diameter Inches*
.22 long rifle	.223
.25 ACP	.251
.32 ACP	.309
.30-06	.308
.38 Special or .357 Magnum	.357
.41 S&W Magnum	.410
.44 Special or Magnum	.429
.45 ACP	.452
9 mm Luger	.355
9 mm Short (.380)	.356
.308 Norma®	.308
.257 Roberts®	.257
.223 Remington (AR-15)	.254
.350 Remington Magnum	.3590

The designation ACP refers to cartridges for use in automatic pistols of that size.

Components of Small Arms Ammunition

Probably the clearest way to describe the components of small arms ammunition and their relations one part to another is to describe the commercial manufacturing of such cartridges.

The Office of the Chief of Military History, Department of the Army has published a detailed history of the Ordnance Department in World War II (Thomson and Mayo, 1960). In the volume on *Procurement and Supply* there is a short but clear description of the production line for small arms ammunition. Although the description is specifically for the St. Louis Ordnance Plant as it operated in World War II, the pattern is applicable to small arms cartridge production in general. The technological discoveries deriving from World War II experiences are incorporated into modern industrial cartridge production.

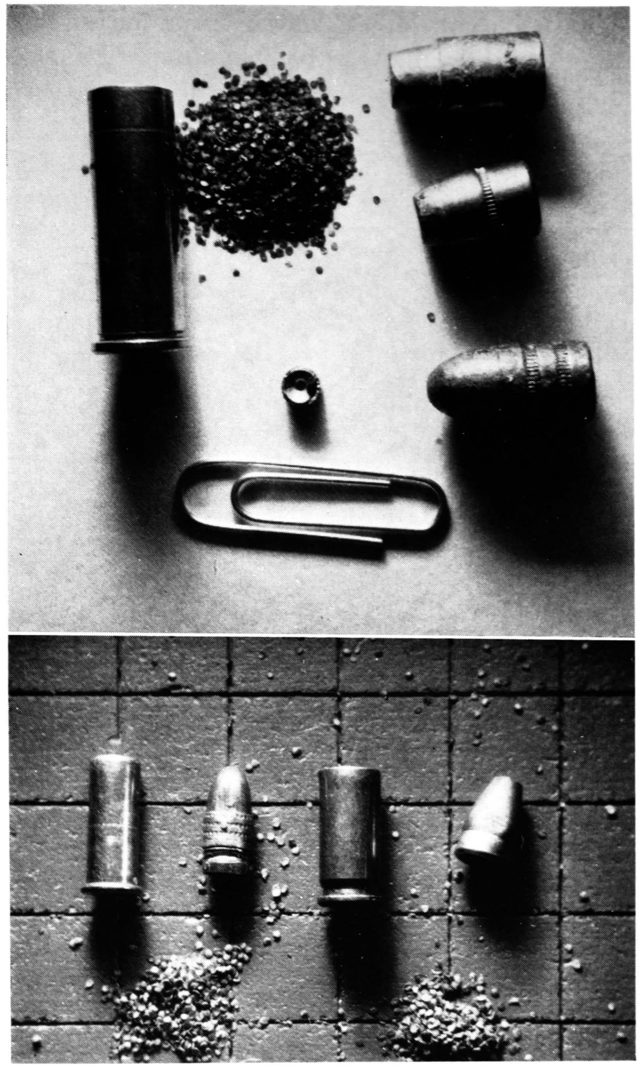

Figure 1-5. Photographs of cartridge components. Upper, .38 Special cartridge components: the brass case, the powder, and three styles of bullets found in such cartridges: a 158-grain lead semiwadcutter on top, 125-grain semijacketed soft-nosed bullet on the bottom. The primer is above the paper clip. Lower, to the left, the components of a .22 long rifle cartridge showing the brass case, the lead bullet, and the powder from the case; the priming compound is pressed into the rimmed head of the case and is not held in a special cup as in the center-fire cartridges. To the right, a separated .32 caliber revolver cartridge showing case, powder, and lead round-nosed bullet; the primer is not shown but is identical to the one used in the .38 Special cartridge. Size reference: the paper clip above is 1 3/16 inch long; the squares below are ½ inch.

The following description of manufacturing process for small arms cartridges is quoted *in extenso* from Thompson and Mayo (1960).

* * * * *

Description of Manufacture

Operations within the St. Louis Ordnance Plant, largest of the small arms ammunition facilities, may be cited as fairly representative of the production process. Covering an area of three hundred acres and employing more than forty thousand workers, this $130 million plant, operated by the United States Cartridge Company, was the largest employer of labor in the St. Louis area. Its first lot of ammunition was accepted by Ordnance on the day after Pearl Harbor, and during the next four years it turned out over seven billion rounds, including ball, armor-piercing, and incendiary types.*

Each cartridge made at St. Louis, as at other plants, consisted of three metal parts—case, primer, and bullet. The case was normally made of brass and, except for size, was similar to an artillery case. The primer, inserted in a pocket in the head of the case, was a small cup containing a sensitive explosive. When struck by the firing pin it burst into flame and ignited the propellant powder in the case. The bullet was an elongated lead slug covered with a thin jacket of gliding metal (a soft copper alloy) or copper-clad steel and was held firmly in the mouth of the case. Each of these parts had to meet rigid specifications governing its weight, shape, lineal measurements, and exterior finish—specifications that had been worked out during many years of experiment and been tested by firing millions of rounds at Ordnance proof ranges.*

Cartridge brass came to the St. Louis plant from Western Cartridge Company's nearby brass mill at East Alton, Ill., in the form of long strips coiled like huge rolls of cellophane tape. The first step in cartridge case manufacture at St. Louis was to feed these brass strips into a blank-and-cup machine that simultaneously stamped out round disks and formed them into cups. These cups were then washed, dried, and placed in furnaces to relieve stresses and strains developed during the cupping process. If not relieved, these metallurgical pressures might cause the case to crack during later manufacturing operations or during storage. Ordnance later transferred this phase of cartridge manufacture to the brass mills as the shipment to ammunition plants of strips containing a good deal of scrap was less economical than shipment of cups.

*(1) History St. Louis Ordnance Plant, OHF; (2) "Bullets by the Billion," a pamphlet for employees and visitors issued by the St. Louis plant in 1943, copy in vol. VI of plant history. For related data on ammunition see TM 9-1900, 18 Jun 45, and "Bullets by the Billion" issued by the Evansville plant. Reports of inspecting officers also contain a wealth of specific information. See OOP 333.1 St. Louis Ord Plant.

*For contemporary description data, see TM 9-1900, "Small-Arms Ammunition," 23 May 42.