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Historical Development of Shotgun Rifled Slugs and the Police Use of Shotguns

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Until about 1850, all long arms and handguns were smooth bore weapons. The armies of the major powers were armed with smooth bore muskets, adequate for hitting man-sized targets up to a 100 yards away. Prior to 1855, the United States military musket was a smooth bore, firing a .69 caliber (approximately 16-gauge) spherical lead ball (Petty and Hauser 1968). Most military long arms were full-length wood stocked muskets, whereas civilian "fowling pieces" were half-stocked arms. Shortly after their introduction, all Western powers adopted new rifled arms.

Shotguns are a continuation of the fowling piece tradition. They are still smooth bore weapons. Chokes first appeared on shotgun barrels around 1870. Previously, they were all completely open tubes so that either ball or shot could be fired. By 1880, most shotguns had choked barrels. This made it difficult to accurately fire lead balls because, for the ball to fit tightly in the barrel, it would not pass through the choke. Until 1900, many shotgun barrels with chokes were stamped "NOT FOR BALL." To compensate for the new choked shotgun barrels, lead balls were made smaller. Previously, a 12-gauge ball had approximately a .729-inch diameter and weighed about 1.33 oz. After choking was introduced, balls were typically made with a .645- to .660-inch diameter and weighed less than 1 oz (Sears 1981). When lead balls were made .040 inches smaller, the accuracy suffered because of the loose barrel fit. Even so, the balls survived in shotgun shell loads in the United States until 1941, and they are still available in Great Britain. These 12-gauge lead balls, commonly called "pumpkin balls," are so small that they can even roll down the barrel of a 16-gauge shotgun. Although inaccurate, they are very safe and not likely to become lodged in even the tightest choke. Some shooters hand-loaded their own shotgun shells, putting patches around the balls to make them fit more tightly.

Meanwhile, to take advantage of the new rifles, round balls were gradually being replaced by pointed projectiles such as the hollow-based bullet invented by French Captain M. Minie. The undersized Minie bullets could be loaded easily into a rifle muzzle without patching. Upon firing, the hollow, conical base spread to grip the rifling of the barrel. The great mass of bullet was forward as it traveled through the air with its skirt-like base behind. This badminton birdie shape made the bullet stable in flight. The same principle was later applied to shotgun slugs designed by Wilhelm Brenneke and Karl M. Foster. Brenneke's weight-forward design depended upon lightweight wads attached to the rear of the slug, whereas Foster's slug more closely copied the Minie design in that its base is hollow and lightweight (Figure 1).

Brenneke's Slugs

The Germans were pioneers in the development of shotgun projectiles other than lead balls. Patented shotgun projectiles appeared as early as 1890, the most famous being that of Wilhelm Brenneke. The Brenneke slug was first produced in Leipzig, Germany and patented in 1898 (Sterett 1966). It has only been slightly modified since then and remains in regular production. It is manufactured in several countries such as Germany, Belgium, Spain, Italy and France. The Brenneke slug has never been widely popular in the United States, perhaps because it is more expensive and less accessible than the American made Foster slugs.

The lead portion of the slug is made in full bore diameter so that it does not need to be initially expanded at ignition. The slug has 12 slightly angled swaged ribs. The nose has a small conical point and a square shoulder, unlike the rounded nose of the Foster type slug. The Brenneke slug has a slight hollow in the middle to allow for swaging as the slug passes through the choke. A wad column is attached directly to the base of the slug by a screw. The wadding serves not only as a gas seal with the barrel, but as a light tail portion to increase stability of the slug in flight (Figure 2).

Figure 1. The Minie bullet (left) pioneered the weight-forward, hollow base design closely copied by the Foster-type rifled slug (right).

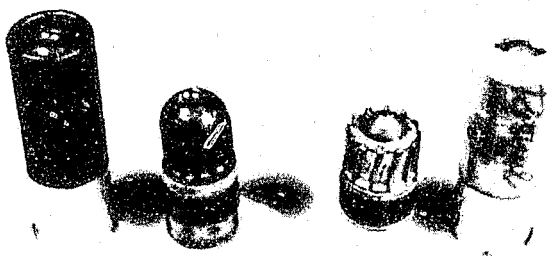

Figure 2. Both the Remington slug (left) and the Brenneke slug (right) use wadding to improve the gas seal between the smooth shotgun barrel and the projectile.

Foster Slugs

The most common rifle slug in the United States is based on the design of Karl M. Foster of Great Barrington, Massachusetts. He developed the slug in 1931 for his personal hunting use. Foster originally cast the slugs to shape in a 20-gauge barrel and then cut the grooves into the sides with a file. He subsequently obtained a custom-made mold from the Lyman Company (Middlefield, CT) and rifled the castings in a handmade die. He soon made the slugs available to his neighbors.

In 1932, some of the Foster slugs were submitted to the Remington Arms Company. Experiments showed that they were more accurate than balls, but Remington was apparently not inclined to develop them further. In 1933, sample slugs were sent to the Winchester Arms Company, where they underwent extensive testing. Winchester accepted the new design, and factory loaded shells were first placed on the retail market in September 1936. The Remington Company soon recognized its error and added them to its product line in 1937. Foster type rifle slugs are now manufactured by Remington, Winchester-Western and Federal (Anoka, MN) cartridge companies. Lyman continues to make casting molds and a swaging kit for hand loaders.

The first factory loaded slugs differed from those of Foster originals in that the weight was reduced to approximately .875 oz. Also, Foster had originally placed wax in the hollow base of his slugs so that accuracy would not be diminished by cardboard wadding sticking to the base. In lieu of wax, Winchester and Remington used a hard cardboard wad at the base. The diameter of the slug was further reduced for safety so it would pass through even the tightest choke.

The basic Foster slug, however, remains a hollow lead cup, heavier at the point. It has 14 small angled ribs swaged into the side of the slug. The rifling tends to be obliterated by the passage of the slug through the barrel, especially through a full choke. Some spin does result from the ribs, however, and tests show a very slow spin of approximately one turn in 24 feet of travel to one turn in 129 feet of travel, depending upon the choke used. In 1980, Remington and other slug manufacturers increased the weight of 12-gauge rifle slugs to a full 1 oz.

Neither Brenneke nor Foster slugs depend upon the rifling ribs or projectile spin for stability. The slugs are stable because they travel through the air like a sand-filled sock with the heavier toe forward (O'Connor 1965), unlike symmetrical lead balls (Figure 3). The trailing light end acts as a stabilizer. The slight rotation imparted by the ribs reduces the effect of manufacturing irregularities. In tests performed by Winchester-Western, the slug rotation was confirmed, resulting in consistently smaller groups for rifled slugs than unrifled slugs (Sterett 1966).

12-Gauge Slug Ballistics

Some manufacturing specifications for three rifled slug loads are summarized in Table 1. The table shows that Foster style slugs are made well below the actual 12-gauge bore diameter. Brenneke slugs are made quite close to actual bore size.

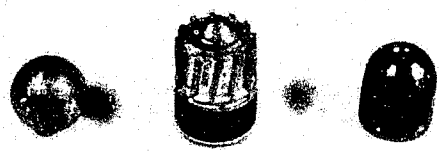

Figure 3. Shotgun slugs are stable in flight because they travel weight-forward, like a sand-filled sock, unlike a symmetrical musket ball (left). Neither the Brenneke (center) or Foster (right) slugs depend upon the rifling ribs for stability, but they do impart a spin to the bullet which improves accuracy.

There are two interior ballistic considerations in rifled slug accuracy (Ramage 1984). Better accuracy is obtained if the slug is kept centered within the bore without tilting or deformation. A slug that is not centered in the bore will bounce from side to side as it travels down the barrel. Secondly, the gas seal formed by the wadding should be as complete as possible, yet the slug must sit on a firm base which does not become imbedded in the slug so that its aerodynamic shape or weight is skewed.

The Remington Arms Company solution is to use three different types of wad behind the slug (Figure 4). On top of the powder is a plastic wad which forms an effective gas seal.

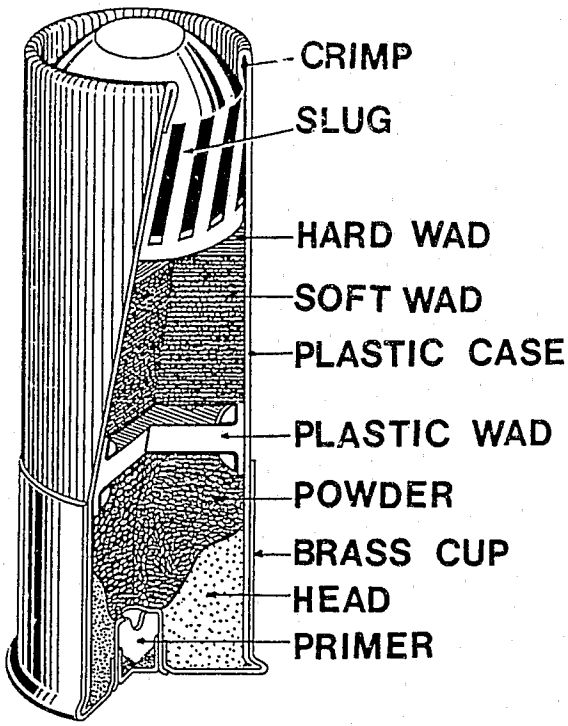

Figure 4. Diagram of a Remington 12-gauge shotgun shell loaded with a rifled slug. Adapted from Wilber (1977).

Next is a relatively soft felt cushion which absorbs some of the initial shock from powder burning. Lastly, a stiff cardboard wad directly beneath the slug spreads the hollow base and supports the slug without itself being trapped or attached to the slug. Once in flight, the "shuttlecock" weight distribution keeps the slug traveling an accurate path.

Table 1. Specifications of Three 12-Gauge Rifled Slugs*

	Weight (Ounces)	Diameter (Inches)**	Number of Ribs	Angle of Ribs
Remington 1 oz.	1.00	.690-.636	14	9°
Winchester 7/8 oz.	.92	.688-.626	14	15°
Brenneke 1 oz.	1.00	.727-.635	12	9°

*Modified from Sterett (1966).

**The first number is the diameter of the rib lands. The second number is the diameter of the groover.

With the heavy nose pulling along the body, the Brenneke attached wads act as a weather vane and further stabilize that slug. In both cases, the rifling lands act as fenders to keep the slug centered as it travels down the barrel, as well as helping to impart a slight spin. This is especially important in the Brenneke slugs and where the ribs extend from the projectile circumference and contact the barrel almost from the moment of ignition.

Ballistic information for Remington and Brenneke 1-ounce rifled slugs is shown in Table 2. The Remington 1-ounce slug loses approximately 43 percent of its kinetic energy at 50 yards. At 100 yards, its kinetic energy is only 926 foot-pounds, which is a considerable reduction from its muzzle energy of 2,364 foot-pounds. The Brenneke slug maintains its kinetic energy longer because of its heavier initial weight, approaching 1.125 oz. The Brenneke slug is also attributed with deeper penetration, a larger entry hole and wider permanent cavity due to its sharp forward shoulder edge. The .875-ounce Remington slug, marketed prior to 1980, lost even more energy — up to 50 percent at 50 yards (Fadala 1984).

Chronograph studies have shown that there is only a slight loss in velocity, and therefore energy, when slugs are fired from barrels shorter than test barrels. Degree of choke is much more important in determining muzzle velocity. A study by Barnes (1985) showed that shortening a barrel from 30 to 22 inches caused less than a 100 feet-per-second decline in muzzle velocity. Within the effective range of the weapon, that reduction has little effect on killing power. The approximate maximum flight distance for a 12-gauge, 1-ounce slug is 2,450 feet (Burch 1980). Burch did not indicate whether this maximum distance was determined theoretically or by experimentation. Trajectory information for Remington slugs is printed on the slug box itself, as well as summarized in Remington literature (Remington 1980). That information is also presented in Figure 5.

Accuracy and Range Recommendations

There are varying opinions about the appropriate range limitations of rifled slugs. The generally recommended maximum range is from 75 to 150 yards, with extremes of 40 yards to 250 yards. O'Connor (1965) believed that slugs are best fired through single barreled shotguns. He believed that side-by-side and even over-and-under double barreled shotguns suffered from crossfiring and recommended that rifled slugs be

Table 2. Ballistics Information for Two 12-Gauge Rifled Slugs*

	Weight in Grains	Velocity (feet per second) Over Range (yards)				
		0	25	50	75	100
Remington 1 oz.	437.5	1560	1345	1175	1057	977
Brenneke 1 oz.	491*	1593	1384	1213	1083	997
		Energy (foot pounds) Over Range (yards)				
		0	25	50	75	100
Remington 1 oz.		2364	1757	1341	1085	926
Brenneke 1 oz.		2756	2090	1606	1280	1049

*Based on Remington Arms Company (1980, 1987) and Sears (1981).

**This includes the weight of attached wads.

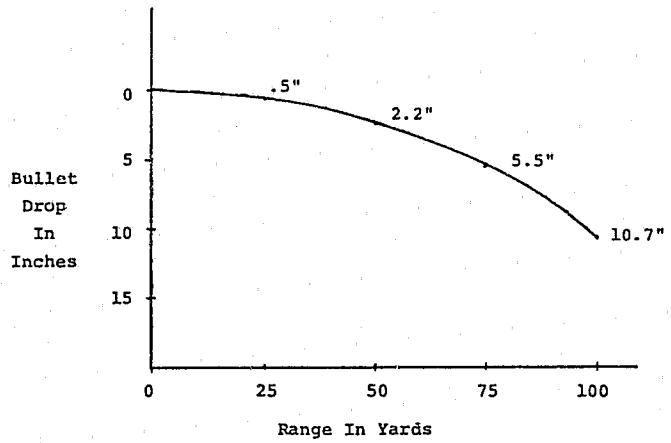

Figure 5. Trajectory path of Remington 12-gauge, 1-ounce rifled slug. Adapted from Remington Arms Company (1980).

used within 40 yards. Fadala (1984) considered 75 yards to be the maximum recommended range for a 12-gauge slug. In his opinion, acceptable accuracy for a shotgun and slug combination was keeping all rounds within a 4- to 5-inch group at 50 yards. Sterett (1966) agreed with O'Connor that the best accuracy is obtained from a single barreled shotgun. He considered 100 yards to be the maximum usable range. Beyond that distance it is still a potent projectile, but accuracy decreases enormously because of the falling trajectory. Whetstone (1987) believed that a shotgun should be capable of placing all rounds within an 8-inch group at 100 yards, and with that achieved accuracy, the rifled slug can be an effective round for use by police officers in excess of 100 yards. The National Rifle Association (NRA) (1968) judged that acceptable accuracy was all rounds within a 6-inch circle at 50 yards and all rounds within a 10-inch circle at 75 yards. With those specifications, they concluded that a rifled slug is sufficiently accurate and far superior to handguns at the same ranges. Matunas (1979) believed that slugs are appropriate for use as far as 100 yards only if the shotguns are equipped with telescopic sights of at least 2.5 X. Robinson (1973) maintained that a shotgun equipped with rifle sights was adequate for a man-sized target to a distance of 150 yards. He believed that an officer should be able to hit a man at that range "with ease". He recommended the shotgun slug for barricaded target personnel to a distance of 100 yards and contended the slug will still display adequate penetration of automobiles at 75 yards. According to Barnes (1985), 12-gauge shotgun slugs are appropriate for small targets to an 80-yard distance and deer-size targets to 125 yards. He maintained that minimum accuracy requirements were all rounds within a 10 to 12-inch circle at whatever the expected range was for the game being pursued.

Ramage (1984) believed that reasonable accuracy for shotguns using rifled slugs was all rounds within a 4-inch circle at 50 yards. He thought the weapon should be limited to "close or medium ranges" which he defined as "not much over 100 yards."

Krieger (1981) estimated that in regular use, a 12-gauge rifled slug has sufficient energy and accuracy for deer hunting as far as 150 yards or more. He obtained what he considered to be satisfactory accuracy to 150 yards by using a custom hand-loaded shell. He used George Vitt's Aerodynamic slug which is a 12-gauge slug weighing 575 grains. He fired that slug from a Remington Model 870 pump action 12-gauge shotgun which originally had a 28-inch modified choke barrel. The barrel was reamed out to re- moved all traces of the choke. On that shotgun, he mounted a Weaver (El Paso, TX) variable power 2-to-7 telescopic sight. With that round, gun and scope combination, he was able to keep all shots within a 14- by 12-inch target at 250 yards, which he considered to be the approximate size of the heart-lung area of a white-tailed deer.

According to Sears (1981), a 12-gauge rifled slug maintained sufficient accuracy and power as far as 100 yards only under the most favorable conditions. He believed a 16-gauge slug was adequate as far as 80 yards, a 20-gauge slug to 60 yards, and that all slugs are most efficiently used at 75 yards or less. He recommended that shotguns be zeroed for a range of 75 yards. At such zeroing, they will tend to shoot approximately 1 inch high at a distance of 50 yards and 3 inches low at 100 yards. A 10 mile-per-hour crosswind should deflect the round no more than 1 inch at 100 yards. If the range is beyond 100 yards, Sears recommended a hold-over of approximately 8 inches for 125 yards and 16 inches for 150 yards. He determined that satisfactory accuracy for American-made Foster slugs is all holes within a 5-inch circle for five consecutive shots at 50 yards. German standards are considerably higher and more definitive. They regarded, at 50 meters, exceptional accuracy to be an impact spread of less than 10 cm (3.94 in), very good accuracy to be up to 15 cm (5.90 in), good accuracy up to 20 cm (7.87 in), and fair accuracy to be any shot spread over 20 cm.

Some authors recognized the importance of choke and types of sights before making range recommendations. For instance, Barnes (1985)

made his recommendations on the assumption that the shotgun is equipped with rifle sights. With only a factory installed single bead on a shotgun barrel, he considered 30 yards to be the maximum effective range. Likewise, Sterett (1966) recommended a 2.5 X telescopic sight or rifle-type, receiver mounted sights on any hunting shotgun. He also recommended improved cylinder or cylinder bores on the shotgun for the best accuracy. A shotgun equipped with a variable choke device in the full open position would provide almost the same accuracy. He believed that full chokes produce "fliers," probably due to uneven swaging of the slug as it passes through the choke. The Remington Company (1980) provided similar information directly on its shotgun slug carton which read "Rifled slugs may be fired through any choke, but improved cylinder is best." Fadala (1984) claimed the best accuracy is obtained from a shotgun which is factory equipped with a barrel intended for shooting rifled slugs. Such guns are produced and marketed by Ithaca (Ithaca Gun Company, Ithaca, NY) and Remington, among others. In decreasing order of accuracy are improved cylinder, modified, and lastly, full choked barrels.

O'Connor (1965) likewise believed that the path of rifled slugs is most accurate in barrels with little or no choke and least accurate in full chokes. He recommended the low power telescopic sight as the best, followed by a receiver-mounted adjustable peep sight or other rifle sight, and lastly, a single ventilated rib barrel with a two-bead sight system, composed of a large forward bead and a small bead mounted midway down the ventilated rib. Sears (1981) also recognized the inadequacy of a single bead shotgun sight and likewise expected greater accuracy by moving up to a double bead system and then up to adjustable rifle sights. My own experiment, which consisted of testing six barrels for a Remington Model 870 pump shotgun, confirmed that the best accuracy was obtained with a factory produced slug barrel — 20-inch open choke with rifle sights. The least accuracy was obtained with a 30-inch full choke barrel, and the rest fell between these two values.

There is a folk belief among shooters that slugs are particularly good "brush busters" and suitable for deer hunting in thick cover. Only Sears (1981) addressed this issue and specifically debunked it. He maintained that slugs are easily deflected because they are soft and only marginally stable in flight. He believed that a deer-sized target 2 feet behind light brush cover will probably be hit by a slug penetrating the brush. However, the same target 10 feet behind the brush will probably not be hit. Indeed, slugs are grossly deformed by impact, as shown by slugs recovered from a soft earth backstop during the test firings (Figure 6). This same massive mushrooming is partly responsible for the tremendous killing power of rifled slugs.

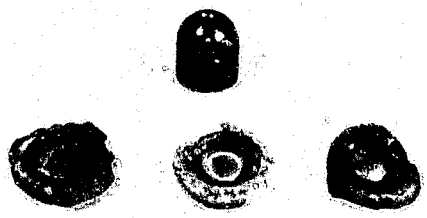

Figure 6. Slugs can be grossly deformed by impact because of their soft lead consistency. Their softness combined with relatively slow velocity means they are easily deflected and have low penetration ability.

Police Use of Shotguns

The shotgun was introduced to civilian law enforcement after the Civil War. By the mid-1870's it had become a standard weapon for Western peace officers and stagecoach guards. In the early 1900's, John Browning's new pump action shotgun allowed officers to carry 4 or 5 shells instead of the previous limitation of a double-barreled shotgun to 2 rounds. Browning's Winchester Model 97 was used throughout World War I and gained wide popularity. Today, the 12-gauge pump shotgun with a 20-inch unchoked barrel remains the standard for American law enforcement, although semi-automatic shotguns are becoming more common.

The shotgun remains popular because of its versatility. It can fire rifled slugs, buckshot, birdshot, rubber bullets, penetrating tear gas rounds or tear gas canisters, using blanks for propellant. Its versatility means that in tactical situations it can replace a handgun, rifle and tear gas launcher.

The three most common shotgun loads in law enforcement are 00 Buck, #4 Buck and rifled slugs. The 00 Buck shells contain 9 or 12 pellets, each approximately .32 caliber, whereas a #4 Buck shell contains approximately 27 pellets of .24 caliber. A 12-gauge rifled slug is approximately equivalent to .72 caliber.

Shotguns have been chosen as police long arms for qualities other than their versatility. They are inexpensive to purchase initially and have a long, functional life. They are also simple to maintain and repair. Officer training is generally fairly easy and skill retention is good. The presence of a shotgun has a positive psychological value for an officer in an armed confrontation, while also scaring the officer's opponent. Furthermore, shotgun shells are easily and safely reloaded because of the low pressures involved (National Rifle Association 1968).

Shotguns for use in law enforcement have been adapted for combat purposes rather than hunting. They are often equipped with rifle sights, carrying slings and recoil pads. They may also be equipped with a stock cuff or some other storage bandolier which attaches additional ammunition to the gun. Extended magazines which raise shell capacity to 7 or 8 are common. Some experts also suggest having shotgun barrels ported to reduce recoil and muzzle climb. Such porting, however, is somewhat offset in value because of the increased noise and muzzle flash (Whetstone 1987).

Rifled slugs in police shotguns were first used primarily in roadblock duty. Now they are seen more in general use and continue to gain popularity over buckshot loads. In most tactical situations, distance between an officer and his opponent is an advantage to the officer, especially if he is equipped with a shotgun. Buckshot loads only duplicate handgun accuracy and range, but a slug extends the range over which an officer can deliver precise, controlled and effective fire. It adds tactical flexibility for the officer since it remains accurate from 25 to 75 yards beyond the effective range of his handgun.

At ranges less than 100 yards, the shotgun slug is accurate and predictable, under the precision control of the shooter. There is reduced liability for the officer because he is not subject to occasional erratic buckshot flight which is beyond his control A slug travels a known trajectory, and its limits and accuracy can be learned by the officer during training. If a complete miss does occur, only one projectile remains in the air instead of many. At all reasonable ranges, the 12-gauge rifled slug has a devastating impact energy and produces wounds equal or greater to those produced by handgun rounds.

Another advantage of using slugs is their high penetration ability. A suspect seeking concealment or cover is common in all but short-range tactical situations. It has been shown that at 100 feet, a rifled slug will perforate a metal or wood house door, an automobile door, an automobile trunk lid and seat, and conventional sheetrock or plaster double walls, This advantage is somewhat offset by the risk of overperforation. A slug can also be used for lock and hinge removal by entry teams.

It is clear from historical precedent, current popularity and expert opinion, that the repeating shotgun, loaded with rifled slugs, is a suitable weapon for law enforcement officers. At common combat ranges it is dependable, predictable, accurate, potent and adaptable to a variety of tactical purposes. For all these reasons, it is likely to remain the long arm of choice for local police agencies.

REFERENCES

Askins, C. (1958). The Shotgunner's Book. Stackpole Books, Harrisburg, Pennsylvania.

Barnes, F. (1985). Cartridges of the World. 5th ed. DBI Books, Northfield, Illinois.

Burch, M. (1980). Shotgunner's Guide. Winchester Press, Tulsa, Oklahoma.

Clede, B. (1986). Police Shotgun Manual. Stackpole Books, Harrisburg, Pennsylvania.

Fadala, S. (1984). The Complete Shooter. DBI Books, Northfield, Illinois.

Krieger, J. (1981). Shotgun Shells at Long Range. In: The Gun Digest. 35th ed. Edited by Ken Warner. DBI Books, Northfield, Illinois, pp. 126-133.

Lesce, T. (1979). The Shotgun in Combat. Desert Publications, Cornville, Arizona.

Long, D. (1987). Streetsweepers: The Complete Book of Combat Shotguns. Paladin Press, Boulder, Colorado.

Matunas, E. (1979). American Ammunition and Ballistics. Winchester Press, Tulsa, Oklahoma.

National Rifle Association. (1968). Shotguns and Ammunition. In: NRA Police Firearms Instructor's Manual. National Rifle Association, Washington, D. C.

O'Connor, J. (1965). Complete Book of Shooting. Outdoor Life/Harper and Row, New York.

Petty, C. S. and Hauser, J. H. (1968). Rifle shotgun slugs, J. Forensic Sci. 13:114-123.

Ramage, C. K., ed. (1984). Lyman Shotshell Handbook. 3rd ed. Lyman Publications, Middlefield, Connecticut.

Remington Arms Company (1980). Remington Sporting Firearms and Ammunition 1980. Remington Arms Company, Wilmington, Delaware.

Robinson, R. H. (1973). The Police Shotgun Manual. Charles C. Thomas, Springfield, Illinois.

Sears, R. N. (1981). Shotgun slugs, American Rifleman 129:2:22-25, 79-80.

Sterett, L. S. (1966). Today's Missiles for Shotguns. In: The Gun Digest. 20th ed. Edited by John T. Amber. Gun Digest Company, Chicago, Illinois, pp. 263-268.

Whetstone, T. S. (1987). Tactical considerations of the police shotgun, Police Marksman 12:5:54-57.

Wilber, C. G. (1977). Ballistic Science for the Law Enforcement Officer. Charles C. Thomas, Springfield, Illinois.