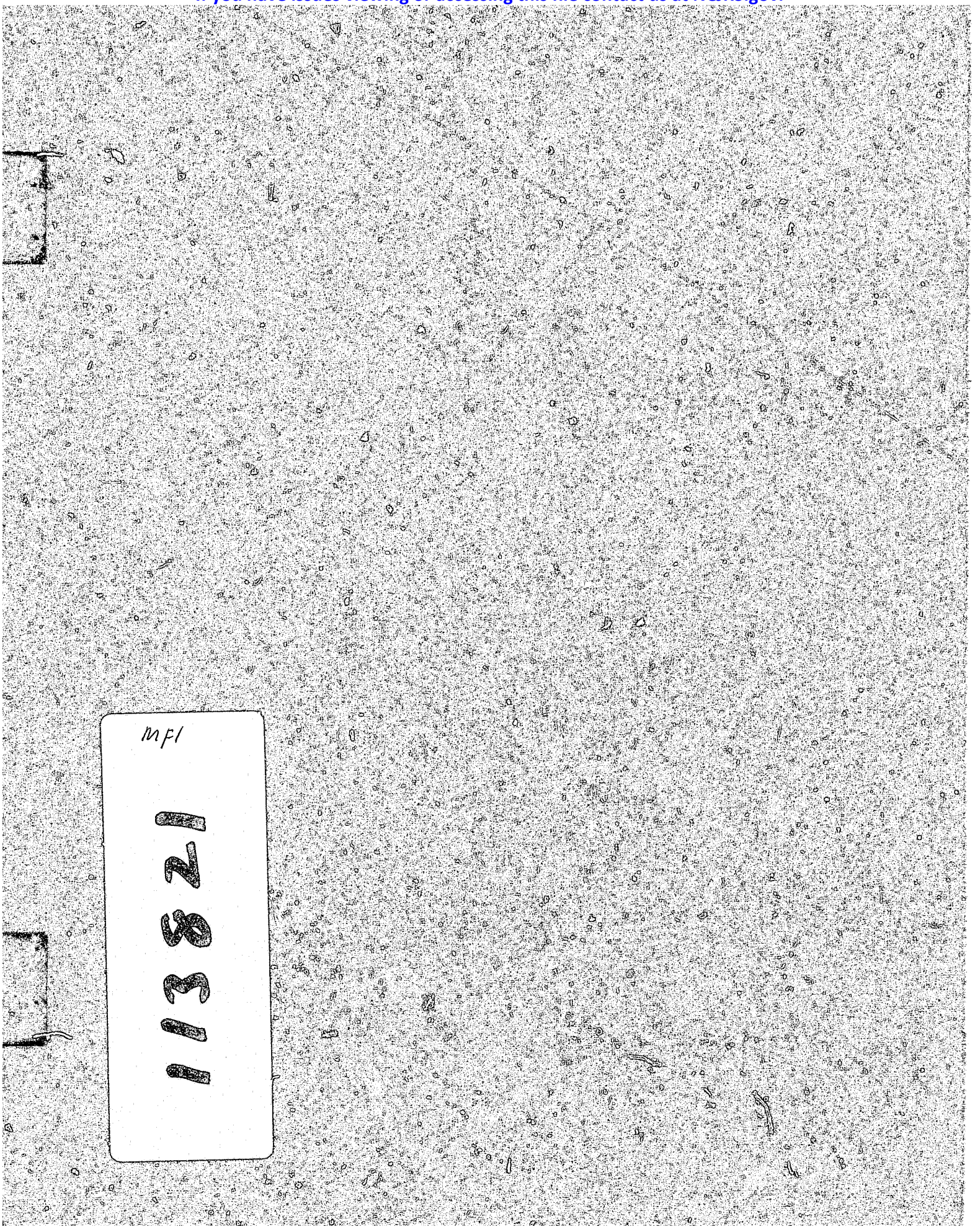

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In response to numerous inquiries from law enforcement agencies nationwide regarding semiautomatic pistols, the information contained herein is being set forth. The information is the result of an evaluation process and a seminar, both of which were held at the FBI Academy, Quantico, Virginia.

During August, 1987, 13 firearms instructors and a gunsmith representing the FBI Academy and eight FBI field divisions formed a Weapons Evaluation and Selection Advisory Group. The purpose of this group was to evaluate 9mm and 45 caliber semiautomatic pistols. The weapons were furnished to the FBI for this testing as the result of a publicized request. Six manufacturers submitted a total of 9 pistols for evaluation. Two samples of each weapon were submitted. The following weapons were evaluated:

MAKE	MODEL	CALIBER
S&W	M645	.45
Sig-Sauer	P220	.45
Sig-Sauer	P226	9mm
S&W	M459	9mm
Beretta	M92	9mm
Glock	17	9mm
Clock	19	9mm
Ruger	P85	9mm
IMI	AT84	9mm

Although a majority of the group concluded the .45 cartridge was significantly better than the 9mm in terms of likelihood of incapacitation, a decision on caliber was deferred until after the sample weapons could be tested. Of specific concern at the time were factors of size and recoil. The issue of capacity (number of rounds) was determined to be of little concern in light of the difference in effectiveness between the two calibers, noting further that 15 rounds in a 9mm is not significantly better than 10-12 in a .45.

Physical comparisons of the weapons revealed no significant size factors. For example, the Sig-Sauer P220 (.45) and P226 (9mm) are identical in size and shape. The Smith & Wesson M645 is 5/8-inch longer in the slide than a S&W M459, but the same height and thinner. The lack of a wide, fat grip necessary on a high-capacity 9mm actually makes the .45 more concealable against the body under a shirt. The M645 and the P220 are essentially the same size, although the P220 is thicker.

Due to continuing controversy over the question of caliber, a panel of nationally recognized experts in the fields of surgery, forensic pathology, and ballistic engineering was

invited to participate in a Wound Ballistics Workshop at the FBI Academy, 9/15-17/87. The results of their findings are included in this article in the section "Relevance of Wound Ballistics."

The final determination of the Workshop was that the .45 caliber was better than 9mm in terms of wounding effectiveness, except for the new 147-grain, 9mm subsonic round. The subsonic round is as effective as the .45. The experts advised the larger bullet of the .45 would be an edge, but not a significant one.

The submitted sample weapons were evaluated in accordance with the Evaluation Criteria. The Evaluation Criteria used were as follows:

1. Design Approach. Each weapon was evaluated relative to its design, materials used, mechanical efficiency, construction, and tolerances.

2. Ease of Care and Maintenance. Each weapon was evaluated relative to the ease of normal care and maintenance by the shooter, as well as ease of gunsmith maintenance in terms of detailed disassembly, necessity for special tools, restoration of finish, and ease of repair of broken parts.

3. Ease of Operation and Use. Each weapon was evaluated relative to its ease of operation in routine duty use, its operating controls, trigger pull, shooting characteristics, etc.

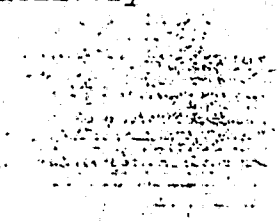
4. Freedom from Breakdowns. Each weapon was evaluated relative to the number and types of stoppages and malfunctions which occurred.

5. Parts Availability. Self explanatory.

6. Accuracy. Each weapon was fired for group at 15 yards double action and at 25 yards single action.

7. Safety. Each weapon was evaluated relative to its safety in normal duty use, potential liability for safety problems, and potential for accidental or unintentional discharges.

8. Delivery. Each weapon was evaluated relative to the manufacturer's stated ability to meet the specified delivery schedule.



9. Resistance to Breakage. Each weapon was subjected to abusive treatment and evaluated upon its resistance to breakage. The following abuse tests were performed:

a. Three drop tests from a height of three feet, with the gun landing on the hammer/ rear of the slide.
   - one drop cocked
   - one drop de-cocked
   - one drop with hammer let all the way down by pulling trigger and easing hammer forward.

b. Striking the trigger guard with a rawhide mallet.

c. Throwing the weapon approximately 15 feet to land on its side, done once for each side.

10. Reputation and Integrity of the Vendor. Self explanatory.

Each weapon was evaluated independently and on its own merits - not relative to any other weapon. The maximum number of points a weapon could amass is 750. The results are as follows:

.45 CALIBER

1.	S&W M645	-	730 Points
2.	Sig-Sauer P220	-	665 Points

9MM CALIBER

1.	Sig-Sauer P226	-	710 Points
2.	S&W M459	-	705 Points
3.	Beretta M92	-	690 Points
4.	Glock 17	-	620 Points
5.	Glock 19	-	620 Points
6.	Ruger P85	-	575 Points

One submission, the Israeli Military Industries (IMI) AT84 was rejected based upon specifications. The specification stated "The pistol must be designed in such a manner as to allow the hammer, striker or firing mechanism to be safely decocked without pulling the trigger." The AT84 was designed in such a manner that the weapon could not be decocked without pulling the trigger, and the submission was therefore rejected.

The remaining weapons were tested extensively, with a total of 17,105 rounds being fired during the testing period. Both samples of each weapon were fired in all the tests except for the final Pistol Qualification Course (PQC). For this course, the best sample of each model was chosen and only that weapon used.

The testing procedure required each evaluator to fire both samples of a submission in a given test and immediately fill out an evaluation form on the weapons. The shooter would then repeat the process in the same test with another pair of weapons. Therefore every weapon tested was fired by all the evaluators in all the courses used in the procedure. The only exception to this rule was the final PQC, in which only the best weapon of the pair was used.

The evaluation form categorized features of the weapons into three classifications, as follows:

Good - The feature was an asset to the shooter.

No Factor - The feature neither helped nor hurt the shooter.

Poor - The feature hurt the shooters performance.

In compiling the results, a value of 3 was given for a Good rating, 2 for No Factor, and 1 for Poor. In the final factor, "Desirability as Issue Weapon," the value assigned was 10 for Good, 5 for No Factor, and 0 for Poor. Each evaluation form was totaled, and the totals for each submission were averaged to arrive at the results. Only those factors pertinent to the respective test were graded on the evaluation form. The maximum possible grade (all "Good" ratings) for each test is noted on the results.

The tests used are as follows:

2x2 The shooter fires a minimum of 20 rounds, two shots at a time. Each two-shot firing is done with the first shot double action, or in the first-shot mode of the weapon, and the second shot in the single-action or second-shot condition. Double-action pistols are characterized by widely disparate trigger pulls between the first shot and any subsequent shots. This test evaluates the critical ability to shoot the weapon efficiently and accurately utilizing both trigger pulls in quick succession, called transition shooting.

5x5 The shooter loads the weapon with five rounds and a second magazine with five rounds. On command, the shooter then fires ten rounds in ten seconds. This is repeated twice. This test evaluates all the operating features and factors of the weapon, including slide stop, magazines, rapid loading, recoil control, trigger control, sight use and acquisition, magazine release and drop, feeding and ejecting reliability, location of controls and operating features.

50 YARD The shooter fired the weapons from all the standard FBI firing positions. This test evaluated the ability of the shooter to fire effectively and operate the weapon efficiently from all the various positions used in FBI training. Firing was done at 50 yards because any negative effect on the shooter will translate into misses at that range. Knowing their ability at 50 yards, the shooter can thus clearly evaluate the effect of the different weapons. At closer ranges, a negative effect may occur but a hit can still be scored because of the proportionately greater margin for error.

PQC The shooter fired a 50-round course as follows:

25 yards	18 rounds in 45 seconds 6 rounds strong-hand kneeling 6 rounds standing 6 rounds weak-hand kneeling
15 yards	10 rounds, standing, 2 shots at a time, first shot always double action.
7 yards	7 rounds in 5 seconds, first-shot double action
7 yards	10 rounds in 15 seconds, five strong hand only, five weak hand only, first-shot double action

The course was fired on the standard FBI "Q" target and scored, in addition to evaluation forms being filled out. No alibis were allowed for any malfunction which prevented the shooter from finishing any stage of fire. This test evaluated overall usage of the weapon and the shooter's ability to perform with it.

In addition, all the submissions were tested for accuracy at 25 and 15 yards. Ten-round groups were fired single action only at 25 yards, and double action only at 15 yards.

The accuracy firing was accomplished on outdoor ranges using sitting positions. Accordingly, unacceptable shooter error was unavoidable, and the results are not a measure of inherent weapon accuracy. The results do prove acceptable accuracy by all submissions.

The following tables reflect the results of the testing procedures that were conducted. A blank copy of the evaluation form used is included after the tables.

Since the completion of the testing procedures, it has become apparent that weapons utilizing alloys for frames or other major components have severe limitations. It has been determined that a weapon with major alloy parts can be expected to have a limited service life. Defined as the longevity of the slide and the frame. The life expectancy of such a weapon is considered to be approximately 10,000 rounds. This is in comparison to steel framed weapons which can have a service life in excess of 100,000 rounds.

In the FBI, an Agent will fire in excess of 4,000 rounds in basic training alone. Thereafter, the Agent will fire approximately 1,600 rounds per year. At this rate, the Agent would fire 10,000 rounds through the weapon within 5 years of his entry on duty.

The FBI intends that the general issue weapon provided to every Agent last for that Agent's entire career. To this end, future FBI procurements will require a service life on the order of 40,000 rounds. Service life is defined as the life of the slide and the frame, but not of the barrel or other parts. The barrel should last 20,000 rounds.

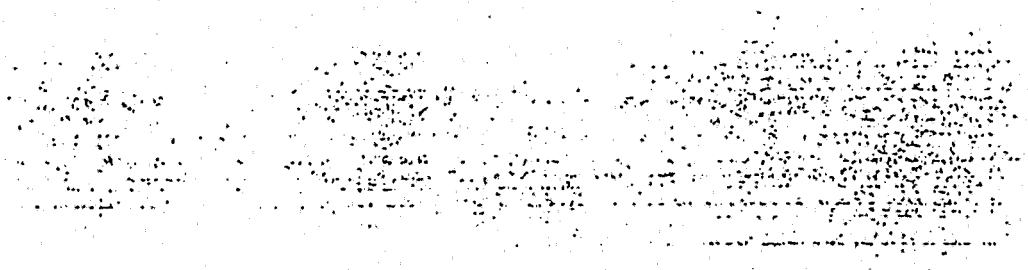
NOTICE: Since these evaluations were done, several of the manufacturers have changed their weapons. Some of the specific problems identified in these tests have been corrected. In some cases, the improvements are so extensive that these tests are no longer valid. In other cases, problems have arisen with others that, had they been known, would have reduced that weapon's point total as listed herein.

NUMBER OF ROUNDS FIRED PER GUN

WEAPON	#ROUNDS	COMMENTS
Ruger P85	475	Became inoperable
Ruger P85*	1301	
Glock 17*	945	
Glock 17*	1139	
Glock 19*	782	
Glock 19	1171	
Beretta 92*	972	
Beretta 92	1360	
Smith & Wesson M459	575	Rear sight lost
Smith & Wesson M459*	1377	
Sig-Sauer P226	850	
Sig-Sauer P226*	1467	
Sig-Sauer P220*	938	
Sig-Sauer P220	1269	
Smith & Wesson M645	904	
Smith & Wesson M645*	1580	

* Denotes weapon never cleaned

NOTE: The weapon in each pair with the highest number of rounds fired is the weapon chosen as the best of the pair for use in the PQC test, except for the Ruger P85 and the S&W M459, of which one sample of each became unusable, as noted.

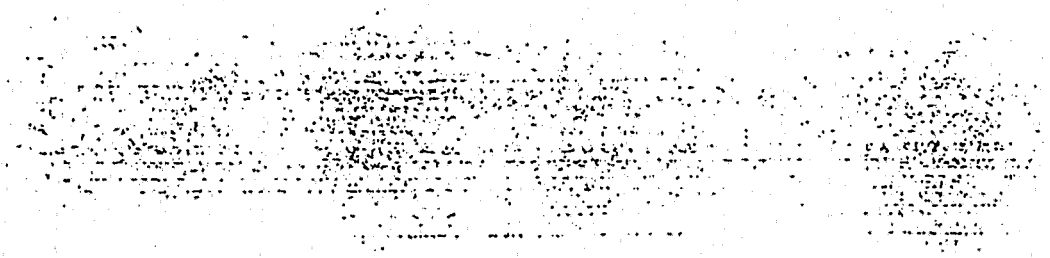


	WEAPON	TEST	NET GRADE
1.	SMITH & WESSON M645	2X2	76.4
2.	SMITH & WESSON M459	2X2	74.2
3.	SIG-SAUER P226	2X2	72.6
4.	SIG-SAUER P220	2X2	68.75
5.	GLOCK 19	2X2	66.7
6.	BERETTA M92	2X2	66.57
7.	GLOCK 17	2X2	60.33
8.	RUGER P85	2X2	52.27

MAX GRADE: 88

	WEAPON	TEST	NET GRADE
1.	SIG-SAUER P226	5X5	81.7
2.	SIG-SAUER P220	5X5	81.5
3.	SMITH & WESSON M645	5X5	76.8
4.	SMITH & WESSON M459	5X5	75.6
5.	BERETTA M92	5X5	69.2
6.	GLOCK 17	5X5	63.6
7.	GLOCK 19	5X5	59.7
8.	RUGER P85	5X5	51.78

MAX GRADE: 88



	WEAPON	TEST	NET GRADE
1.	SIG-SAUER P220	DA 15 YARD	4.99
2.	SIG-SAUER P226	DA 15 YARD	5.13
3.	BERETTA M92	DA 15 YARD	5.14
4.	GLOCK 17	DA 15 YARD	5.2
5.	SMITH & WESSON M645	DA 15 YARD	5.34
6.	SMITH & WESSON M459	DA 15 YARD	5.5
7.	RUGER P85	DA 15 YARD	5.59
8.	GLOCK 19	DA 15 YARD	6.06

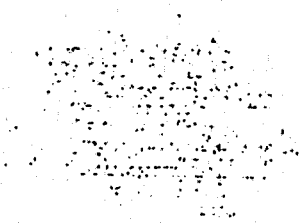
	WEAPON	TEST	NET GRADE
1.	SMITH & WESSON M459	SA 25 YARD	5.9
2.	SIG-SAUER P220	SA 25 YARD	6.55
3.	BERETTA M92	SA 25 YARD	6.6
4.	SIG-SAUER P226	SA 25 YARD	6.69
5.	GLOCK 17	SA 25 YARD	6.71
6.	SMITH & WESSON M645	SA 25 YARD	6.96
7.	GLOCK 19	SA 25 YARD	7.04
8.	RUGER P85	SA 25 YARD	7.41

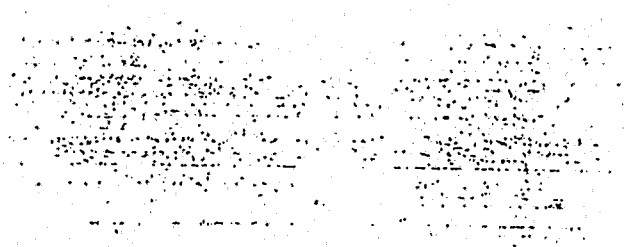
	WEAPON	TEST	NET GRADE
1.	SIG-SAUER P226	PQC	84.38
2.	SMITH & WESSON M645	PQC	81.8
3.	SIG-SAUER P220	PQC	80.7
4.	BERETTA M92	PQC	75.89
5.	SMITH & WESSON M459	PQC	75.44
6.	GLOCK 19	PQC	63.33
7.	GLOCK 17	PQC	61.43
8.	RUGER P85	PQC	53.88

MAX GRADE: 94

	WEAPON	TEST	AVERAGE SCORE
1.	GLOCK 17	PQC SCORE	94.00
2.	BERETTA M92	PQC SCORE	92.5
3.	SMITH & WESSON M459	PQC SCORE	92.4
4.	SIG-SAUER P226	PQC SCORE	91.5
5.	SMITH & WESSON M645	PQC SCORE	89.1
6.	RUGER P85	PQC SCORE	88.6
7.	GLOCK 19	PQC SCORE	85.7
8.	SIG-SAUER	PQC SCORE	84.5

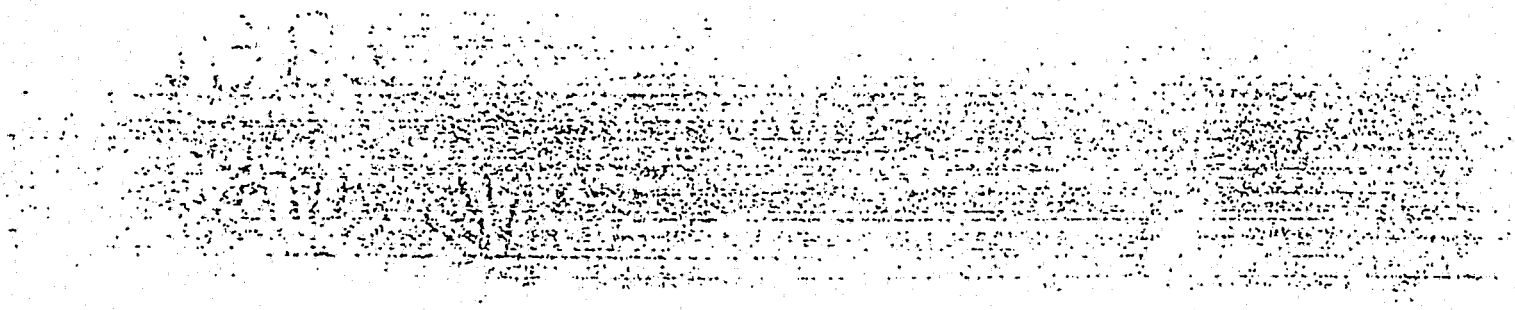
MAX SCORE: 100





	WEAPON	TEST	NET GRADE
1.	SMITH & WESSON M645	50 YARD	28.33
2.	GLOCK 17	50 YARD	26.71
3.	SIG-SAUER P220	50 YARD	25.11
4.	BERETTA M92	50 YARD	24.56
5.	SIG-SAUER P226	50 YARD	23.89
6.	SMITH & WESSON M459	50 YARD	23.88
7.	GLOCK 19	50 YARD	20.00
8.	RUGER P85	50 YARD	14.25

MAX GRADE: 37



MALFUNCTION RATE

	MALFUNCTIONS/#OF ROUNDS		%
RUGER P85	46/1776	1 per 39	2.59%
GLOCK 17	44/2084	1 per 47	2.11%
GLOCK 19	32/1953	1 per 61	1.63%
SIG-SAUER P220	12/2207	1 per 184	0.54%
SMITH & WESSON 645	8/2484	1 per 311	0.32%
SMITH & WESSON M459	4/1952	1 per 488	0.20%
SIG-SAUER P226	4/2317	1 per 579	0.17%
BERETTA M92	2/2332	1 per 1166	0.08%

For the purposes of this evaluation, any failure to feed, failure to extract, failure to eject, or failure to chamber a round or any other stoppage which prevented firing, (but which could have been remedied by the shooter) was considered a malfunction. Any malfunction rate greater than 1 malfunction per 200 rounds (0.5%) is unacceptably high.

APPENDIX H

EVALUATION CRITERIA

(MAXIMUM POINTS ALLOWED)

WEAPON	DESIGN APPROACH (100)	EASE OF CARE CARE AND MAINTENANCE (100)	EASE OF OPERATION AND USE (125)	FREEDOM FROM BREAKDOWNS (25)	PARTS AVAILABILITY (100)	ACCURACY (100)	SAFETY (100)	DELIVERY (25)	RESISTANCE TO BREAKAGE (50)	REPUTATION AND INTEGRITY OF THE VENDOR (25)	TOTAL (750)
Smith & Wesson M645	95 (a)	100	110 (b)	25	[illegible]0	100	100	25	50	25	730
Sig-Sauer P220	100	100	115 (c)	20 (d)	85 (e)	100	50 (f)	25	45 (g)	25	665
Sig-Sauer P226	100	100	115 (c)	25	85 (e)	100	90 (f)	25	45 (g)	25	710
Smith & Wesson M459	90 (h)	95 (i)	100 (j)	20 (k)	100	100	100	25	50	25	705
Beretta M92	100	90 (l)	90 (m)	25	85 (e)	100	100	25	50	25	690
Glock 17	100	95 (n)	80 (o)	10 (p)	85 (e)	100	50 (q)	25	50	25	620
Glock 19	100	95 (n)	75 (o)	15 (r)	85 (e)	100	50 (q)	25	50	25	620
Ruger P85	75 (s)	90 (t)	50 (u)	10 (v)	100	100	50 (w)	25	50	25	575

SEE FOOTNOTES FOLLOWING

FOOTNOTES

a. Right side safety lever continually comes loose. On one sample it fell off. This does not effect the weapon at all, but is not a good design feature.

b. Double action on one sample undesirably long and the single action was heavy with creep. Loosening or loss of right-side safety lever affects left-handed shooters.

c. Sights somewhat difficult to pick up. Front sight insert darkens quickly with residue and worsens sight acquisition. Decocking awkward for left-handed shooters.

d. Frequent magazine malfunctions.

e. Based on extensive experience with foreign parts supply for weapons in FBI inventory.

f. Failed the drop test. Primed cartridge case fired when P220 dropped on hammer from three feet. Primer marked when P226 dropped, although not enough to fire.

g. Failed hammer blow to trigger guard test. When struck on the trigger guard with a rawhide mallet, the trigger guard bent up against the bottom of the trigger rendering the weapon inoperative. The trigger could not be moved, nor could the hammer, and thus the slide was frozen shut.

h. Based on FBI experience with alloy-framed S&W M459. After five years use, the frames have begun to crack and require replacement. Although most other designs submitted also employ alloy frames, their lifetime can only be assumed to be limited since the FBI has no history with these weapons.

i. More difficult to disassemble/assemble due to necessity of aligning barrel bushing while installing main spring and the inability to remove slide stop without some hard object with which to press it out.

j. Double-action trigger long and stiff. Location of safety lever awkward for some shooters. Grips too thick.

k. Rear sight fell off while firing.

l. Special tools required for total breakdown.

m. Grips too thick and trigger reach too long for several shooters. Front sight small. Front sight insert darkens quickly when firing and worsens sight acquisition. Double-action trigger very long and recovery for single action requires excess trigger movement. Exposed barrel burned shooter hands.

n. Small takedown lever awkward to manipulate for most shooters.

o. Slide stop too small, awkward to lock back slide. Smooth grips harder to hold consistently in rapid fire. Magazine release awkward and inconsistent in releasing magazine. Left-handed shooter inadvertently operated magazine release while firing. Magazines drop out occasionally while firing. Light, first-shot trigger resulted in occasional premature or inadvertent shots on the part of all shooters.

p. Frequently failed to lock back slide on last shot. Two failures to fire. Two magazines simply fell apart while in the gun, dropping the magazine bottom, spring, follower, and all cartridges on the ground.

q. Unintentional discharges of the first shot lead to safety and liability issues in view of the manner handguns are routinely used by FBI Agents.

r. Instances of light, striker hits on primers due to striker releasing while slide not in battery. Failures to extract and failures of slide to lock back.

s. Poor design of extractor resulted in one sample breaking down and becoming unusable. Magazine catch design tends to hold magazines in.

t. Disassembly requires putting finger in action with slide locked back. If inadvertently released, would result in injury to finger.

u. Long, double-action pull. Extremely long recovery travel for single action. Very poor single action requires almost full range of trigger motion with no resistance before sear releases, resulting in unintentional single-action shots or in failures to fire due to not letting trigger travel forward far enough. Magazine release awkward awkward to operate. Safety hard to manipulate due to high location relative to hand. Sharp corners and edges on safety hard on fingers. Sight inserts too small.

v. One sample became inoperable after 475 rounds due to the bad extractor design. The second sample became inoperable at the end of the testing.

w. Unintentional single-action shots fired due to lack of resistance in trigger before sear releases. Safety/decock lever would not consistently decock the gun. Empty cartridge cases ejected in random patterns, frequently striking shooters in head or face.

SHOOTER NOTES

WEAPON

___ New Agent
___ Field Agent
___ SOG Agent
___ SWAT Agent
___ HRT Agent
___ F/A Instructor

NAME:

Male ____ Female ____ Right-Handed ____ Left-Handed ____

GRIP

Size and Shape in Hand	Good __	No Factor __	Poor __
Maintainable During Firing	Good __	No Factor __	Poor __
Ease of Getting Grip	Good __	No Factor __	Poor __

TRIGGER CONTROL

First-Shot Trigger Pull			
50 yards	Good___	No Factor___	Poor___
25 yards	Good___	No Factor___	Poor___
15 and closer	Good___	No Factor___	Poor___
Second-Shot Trigger Pull			
50 yards	Good___	No Factor___	Poor___
25 yards	Good___	No Factor___	Poor___
15 and closer	Good___	No Factor___	Poor___
Fast Transition From 1st and 2nd Shot	Good___	No Factor___	Poor___

ACCURACY

Shoots to Point of Aim	Good___	No Factor___	Poor___
In Transition From 1st to 2nd	Good___	No Factor___	Poor___
Rapid Fire	Good___	No Factor___	Poor___

RECOIL

Felt in Hand	Good___	No Factor___	Poor___
Control For Multiple Shots	Good___	No Factor___	Poor___

SLIDE STOP

Ease of Release	Good___	No Factor___	Poor___
Location for One-Hand Operation	Good___	No Factor___	Poor___
Ease of Locking Slide Back	Good___	No Factor___	Poor___

DECOCK/SAFETY

Ease of Operation	Good___	No Factor___	Poor___
Location	Good___	No Factor___	Poor___
Lack of Inadvertent Operation	Good___	No Factor___	Poor___

SLIDE OPERATION

Ability to Function	Good___	No Factor___	Poor___
Ability to Grip for Function	Good___	No Factor___	Poor___

MAGAZINE RELEASE

Functioning	Good___	No Factor___	Poor___
Function While Keeping Grip	Good___	No Factor___	Poor___

SIGHTS

Visibility	Good___	No Factor___	Poor___
Sighting Aids (Dots, Inserts, Etc.)	Good___	No Factor___	Poor___

LOADING

Ease of Magazine Insertion	Good___	No Factor___	Poor___
Ease of Slide Release and Recovery to Shoot	Good___	No Factor___	Poor___
Magazine Removal	Good___	No Factor___	Poor___

DESIRABILITY AS ISSUE WEAPON Good___ No Factor___ Poor___

SHOOTER COMMENTS

RELEVANCE OF WOUND BALLISTICS

The handgun is the primary weapon in law enforcement. It is the one weapon any officer or Agent can be expected to have available whenever needed. The use of the handgun is allowable to protect the life of the officer, or of others, as well as to prevent serious physical harm. When an officer shoots a subject, it is done with the explicit intention of incapacitating the subject immediately in order to terminate the threat to life or physical safety posed by the subject. Immediate incapacitation is defined as the sudden physical or mental inability to pose any further risk of death or injury to others.

The concept of immediate incapacitation is the only goal of any law enforcement shooting, as well as the underlying rationale for decisions regarding weapons, ammunition, calibers, and training. It is subject to conflicting theories, widely held misconceptions and varied opinions generally distorted by personal experiences. Yet the concept is critical to any analysis and selection of weapons, ammunition, and calibers for use by law enforcement.

In August, 1987, the Federal Bureau of Investigation began a testing and selection process to identify and recommend for procurement a semiautomatic pistol for use by Special Agents. Technical evaluation of the test weapons submitted was accomplished, but the recommendation for procurement became embroiled in a controversy over caliber. Specifically, the question as to whether immediate incapacitation was more likely to be achieved with a 9mm or with a .45 clouded the selection process.

As a result of the controversy, a Wound Ballistics Workshop was formed. Nationally recognized experts in various fields pertinent to the subject of handgun wounding and wounding effects were invited to attend. The purpose of the Workshop, which occurred during the period September 15-17, 1987, was to analyze and identify wounding factors, examine their effects upon the human target, and make recommendations as to calibers and/or bullets which would best realize the goal of immediate incapacitation, relative to the tactical realities of law enforcement usage. A discussion of their findings and conclusions is the subject of this article. The eight attendees are listed at the end.

TACTICAL REALITIES

It is not enough to dismiss suitability as a matter of shot placement rather than caliber. For example, a bullet through the central nervous system with any caliber of ammunition is immediately incapacitating. A .22 rimfire penetrating the brain will cause immediate incapacitation. Obviously, this does not mean the law enforcement agency should issue .22 rimfires and train for head shots as the primary target. The realities of shooting incidents prohibit such a solution.

Few, if any, shooting incidents will present the officer with an opportunity to take a careful, precisely aimed shot at a subject's head. Rather, shootings are characterized by their sudden, unexpected occurrence; by rapid and unpredictable movement of both officer and adversary; by limited and partial target opportunities; by poor light and unforeseen obstacles; and by the life or death stress of sudden, close, personal violence. Training is quite properly oriented towards "center of mass" shooting. That is to say, the officer is trained to shoot at the center of whatever is presented for a target. Proper shot placement is a hit in the center of that part of the adversary which is presented, regardless of anatomy or angle.

A realistic appraisal of handgun shootings reveals the simple truth that regardless of the number of rounds fired, most of the time an officer will attain only one or two solid torso hits on his adversary. This is easily understood because of the nature of shooting incidents and the extreme difficulty of shooting a handgun well under such dire conditions. The probability of multiple hits with a handgun is not high, and experienced officers recognize that fact. When potential violence is reasonably anticipated, preparations are characterized by obtaining as many shoulder weapons as possible. Unfortunately, most shootings are not anticipated and the officer involved cannot be prepare din advance with heavier armaments. One should not plan to meet an <u>expected</u> attack armed only with a handgun.

The handgun is the primary weapon for defense against an unexpected attack. Nevertheless, a majority of shootings occur in manners and circumstances in which the officer either does not have any other weapon available, or cannot get to it. The handgun must be relied upon, and must prevail. In analyzing calibers and ammunition, the Workshop goal was to identify calibers and projectiles which cause the greatest effects with one or two torso hits, the most which reasonably can be expected in a handgun shooting incident. The ammunition must maximize the likelihood of immediate incapacitation.

MECHANICS OF PROJECTILE WOUNDING

In order to reach any judgment about the likelihood of incapacitation with any handgun round, an understanding of the mechanics of wounding is necessary. There are four components of any projectile wound:

(1) Penetration. The tissue through which the projectile passes, and which it disrupts or destroys.

(2) Permanent Cavity. The volume of space once occupied by tissue that has been disintegrated by contact with the projectile. This is a function of penetration and the frontal area of the projectile. Quite simply, it is the hole left by the passage of the bullet.

(3) Temporary Cavity. The expansion of the permanent cavity by stretching due to the transfer of kinetic energy during the projectile's passage.

(4) Fragmentation. Projectile pieces or secondary fragments of bone which are impelled outward from the permanent cavity and sever muscle tissues, blood vessels, etc., apart from the permanent cavity. Fragmentation is not necessarily present in every projectile wound. It may, or may not, occur and can be considered a secondary effect.

When these wound effects occur in the human target, there are possible only two mechanisms of immediate death due to projectile wounds. The term "immediate" is used in the causative sense, not the temporal meaning. These mechanisms are:

(1) Central Nervous System Injuries.

(2) Hemorrhage.

Projectiles kill by damaging or destroying the central nervous system, or by causing lethal blood loss. To the extent the wound components cause or increase the effects of these two mechanisms, the likelihood of incapacitation increases. Accordingly, the Workshop focused its examination of handgun wounding relative to law enforcement use on torso wounds and probable results.

MECHANICS OF HANDGUN WOUNDING

All handgun wounds will combine the components of penetration, permanent cavity, and temporary cavity to a greater or lesser degree. The component0 of fragmentation does not reliably occur in handgun wounds. Bullet fragmentation occurs when the bullet breaks up within the target. It is a function of bullet design, construction, and velocity. It reliably appears in high velocity projectile wounds (impact velocity in excess of 2000 feet per second) inflicted by soft point or hollow point bullets. In such a case, the permanent cavity is stretched so far, and so fast, that tearing and rupturing can occur in tissues remote from the wound channel which were weakened by fragmentation damage. It is the only cause of significant remote damage in bullet wounds.

Since the highest handgun velocities do not exceed 1400-1500 feet per second (fps) at the muzzle, reliable fragmentation could only be achieved by constructing a bullet so frangible as to eliminate any reasonable penetration. Such a bullet would break up too fast, too soon, and not reach vital organs. In cases where some fragmentation has occurred in handgun wounds, the bullet fragments are generally found within one centimeter of the permanent cavity. Any additional wounding effect caused by such fragmentation is inconsequential.

Temporary cavity is totally overrated as a wounding factor when analyzing handgun wounds. Nevertheless, historically it has been the primary means of assessing the wounding effectiveness of handgun bullets.

The most notable example is the Relative Incapacitation Index (RII) which resulted from a study of handgun effectiveness sponsored by the Law Enforcement Assistance Administration (LEAA). In the study, the assumption was made that the greater the temporary cavity, the greater the wounding effect of the round. This assumption regarding temporary cavity was based on the even more basic assumption that the tissue bounded by the temporary cavity was damaged or destroyed.

Virtually every handgun round available to law enforcement was fired into ballistic gelatin. The temporary cavity was measured, and the rounds ranked based on the results. The depth of penetration and the permanent cavity were ignored. The result was that according to the RII, a bullet which causes a large but shallow temporary cavity is a better incapacitator than a bullet which causes a small temporary cavity with deep penetration.

Since vital organs are located deep within the body, it should be obvious that to ignore penetration and permanent

cavity is to ignore the only means of damaging or disrupting vital organs. Further, the temporary cavity is caused by the tissue being stretched away from the permanent cavity, not being destroyed. By definition, a cavity is a space in which nothing exists. A temporary cavity is only a temporary space caused by tissue being pushed aside. That same space then disappears when the tissue returns to its original status.

Forensic pathologists cannot distinguish the wound track caused by a hollow point bullet (large temporary cavity) from that caused by a solid bullet (very small temporary cavity) unless they revolver the bullet itself. There is no physical difference in the wound. If there is no fragmentation, remote damage due to temporary cavitation is minor <u>even with high velocity rifle projectiles</u>.

The reason is that most tissue in the human target is extremely elastic in nature. Muscle, blood vessels, lung, bowels, all are capable of substantial stretching with minimal damage. Studies have shown that the outward velocity of the tissues in which the temporary cavity forms is not more than one tenth of the velocity of the projectile. This is well within the elasticity limits of tissue such as muscle, blood vessels, lungs, etc. Only inelastic tissue like liver, or the extremely fragile tissue of the brain, would show significant damage due to temporary cavitation.

The tissue disruption caused by a handgun bullet is limited to two mechanisms. the first, or crush, mechanism is the hole the bullet makes passing through the tissue. The second, or stretch, mechanism is the temporary cavity formed by the tissues being driven outward in a radial direction away from the path of the bullet. Temporary cavitation is nothing more than a stretch of the tissues, generally no larger than 15 times the bullet diameter, and elastic tissues sustain little, if any, residual damage.

The crush mechanism, the result of penetration and permanent cavity, is the <u>only</u> handgun wounding mechanism which damages tissue. To cause significant injuries to a structure within the body using a handgun, the bullet must directly strike the structure. Temporary cavity has no wounding effect.

THE HUMAN TARGET

The Workshop was unanimous that with the exceptions of hits to the brain or upper spinal cord, the concept of reliable and reproducible immediate incapacitation of the human target by gunshot wounds to the torso is a myth. The human target is a complex and durable one. A wide variety of psychological, physical, and physiological factors exist, all of them pertinent to the probability of incapacitation. Except for the location of the wound, and the amount of tissue destroyed, none of the factors are within the control of the law enforcement officer.

Physiologically, a determined adversary can be stopped reliably and immediately only by a shot that disrupts the brain or upper spinal cord. Given this limitation, massive bleeding from holes in the heart or major blood vessels of the torso causing circulatory collapse is the only other way to force incapacitation upon an adversary, and this takes time. For example, there is sufficient oxygen within the brain to support full, voluntary action for 10-15 seconds after the heart has been destroyed. During that time the adversary can walk, talk, run, or fight as he pleases.

In fact, physiological factors may actually play a relatively minor role in achieving rapid incapacitation. Barring central nervous system hits, there is no physiological reason for an individual to be incapacitated by even a fatal wound, until the blood loss is sufficient to drop blood pressure and/or the brain is deprived of oxygen. The effects of pain, which could contribute greatly to incapacitation, are commonly delayed in the aftermath of serious injury such as a gunshot wound. The body engages survival patterns, the well known "fight or flight" syndrome. Pain is irrelevant to survival and is commonly suppressed until some time later. In order to be a factor, pain must first be perceived, and second must cause an emotional response. In many individuals, pain is ignored even when perceived, or the response is anger and increased resistance, not surrender.

Psychological factors are probably the most important relative to achieving rapid incapacitation from a gunshot wound to the torso. Awareness of the injury (often delayed by the suppression of pain); fear of injury, death, blood, or pain; intimidation by the weapon or the act of being shot; preconceived notions of what people do when they are shot; or the simple desire to quit can lead to rapid incapacitation even from minor wounds. However, psychological factors are also the primary cause of incapacitation failures.

The individual may be unaware of the wound and thus has no stimuli to force a reaction. Strong will, survival instinct, or sheer emotion such as rage or hate can keep a grievously injured individual fighting, as is common on the battlefield and in the street. The effects of chemicals can be powerful stimuli preventing incapacitation. Adrenalin alone can be sufficient to keep a mortally wounded adversary functioning. Stimulants, anesthetics, pain killers, or tranquilizers can all prevent incapacitation by suppressing pain, awareness of injury, or eliminating any concerns over the injury. Drugs such as cocaine, PCP, and heroin are disassociative in nature. One of their effects is that the individual "exists" outside of his body. He sees and experiences what happens to his body, but as an outside observer who can be unaffected by it yet continue to use the body as a tool for fighting or resisting.

Physical factors such as energy deposit, momentum transfer, size of the temporary cavity, or calculations such as the RII are irrelevant or erroneous. The impact of the bullet upon the body is less than the recoil of the weapon. The ratio of bullet mass to target mass is too extreme. A bullet simply cannot knock a man down. If it had the energy to do so, then equal energy would be applied against the shooter and he too would be knocked down. That is simple physics. The amount of energy deposited in the body by a bullet is approximately equivalent to being hit with a baseball. Only tissue damage has any physical link to incapacitation, but excluding the central nervous system, it is not a causative factor for incapacitation within the desired time frame, i.e., immediately.

The human target can be reliably incapacitated only by disrupting or destroying the brain or upper spinal cord. Absent that, incapacitation is subject to a host of variables, the most important of which are beyond the control of the shooter. Incapacitation becomes an eventual event, not a necessarily immediate one. If the psychological factors which can contribute to incapacitation are present, then even a minor wound can be immediately incapacitating. If they are not present, then incapacitation can be long delayed even with major, nonsurvivable wounds. Field results are a collection of individualistic reactions on the part of each person shot which can be analyzed and reported as percentages. However, no one individual responds as a percentage, but as an all or none phenomenon which the officer cannot possibly predict.

AMMUNITION SELECTION CRITERIA

The critical wounding components for handgun ammunition, in order of importance, are penetration and permanent cavity. The bullet must penetrate the torso far enough to strike vital organs and do so from less than optimal angles; for example, from the side through an arm (about 10-12 inches through the heart) or from the front through the abdomen (about 7 inches in a slender adult to the major blood vessels in the back of the abdominal cavity). Penetration must be sufficiently deep to reach and pass through vital organs, and the permanent cavity large enough to maximize tissue destruction and consequent hemorrhaging.

Several design approaches have been made in handgun ammunition which are intended to increase the wounding effectiveness of the bullet. Most notable of these is the use of a hollow point bullet designed to expand on impact.

Expansion accomplishes several things. On the positive side, it increases the frontal area of the bullet and thereby increases the amount of tissue disintegrated in the bullet's path. Also, due to the increasing resistance of the larger frontal area and the resultant greater rate of energy loss, it will result in a larger temporary cavity. On the negative side, expansion limits penetration. It can prevent the bullet from penetrating to vital organs, especially if the projectile is of relatively light mass and the penetration must be through several inches of fat, muscle, or clothing.

Increasing bullet mass will increase penetration, while increasing the bullet's velocity will decrease penetration, all else being the same. Permanent cavity can be increased by the use of expanding bullets, and/or larger diameter bullets, which have adequate penetration. However, in no case should selection of a bullet be made where bullet expansion is necessary to achieve the desired performance. Handgun bullets expand in the human target only 60-70% of the time. Damage to the hollow point by hitting bone, glass, or other intervening obstacle can prevent expansion. Clothing fibers can wrap the nose of the bullet in a cocoon like manner and prevent expansion. Insufficient impact velocity caused by short barrels, longer range, or simple manufacturing variations will prevent expansion. Expansion must never be a basis for bullet selection, but considered a bonus when, and if, it occurs. Bullet desirability should be determined based on penetration first, and the unexpanded diameter of the bullet second, as that is all that the shooter can reliably expect.

It is essential, however, to bear in mind that the single most critical factor remains penetration. A handgun bullet MUST reliably penetrate 10-12 inches of soft body tissue at a minimum, regardless of whether it expands or not. Penetration up to 18 inches would be even better. If the bullet does not reliably penetrate to these depths, it is not an effective bullet for law enforcement use.

Given adequate penetration, a larger diameter bullet may have an edge. It will damage a blood vessel the smaller projectile barely misses. The larger permanent cavity may lead to faster blood loss. The Workshop agreed, however, that although such an edge exists, its significance cannot be measured.

The Workshop identified a widespread fear of over penetration on the part of law enforcement, i.e., the concern that a bullet would pass through the body of a subject and injure an innocent bystander. This is largely erroneous.

First, a review of law enforcement shootings reveals that the majority of shots fired by officers do not hit any subjects at all. The relatively few shots that do hit a subject are not somehow more dangerous to bystanders if they penetrate than the shots that miss the subject entirely. Secondly, the burst strength of the skin on the exit side of the body is very strong. The skin is tough and flexible. Experiments show that it has the same resistance to bullet passage as approximately four inches of muscle tissue. The conclusion of the Workshop was that fear of over penetration was largely unfounded, except in the possible case of full metal jacketed (FMJ) bullets. Choosing a bullet because of relatively shallow penetration will seriously compromise weapon effectiveness.

CONCLUSIONS

Absolutely no caliber or bullet is certain to incapacitate any one individual unless the brain is hit. Some individuals are passive and will be incapacitated by miknor or small caliber wounds. Some are not, or are stimulated by fear, adrenalin, drugs, alcohol, and/or sheer will and survival determination which may prevent them from going down even if mortally wounded.

The will to survive and to fight despite horrific damage to the body is commonplace on the battlefield, and on the street. Barring a hit to the brain, the only way to force incapacitation is to cause sufficient blood loss that the subject can no longer function, and that takes time. Even if the heart is instantly destroyed, there is sufficient oxygen in the brain to support full and complete voluntary action for 10-15 seconds.

Kinetic energy does to wound. Temporary cavity does no wound. The mush discussed "shock" of bullet impact is less than the recoil of the weapon firing the bullet. "Knock down" power is a myth. The only thing that matters is penetration. The bullet must pass through the large, blood bearing organs and be of sufficient diameter to promote rapid bleeding. Penetration less than 10-12 inches is too little, and, in the words of one of the Workshop participants, too little penetration will get you killed.

Using these performance parameters, the Workshop concluded that with one exception (and discounting FMJ bullets), there are no 9mm rounds which are effective for law enforcement use. All the light, 9mm hollow point bullets popular in law enforcement today dangerously lack penetration, as do the light, high velocity .38 and .357 bullets. They characteristically give 6-7 inches of penetration, and that is not enough to reach vital organs in any situation except an ideal, and unlikely, frontal chest shots. The exception is a new 147 grain subsonic round being produced by Winchester. In testing to date, this bullet penetrates almost 15 inches of soft body tissue and is the only bullet recommended in 9mm by the Workshop.

Most of the currently available .45 hollow points are recommended as better than any of the 9mm bullets, except for the subsonic round. Compared to the subsonic round, they given good penetration on the order of 10-12 inches. The .45's will also cause a larger diameter hole which the Workshop identified as an edge, albeit an unmeasurable one.

The choice between 9mm and .45 ultimately becomes one of weapon type and capacity, officer confidence and perception of weapon adequacy, and training and policy matters unrelated to ammunition effectiveness. Provided the 9mm subsonic round is used, there is no clear difference between the two calibers. In

this case, the Workshop recommended that both calibers be allowed for use, thereby enabling the officer to carry and use that caliber in which he has the most confidence and with which he feels safest. The individual officer's belief in the efficacy of his weapon/ammunition has more influence on his effectiveness and ability than any expert advice. If the subsonic round is not used, the .45 is clearly superior to its wounding effectiveness.

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