LESP-RPT-0101.01
OCTOBER 1975

LAW ENFORCEMENT STANDARDS PROGRAM

AN EVALUATION OF POLICE HANDGUN AMMUNITION: SUMMARY REPORT

STANDARDS PROGRAM

U.S. DEPARTMENT OF JUSTICE
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AN EVALUATION OF POLICE HANDGUN AMMUNITION: SUMMARY REPORT

prepared for the
National Institute of Law Enforcement and Criminal Justice
Law Enforcement Assistance Administration
U.S. Department of Justice

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Law Enforcement Assistance Administration

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LAW ENFORCEMENT ASSISTANCE ADMINISTRATION

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ACKNOWLEDGMENT

This report was prepared by the Law Enforcement Standards Laboratory of the National Bureau of Standards under the direction of Ronald C. Dobbyn, Manager, Protective Equipment Program, and Jacob J. Diamond, Chief of LESL.

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CONTENTS

FOREWORD

Following a Congressional mandate[1] to develop new and improved techniques, systems, and equipment to strengthen law enforcement and criminal justice, the National Institute of Law Enforcement and Criminal Justice (NILECJ) has established the Law Enforcement Standards Laboratory (LESL) at the National Bureau of Standards. LESL's function is to conduct research that will assist law enforcement and criminal justice agencies in the selection and procurement of quality equipment.

In response to priorities established by NILECJ, LESL is (1) subjecting existing equipment to laboratory testing and evaluation and (2) conducting research leading to the development of several series of documents, including national voluntary equipment standards, user guidelines, state-of-the-art surveys and other reports.

This document, LESP-RPT-0101.01, An Evaluation of Police Handgun Ammunition: Summary Report, is a law enforcement equipment report prepared by LESL and issued by NILECJ. Additional reports as well as other documents are being issued under the LESL program in the areas of protective equipment, communications equipment, security systems, weapons, emergency equipment, investigative aids, vehicles and clothing.

Technical comments and suggestions concerning the subject matter of this report are invited from all interested parties. Comments should be addressed to the Program Manager for Standards, National Institute of Law Enforcement and Criminal Justice, Law Enforcement Assistance Administration, U.S. Department of Justice, Washington, D.C. 20531.

Lester D. Shubin, Manager
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National Institute of Law
Enforcement and Criminal Justice

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[1] Section 402(b) of the Omnibus Crime Control and Safe Streets Act of 1968, as amended.

AN EVALUATION OF POLICE HANDGUN AMMUNITION: SUMMARY REPORT

PREFACE

In 1973, the National Institute of Law Enforcement and Criminal Justice of the Law Enforcement Assistance Administration approved and funded a project, submitted by the Law Enforcement Standards Laboratory (LESL), National Bureau of Standards, to conduct a study of the terminal effects of police handgun ammunition. LESL contracted with the U.S. Army Ballistic Research Laboratories, Aberdeen Proving Ground, Maryland, September, 1973, to conduct this study, to prepare a report of their findings and to draft guidelines for the selection of law enforcement service handgun ammunition. The full report entitled, "An Evaluation of Handgun Ammunition," is forthcoming as a publication of the National Institute of Law Enforcement and Criminal Justice.

The full report will contain a complete description of a model for human incapacitation by handgun bullets, comparisons of presently available factory-loaded handgun cartridges according to their potential to incapacitate humans, to penetrate common materials, and to pose a hazard to bystanders. It will also contain lengthy tables of experimental data which are not included in this summary report.

The fact that the National Institute of Law Enforcement and Criminal Justice furnished financial support to the activity resulting in this publication does not necessarily indicate the concurrence of the Institute or of the Law Enforcement Assistance Administration in any statements or conclusions contained herein.

1. INTRODUCTION

Law enforcement agencies throughout the United States are presently questioning the effectiveness of their service handgun ammunition. Many who have not already adopted a new type or caliber are considering the possibility of doing so. The major trends are ammunition of higher velocity and bullets of different shape.

The tendency to change has been prompted by law enforcement's widespread impression that the traditional police service round, the caliber .38 Special round-nose lead bullet, is relatively ineffective. This has often been dramatically demonstrated by the wounding or killing of a policeman who was able to shoot his assailant but was unable to incapacitate him. The change from one service load or weapon to another is a very complex problem for the department and the local government, which must consider every effect that a change might have on the community.

Experience has shown that the choice of one cartridge over another, or one caliber in favor of another, hangs on the answers to technical questions. It has been the lack of fully credible answers to these questions that has made such decisions complex and speculative. Opinion has been substituted for fact, and emotion for reason.

Numerous arguments have been raised concerning the use of hollow point, semi-wadcutter and other variations of the traditional round-nose lead bullet. Opponents of change have quoted reports that the other bullets cause more severe wounds, are not permitted in international warfare, are dangerous to bystanders, etc. Some medical examiners have stated that they find no differences in the nature of the wounds caused by different bullet types, but these judgments are not widely known or accepted.

The argument that these bullets are in violation of the Hague Convention has been countered by the assertion that only full-jacketed bullets may be used under these rules, and that the traditional police bullet is also not in accord with the Convention. The fact that full-jacketed bullets have a greater ricochet potential than lead bullets is rarely considered.

The myths should be dispelled. State and local governments should be able to make their decisions on the basis of solid fact. Bullet selections should be made with due regard to their effectiveness against the criminal, as defined by their incapacitation potential (not their lethality), and with maximum safety to the general public.

The goal of the present NILECJ study of police handgun ammunition is to provide State and local law enforcement agencies with at least some of the basic factual information which they need. Three basic terminal effects of handgun bullets have been studied: their relative incapacitation potential for human targets, their ricochet behavior, and their material penetration characteristics. The focus has been on commercially available handgun ammunition in the caliber range 9mm (.355 in) to .45. The test methods and evaluation techniques are, however, applicable to other penetrating projectiles.

This interim summary report gives some of the results of the recent laboratory investigations and outlines a model for the relative stopping power or incapacitation potential of handgun bullets.

2. TEST PROGRAM

An extensive laboratory investigation of all significantly different handgun bullets in the caliber range 9mm to .45, which are currently available to law enforcement agencies in the United States, has been essentially completed. These experiments included the following:

a. A determination of each bullet's behavior on striking and penetrating ordnance gelatin, as a function of its impact velocity.

b. Measurement of the formation and subsequent development of the temporary cavity produced in the gelatin by each projectile, using high-speed motion pictures.

c. Measurement of the dynamic behavior of each bullet as it penetrated the gelatin, i.e., its stability and deformation, using flash X-ray photography.

d. Measurement of the impact velocity of factory-loaded ammunition corresponding to each bullet under study, when fired from various handguns currently used by law enforcement agencies.

e. Measurements designed to determine the ricochet and penetration potentials of each bullet, as a function of angle of incidence and velocity, when striking various common materials.

These experiments were conducted in an attempt to determine what produces human incapacitation by handgun bullets (relative stopping power), which, if any, of the existing theories on this subject are correct and, in particular, whether relative incapacitation can be predicted solely in terms of the properties of the bullet, i.e., its mass, velocity, shape, construction, and caliber. An understanding and assessment of the relative hazards due to the ability of these bullets to ricochet from and to penetrate materials was also sought.

In addition to the experimental effort, theoretical models of cavity formation in gelatin by both deforming and non-deforming, non-tumbling handgun bullets have been developed. These models have successfully predicted the observations made experimentally.

3. RELATIVE INCAPACITATION (RELATIVE STOPPING POWER)

The model for relative incapacitation developed in this study is based on a complete assessment of the confrontation between a law enforcement officer and an armed criminal. The behavior of a bullet in the target is only a part of this model. The vulnerability of humans to incapacitation by handgun bullets, the path of the bullet within the target, the point of aim, and the ability of the officer to hit his target are other important aspects of the general problem and have been considered in detail.

The incapacitation criterion imposed on the model is a stringent one, as it must be if meaningful estimates are to be made. To identify those parts of the human anatomy which,

when rendered temporarily or permanently non-functional, will result in the instantaneous incapacitation of the criminal, the following scenario was presented to a team of medical experts:

> An armed criminal has been placed in a high-stress situation in which he is convinced that only continued aggression on his part will prevent the loss of his life; he is armed with a hand-held weapon and he is being approached by an armed law enforcement officer; he attacks the officer. The officer must administer a swift, incapacitating injury to the assailant with his handgun, in order to save his own life.

The medical experts were asked to assign relative values to those parts of the body which, when wounded, would result in this instantaneous incapacitation. Their judgments were further constrained by a definition of instantaneous incapacitation:

> Instantaneous incapacitation is that which will render the assailant incapable of posing a continued threat to the safety of the officer by use of a hand-held weapon. Such injury may include clinical death, unconsciousness, biomedical dysfunction, etc., but pain may not be considered a contributing factor.

These data have been encoded for use in conjunction with an elaborate three-dimensional computerized model of the human anatomy, known as the Computer Man. The Computer Man is the result of several years of effort on the part of personnel at the Ballistic Research Laboratories, Aberdeen Proving Ground, and has proven to be a valuable tool in their overall program in wound ballistics.

The Computer Man consists of volume elements of the body of a man in the form of rectangular sections 5 x 5 x 25mm (0.2 x 0.2 x 1 in) in size. Within each volume element, all tissue types have been identified and encoded. The composite of the above injury criterion (instantaneous incapacitation), the Computer Man, and the probable distribution of the impact points and trajectories of the bullets from a given handgun in terms of the range to the target and the point of aim, all enter into the assessment of the vulnerability of a human target to incapacitation by a particular handgun bullet type.

The feature of a bullet's interaction with soft tissue that has been identified as contributing most to instantaneous incapacitation is the temporary cavity which the bullet generates as it penetrates. This one feature has the most likelihood of interacting with those relatively few centers of vital activity required for continued aggression. For a given impact point, the bullet producing the largest temporary cavity at the proper depth of penetration—defined by the location of vital organs—will have the greatest chance for success in producing instantaneous incapacitation. In other words, such a round will possess the greatest stopping power.

The radius of the maximum temporary cavity, as a function of depth of penetration, has been chosen as the measure of *relative bullet performance*. This performance can now be predicted for several types of bullets, without recourse to experiment, because of the present ability to calculate these cavities using solely the velocity, shape, construction, mass, and caliber of the bullet.

However, the *relative incapacitation potential* of a given bullet type will also depend on the point of aim and the probabilities of the bullet impacting the target at various points surrounding the point of aim. This latter is in turn dependent on the range, the marksmanship of the shooter, and the characteristics of the bullet/weapon combination.

The present study has generated a very large volume of data that relate the maximum temporary cavity generated by a handgun bullet to its velocity, shape, construction, mass and caliber. These data are still being analyzed. However, progress to date does permit certain tentative conclusions to be drawn; these may provide some immediate assistance to law enforcement agencies now involved in ammunition selection.

4. CONCLUSIONS

A. Bullet Velocity

In the range of calibers studied the most important property of a moving handgun bullet affecting its performance in the target medium is its velocity. There are several reasons:

1. The size of the Maximum Temporary Cavity (MTC) depends partly on the striking kinetic energy, $1/2\ mv_0^2$, i.e., the volume of the MTC depends on the total energy available.

2. There is a threshold velocity, below which a bullet will not deform; deformation of the bullet greatly affects the size and shape of the MTC.

It should be stressed, however, that one cannot use the striking kinetic energy as the sole criterion for ranking handgun bullets. It is the size and shape of the resulting MTC and how it overlaps vital organs that ultimately gives one bullet a higher Relative Incapacitation Index (RII) than another. Some lighter bullets yield a higher RII than heavier ones having the same striking kinetic energy, shape, construction and caliber. This is shown in figure 1.

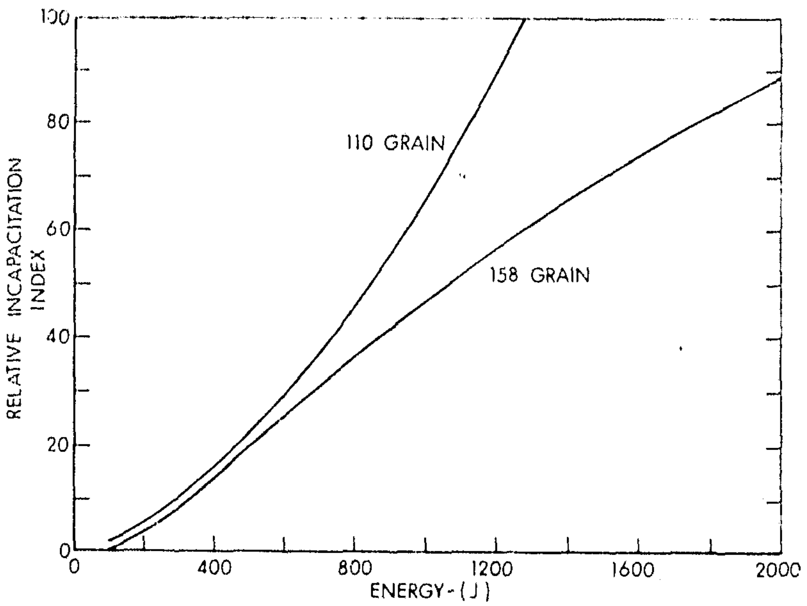

Figure 1. A comparison of a light bullet with a heavier bullet. Note the different values of relative incapacitation index at equal values of striking energy. Each are caliber .357 (.38 Spec.) semi-jacketed hollow points.

B. Bullet Mass

The mass of the bullet affects the size and shape of the MTC. A lighter bullet will slow down more rapidly in the target medium and a heavier bullet will penetrate further; this affects the location of the maximum radius of the MTC. Again, it is the location of the temporary cavity with respect to that of vital organs that produces varying degrees of incapacitation.

C. Bullet Shape

The effect of bullet shape (bluntness of the nose) is important only in that it establishes the initial value of the hydrodynamic drag coefficient, $C_D(O)$. This coefficient enters the formula for the envelope of the MTC and it is also a part of the formula for the threshold deformation velocity. At velocities too low for deformation to occur, C_D is a constant and the effect is that blunter bullets (larger $C_D(O)$) yield higher values of RII. This is shown in figure 2. The wadcutter (WC) has the largest value of $C_D(O)$.

At velocities sufficient to cause deformation of the bullet, C_D changes as the bullet deforms. Bullets with smaller initial values of C_D can deform in such a way as to out-perform those with a higher initial C_D. This is also shown in figure 2.

D. Caliber

The caliber of a bullet, together with its shape, establish the initial value of its area function, A(O). It is this area of the interface between the bullet and the target medium that enters the formula for the envelope of the MTC; the sectional area of the bullet (proportional to the caliber squared) cannot be used once the bullet begins to deforms. Thus, a larger caliber bullet will yield a higher RII at non-deforming velocities; once deformation is possible, smaller caliber bullets may out-perform larger calibers.

E. Deformation and Bullet Construction

Deformation of a handgun bullet depends strongly on both velocity and construction. Construction involves principally whether the bullet is jacketed or not; the length, thickness, and hardness of the jacket material; the presence of hollow noses, cavities or hollow bases; and the hardness of the lead. Construction also directly affects fragmentation of the bullet in both hard and soft targets.

Figure 2 shows that, over a wide range of velocities, the ranking, in order of decreasing RII is:

a. Lead hollow point (LHP)
b. Jacketed hollow point (JHP)
c. Semi-wadcutter (SWC)
d. Wadcutter (WC)
e. Jacketed soft point (JSP)
f. Lead round nose (LRN)
g. Full metal jacketed (FMJ)

The low velocity performance of the wadcutter has been discussed under bullet shape. With the exception of the full-metal-jacketed bullet, the onset of deformation occurs at a given velocity for each bullet construction type (a through f); i.e., a hollow-point bullet will begin deforming, at a velocity above 215 meters (705 feet) per second and a lead round nose at a velocity above 340 meters (1115 feet) per second. Unless the bullet's muzzle velocity exceeds this threshold value, bullet deformation is highly unlikely. Note that these threshold velocities were obtained by flash X-ray photography; they cannot be obtained by an inspection of figure 2, although they are consistent with the curves shown there.

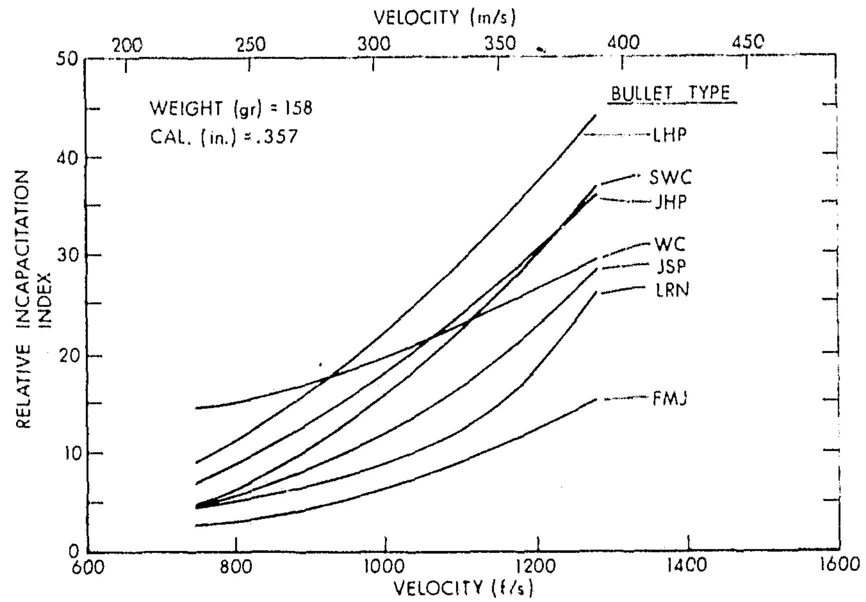

Figure 2. Relative incapacitation index as a function of velocity for seven bullet types in caliber .357 (.38 Special). Each curve represents the average performance for all brands of the given bullet type. Differences among manufacturers can be distinguished, and will be reported in the final report.

F. Shooter Accuracy

The relative incapacitation index increases as shooter accuracy increases, and accuracy increases as the engagement range decreases. See figures 3 and 4. However, the effect of handgun type/cartridge combinations on shooter accuracy has not been systematically addressed in this study; it is the subject of possible future work.

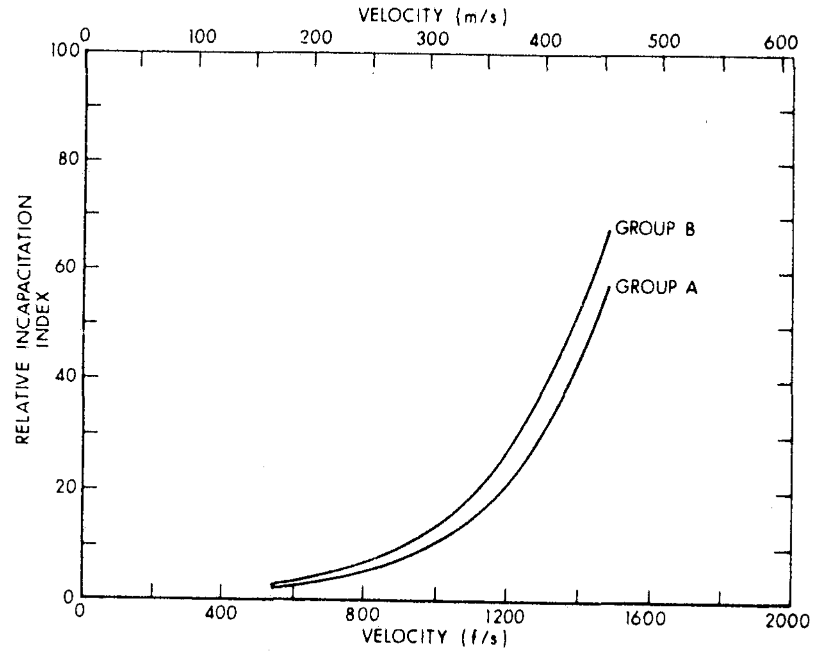

Figure 3. Effect of accuracy on relative incapacitation index for two groups of officers using 125 grain semi-jacketed hollow point, caliber .357 (.38 Spec.) bullets at a range of 6 meters.

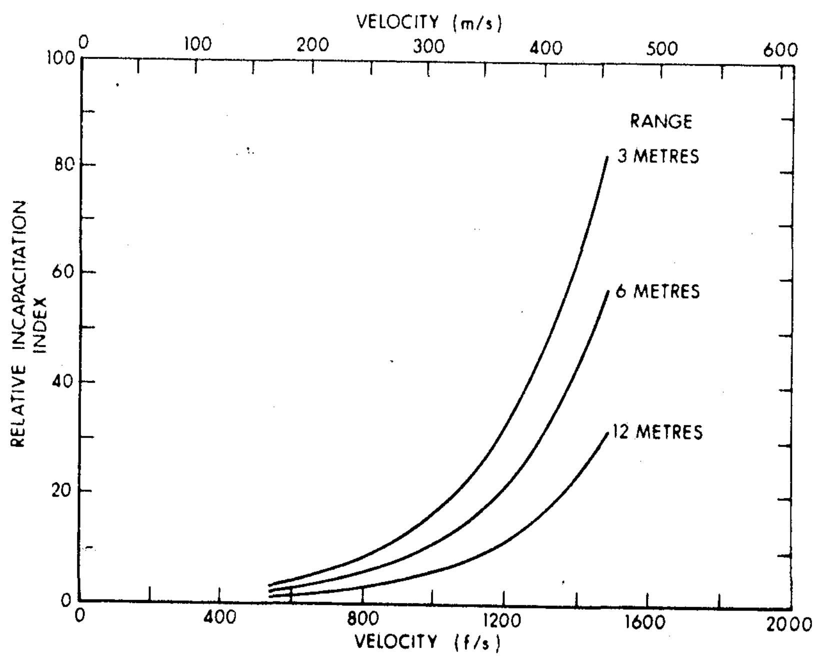

Figure 4. Effect of engagement range on relative incapacitation index for 125 grain semi-jacketed hollow point caliber .357 (.38 Spec.) bullets.

G. Point of Aim

The relative incapacitation index is dependent on the aim point chosen by the officer. Assuming a given degree of shooter accuracy, the data indicate that an aim point slightly higher (armpit level) than that used on standard silhouette targets increases stopping power. See figures 5 to 10.

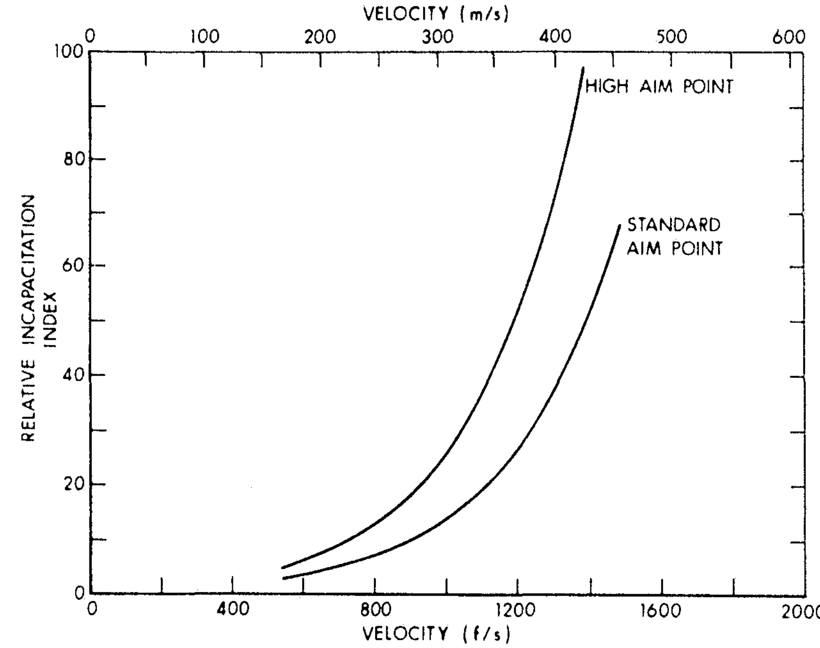

Figure 5. Effect of aim point on relative incapacitation index for group A officers at a range of 6 meters.

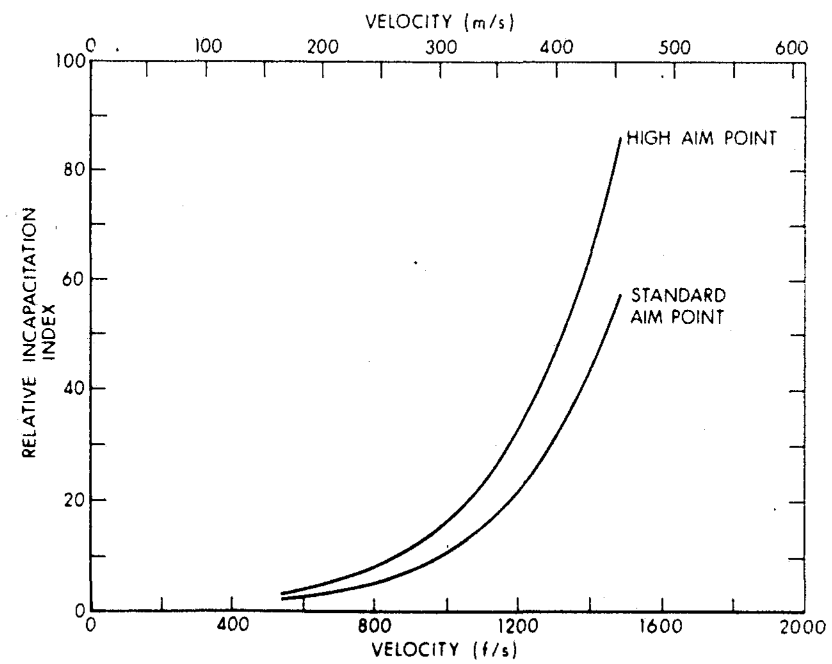

Figure 6. Effect of aim point on relative incapacitation index for group B officers at a range of 6 meters.

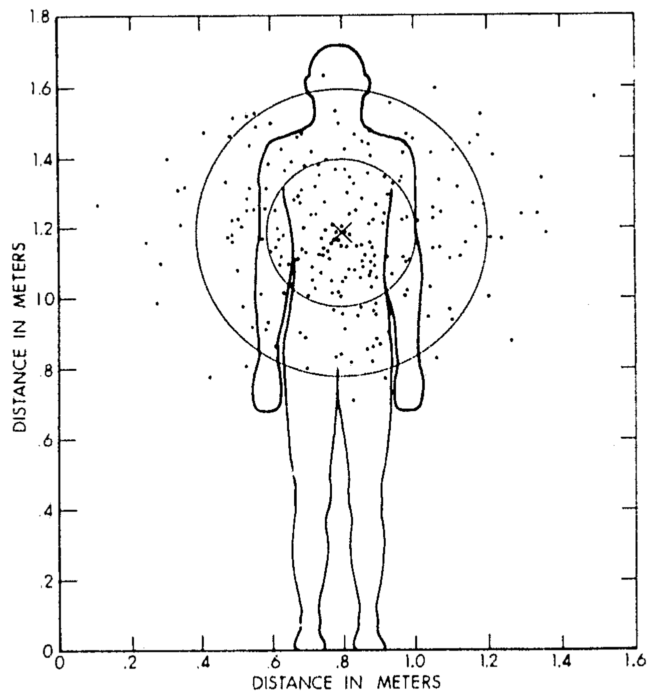

Figure 7. Hit distribution superimposed on a computer man silhouette. (Standard aim point; group A officers; 6 meter range.)

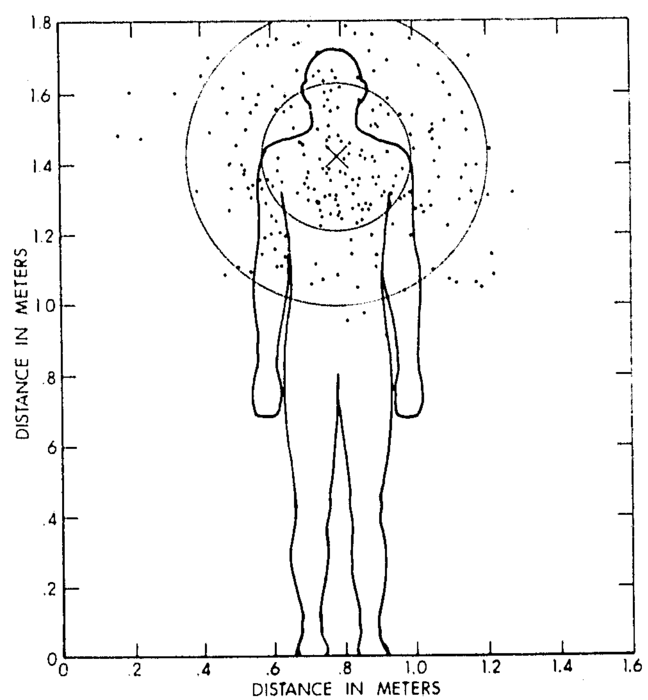

Figure 8. Hit distribution superimposed on a computer man silhouette. (High aim point; group A officers; 6 meter range.)

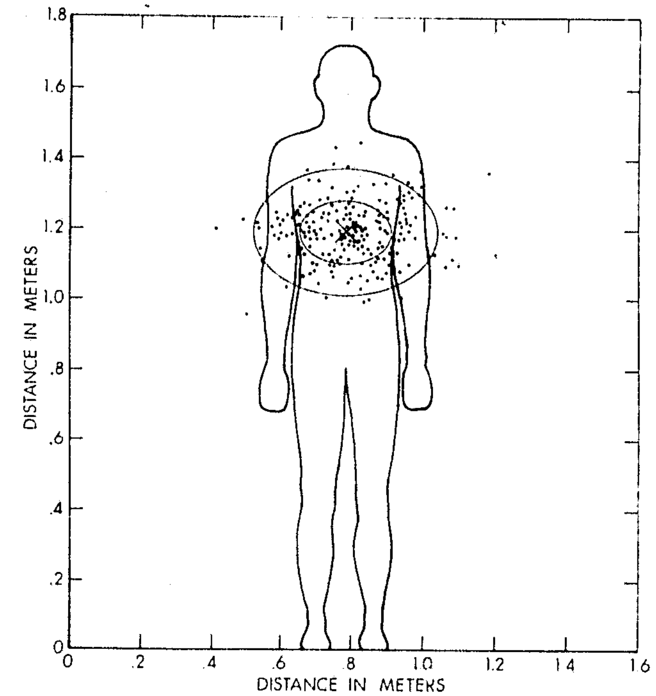

Figure 9. Hit distribution superimposed on a computer man silhouette. (Standard aim point; group B officers; 6 meter range.)

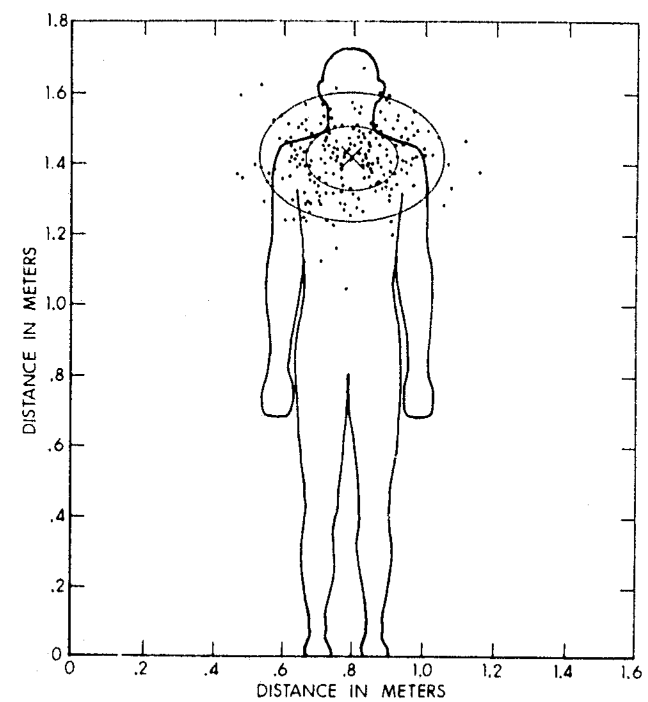

Figure 10. Hit distribution superimposed on a computer man silhouette. (High aim point; group B officers; 6 meter range.)

H. Hazard to Bystanders

A hazard to innocent bystanders can occur if the officer misses his target or if the bullet overpenetrates the target and exits with sufficient velocity to inflict a wound. With regard to the latter, overpenetration can occur if the bullet velocity is too low (absence of deformation) or if it is too high. Overpenetration can be avoided by specifying an acceptable range for bullet muzzle velocity.

The hazard due to a miss can result either from a ricochet or from the bullet striking the bystander directly after missing the target.

The ricochet and penetration potentials of bullets were studied simultaneously, since one is a limiting case of the other; i.e., a bullet which ricochets from a material does not penetrate that material. Experimental data were obtained for a variety of common materials. General conclusions are:

1. The angle of reflection does not equal the angle of incidence; the bullet tends to remain close to the surface from which it ricochets.

2. The hazard due to ricochet *decreases* as the velocity of the bullet *increases;* high velocities produce fragmentation.

3. The hazard due to ricochet *decreases* as the frangibility of the bullet *increases*. Frangibility is strongly dependent on construction. For example, a jacketed hollow-point moving at 355 m/s (1100 ft/s) poses less of a hazard due to ricochet than a round-nose lead bullet moving at the same velocity.

4. The hazard due to ricochet decreases as the mass of the bullet decreases.

5. Light, fast bullets with a tendency to fragment are poor penetrators. Despite the myth to the contrary, magnum hollow-point handgun rounds will not penetrate engine blocks.

6. With the exception of the Glaser Safety Slug, all handgun bullets studied pose a serious ricochet hazard to bystanders.

5. PERFORMANCE OF COMMERCIALLY AVAILABLE HANDGUN AMMUNITION

Tables 1 and 2 list the commercial handgun ammunition examined as part of this project. Table 1 is arranged in order of decreasing Relative Incapacitation Index (RII); table 2 presents the same information arranged by calibers and, within a caliber, in order of increasing bullet weight.

TABLE 1
Performance of Commercially Available Handgun Ammunition

Bullet ID No.	Caliber	Weight (grains)	Bullet Type	Manufacturer	Barrel Length (in)	Velocity Nominal* (fps)	Velocity Measured (fps)	Velocity Measured (mps)	RI Index
1	.44 MAG	200	JHP	Speer	4.00	1675	1277	389	54.9
2	9MM	96	Safety Slug	Deadeye Assoc	4.00	1365	1839	560	54.5
3	.41 MAG	210	JSP	Remington	4.00	1500	1260	384	51.9
4	.357 MAG	96	Safety Slug	Deadeye Assoc	4.00	1120	1725	525	50.0
5	.44 MAG	240	SWC	Winch-Western	4.00	1470	1330	405	50.0
6	.44 MAG	240	SWC	Browning	4.00	1470	1311	399	49.8
7	.44 MAG	240	SWC	Remington	4.00	1470	1286	391	48.9
8	.44 MAG	240	JHP	Browning	4.00	1330	1257	383	47.9
9	.44 MAG	240	JHP	Remington	4.00	1470	1229	374	46.7
10	.357 MAG	96	Safety Slug	Deadeye Assoc	2.75	1120	1615	492	46.0
11	.44 MAG	240	JSP	Speer	4.00	1650	1203	366	45.7
12	.357 MAG	125	JHP	Speer	4.00	1900	1301	396	44.4
13	.357 MAG	140	JHP	Speer	4.00	1780	1221	372	44.4
14	.357 MAG	125	JHP	Remington	4.00	1675	1366	416	42.5
15	.38 SPEC	96	Safety Slug	Deadeye Assoc	4.00	1800	1585	483	41.8
16	.44 MAG	180	JSP	Super Vel	4.00	1995	1495	455	41.6
17	9MM	115	JHP	Remington	4.00	1160	1192	363	38.0
18	.38 SPEC	96	Safety Slug	Deadeye Assoc	2.00	1800	1496	455	37.5
19	.357 MAG	125	JHP	Remington	2.75	1675	1173	357	37.1
20	.357 MAG	140	JHP	Speer	2.75	1780	1125	342	34.4
21	.357 MAG	110	JHP	Speer	4.00	1700	1246	379	33.4
22	.357 MAG	125	JHP	Speer	2.75	1900	1161	353	30.6
23	.357 MAG	158	JSP	Speer	4.00	1625	1156	352	28.0
24	38 SPEC	95	JHP(+P)	Remington	4.00	985	1187	361	28.0
25	9MM	100	JHP	Speer	4.00	1315	1188	362	27.9
26	.38 SPEC	125	JHP	Remington	4.00	1160	1108	337	25.5
27	.38 SPEC	110	JHP	Super Vel	4.00	1370	1159	353	25.1
28	.38 SPEC	110	JHP	Super Vel	2.00	1370	1148	349	24.8
29	.357 MAG	110	JHP	Smith & Wesson	4.00	1800	1226	373	24.0
30	.357 MAG	110	JHP	Speer	2.75	1700	1178	359	23.3
31	.38 SPEC	125	JSP(+P)	Speer	4.00	1425	1047	319	22.5
32	.357 MAG	125	JHP	Smith & Wesson	4.00	1775	1227	373	22.1
33	.357 MAG	158	JSP(HI-VEL)	Federal	4.00	1550	1255	382	21.1
34	.45 AUTO	185	JHP	Remington	5.00	950	895	272	21.1
35	.357 MAG	110	JHP	Western Sup-X	4.00	1500	1309	398	21.0
36	.357 MAG	110	JHP	Western Sup-X	2.75	1500	1258	383	20.2
37	.38 SPEC	125	JHP(+P)	Speer	4.00	1425	1006	306	19.9
38	.38 SPEC	90	MP	KTW	4.00	1030	922	281	19.6
39	.38 SPEC	110	JSP	Super Vel	4.00	1370	1202	366	19.4
40	.38 SPEC	110	JHP(LOT-Q4070)	Winch-Western	4.00	####	1106	337	19.3
41	.357 MAG	158	JSP(HI-VEL)	Federal	2.75	1550	1195	364	18.7
42	.38 SPEC	140	JHP(+P)	Speer	4.00	1200	978	298	18.6
43	.38 SPEC	140	JHP(+P)	Speer	2.00	1200	897	273	18.5
44	.38 SPEC	158	LHP	Winch-Western	4.00	855	915	278	18.4
45	.357 MAG	125	JHP	Smith & Wesson	2.75	1775	1188	362	17.7
46	.357 MAG	158	JSP	Speer	2.75	1625	1030	313	17.5
47	.357 MAG	158	JSP	Smith & Wesson	4.00	1500	1168	356	17.2
48	.357 MAG	158	JSP	Smith & Wesson	2.75	1500	1091	332	17.0
49	9MM	115	JHP	Smith & Wesson	4.00	1145	1193	363	16.6
50	.357 MAG	158	LRN(Lubaloy)	Western Sup-X	4.00	1410	1230	374	16.6
51	.38 SPEC	125	JSP	3-D	4.00	1085	1091	332	16.5
52	.38 SPEC	90	MP	KTW	2.00	1030	734	223	15.6

* - Advertised Velocity
- Velocity not available

TABLE 1 (CONTINUED)
Performance of Commercially Available Handgun Ammunition

Bullet ID No.	Caliber	Weight (grains)	Bullet Type	Manufacturer	Barrel Length (in)	Velocity Nominal* (fps)	Velocity Measured (fps)	Velocity Measured (mps)	RI Index
53	.38 SPEC	125	JHP(+P)	Speer	2.00	1425	931	283	15.5
54	9MM	100	FJ(FMC)	Smith & Wesson	4.00	1250	1341	408	15.2
55	.45 AUTO	185	WC(Targetmaster)	Remington	5.00	775	821	250	14.7
56	.38 SPEC	125	JSP	Smith & Wesson	4.00	1350	1064	324	14.5
57	.357 MAG	158	JHP	Smith & Wesson	4.00	1050	1116	340	14.4
58	.357 MAG	158	LRN(Lubaloy)	Western Sup-X	2.75	1410	1169	356	14.4
59	.38 SPEC	158	SWC	Winchester	4.00	855	924	281	14.3
60	.38 SPEC	95	JHP(+P)	Remington	2.00	985	1019	310	14.0
61	.38 SPEC	110	JHP(LOT-Q4070)	Winch-Western	2.00	####	956	291	14.0
62	.38 SPEC	110	JSP	Super Vel	2.00	1370	1076	327	14.0
63	.357 MAG	110	JHP	Smith & Wesson	2.75	1800	1044	318	13.9
64	9MM	124	FJ(FMC)	Remington	4.00	1120	1084	330	13.8
65	.41 MAG	210	SWC	Remington	4.00	1050	944	287	13.7
66	.38 SPEC	125	JSP(+P)	Speer	2.00	1425	983	299	13.2
67	.38 SPEC	158	JHP	Smith & Wesson	4.00	1050	1047	319	13.0
68	.38 SPEC	90	JSP(HEMI)	Smith & Wesson	4.00	1350	1158	352	12.4
69	.38 SPEC	110	JHP	Smith & Wesson	4.00	1380	1014	309	12.4
70	.38 SPEC	148	WC	Remington	4.00	770	741	225	12.4
71	.38 SPEC	148	WC	Browning	4.00	770	731	222	12.3
72	.38 SPEC	148	WC	Federal	4.00	770	737	224	12.3
73	.38 SPEC	148	WC	Smith & Wesson	4.00	800	726	221	12.3
74	.38 SPEC	148	WC	Remington	2.00	770	700	213	12.2
75	.38 SPEC	148	WC	Federal	2.00	770	674	205	12.1
76	.38 SPEC	148	WC	Smith & Wesson	2.00	800	662	201	12.1
77	.38 SPEC	148	WC	Speer	4.00	825	679	206	12.1
78	.38 SPEC	148	WC(Clean Cutting)	Western	4.00	770	696	212	12.1
79	9MM	115	JSP(Power Point)	Western Sup-X	4.00	1160	1272	387	12.0
80	.38 SPEC	148	WC	Speer	2.00	825	652	198	12.0
81	.38 SPEC	148	WC	Browning	2.00	770	618	188	11.9
82	.38 SPEC	148	WC(Clean Cutting)	Western	2.00	770	618	188	11.9
83	.38 SPEC	90	JSP	Smith & Wesson	4.00	1350	1118	340	11.8
84	.357 MAG	158	JHP	Smith & Wesson	2.75	1050	982	299	11.1
85	.38 SPEC	158	LHP	Winch-Western	2.00	855	805	245	11.0
86	.38 SPEC	158	SWC	Federal	4.00	855	823	250	10.9
87	.38 SPEC	158	SWC	Smith & Wesson	4.00	850	1006	306	10.8
88	.38 SPEC	158	JHP	Smith & Wesson	2.00	1050	950	289	10.6
89	.38 SPEC	110	JHP	Speer	4.00	1245	857	261	10.5
90	9MM	115	FJ(FMC)	Smith & Wesson	4.00	1145	1192	363	10.3
91	.357 MAG	158	SWC	Remington	4.00	1410	1088	331	10.2
92	.38 SPEC	125	JSP	3-D	2.00	1085	957	291	10.1
93	9MM	125	JSP	Speer	4.00	1120	1058	322	9.9
94	9MM	115	FJ(FMC)	Winchester	4.00	1140	1126	343	9.7
95	.45 AUTO	185	WC	Federal	5.00	775	751	228	9.7
96	.38 SPEC	125	JHP	Smith & Wesson	4.00	1350	1002	305	9.6
97	.357 MAG	158	SWC	Remington	2.75	1410	958	291	9.3
98	9MM	115	FJ(FMC)	Browning	4.00	1140	1067	325	9.2
99	.38 SPEC	158	LRN(+P)	Federal	4.00	1090	999	304	9.0
100	.38 SPEC	125	JHP	Smith & Wesson	2.00	1350	899	274	8.9
101	.38 SPEC	158	SWC	Federal	2.00	855	796	242	8.5
102	.38 SPEC	158	SWC	Speer	4.00	975	803	244	8.5
103	.38 SPEC	158	LRN(+P)	Federal	2.00	1090	947	288	8.2
104	.38 SPEC	158	SWC	Winchester	2.00	855	779	237	8.2

* - Advertised Velocity
- Velocity not available

TABLE 1 (CONTINUED)
Performance of Commercially Available Handgun Ammunition

Bullet ID No.	Caliber	Weight (grains)	Bullet Type	Manufacturer	Barrel Length (in)	Velocity Nominal* (fps)	Velocity Measured (fps)	Velocity Measured (mps)	RI Index
105	.38 SPEC	158	LRN	Winchester	4.00	855	919	280	8.0
106	.38 SPEC	110	JHP	Speer	2.00	1245	789	240	7.7
107	.38 SPEC	90	JSP(HEMI)	Smith & Wesson	2.00	1350	1053	320	7.2
108	.38 SPEC	125	JHP	Remington	2.00	1160	911	277	7.0
109	.38 SPEC	110	JHP	Smith & Wesson	2.00	1380	888	270	6.8
110	.45 AUTO	230	FJ	Remington	5.00	855	839	255	6.7
111	.45 LC	255	LRN	Winch-Western	7.50	860	821	250	6.6
112	.38 SPEC	90	JSP	Smith & Wesson	2.00	1350	975	297	6.5
113	.45 AUTO	230	FJ	Winch-Western	5.00	850	740	225	6.5
114	.44 SPEC	246	LRN	Remington	3.00	755	640	195	6.3
115	.38 SPEC	125	JHP	Smith & Wesson	4.00	1350	900	274	5.9
116	.38 SPEC	158	SWC	Speer	2.00	975	640	195	5.7
117	.38 SPEC	125	JSP	Smith & Wesson	2.00	1350	896	273	5.6
118	.38 SPEC	158	LRN	Federal	4.00	855	795	242	5.0
119	.38 SPEC	158	LRN	Winchester	2.00	855	780	237	4.6
120	.38 SPEC	158	LRN	Remington	4.00	855	749	228	4.5
121	.38 SPEC	158	LRN	Speer	4.00	975	749	228	4.5
122	.38 SPEC	200	LRN	Remington	4.00	730	647	197	4.5
123	.38 SPEC	200	LRN	Speer	4.00	850	710	216	4.5
124	.38 SPEC	158	LRN	Remington	2.00	855	694	211	4.4
125	.38 SPEC	158	LRN	Speer	2.00	975	635	193	4.4
126	.38 SPEC	158	LRN	Smith & Wesson	4.00	910	708	215	4.4
127	.38 SPEC	158	LRN	Federal	2.00	855	632	192	4.2
128	.38 SPEC	200	LRN(Lubaloy)	Western Sup-X	4.00	730	626	190	4.2
129	.38 SPEC	200	LRN	Speer	2.00	850	598	182	4.1
130	.38 SPEC	200	LRN(Lubaloy)	Western Sup-X	2.00	730	592	180	4.1
131	.38 SPEC	158	SWC	Smith & Wesson	4.00	1060	875	266	4.0
132	.38 SPEC	158	SWC	Smith & Wesson	2.00	850	870	265	4.0
133	.38 SPEC	200	LRN	Remington	2.00	730	593	180	4.0
134	380 AUTO	95	FJ	Western Sup-X	3.86	955	948	288	4.0
135	.38 SPEC	158	LRN	Smith & Wesson	2.00	910	626	190	3.5
136	.38 SPEC	125	JHP	Smith & Wesson	2.00	1350	716	218	3.0
137	.38 SPEC	158	JSP	Smith & Wesson	4.00	1050	828	252	2.9
138	.38 SPEC	158	SWC	Smith & Wesson	2.00	1060	678	206	2.5
139	.22 CAL	37	LHP	Winch-Western	2.00	1365	872	265	2.3
140	.38 SPEC	158	JSP	Smith & Wesson	2.00	1050	730	222	2.0
141	.38 SPEC	64	Short Stop	MBA	4.00	####	738	224	0.9
142	.38 SPEC	64	Short Stop	MBA	2.00	####	671	204	0.4

* - Advertised Velocity
- Velocity not available

TABLE 2
Performance of Commercially Available Handgun Ammunition

Bullet ID No.	Caliber	Weight (grains)	Bullet Type	Manufacturer	Barrel Length (in)	Velocity Nominal* (fps)	Velocity Measured (fps)	Velocity Measured (mps)	RI Index
139	.22 CAL	37	LHP	Winch-Western	2.00	1365	872	265	2.3
2	9MM	96	Safety Slug	Deadeye Assoc	4.00	1365	1839	560	54.5
54	9MM	100	FJ(FMC)	Smith & Wesson	4.00	1250	1341	408	15.2
25	9MM	100	JHP	Speer	4.00	1315	1188	362	27.9
98	9MM	115	FJ(FMC)	Browning	4.00	1140	1067	325	9.2
90	9MM	115	FJ(FMC)	Smith & Wesson	4.00	1145	1192	363	10.3
94	9MM	115	FJ(FMC)	Winchester	4.00	1140	1126	343	9.7
17	9MM	115	JHP	Remington	4.00	1160	1192	363	38.0
49	9MM	115	JHP	Smith & Wesson	4.00	1145	1193	363	16.6
79	9MM	115	JSP(Power Point)	Western Sup-X	4.00	1160	1272	387	12.0
64	9MM	124	FJ(FMC)	Remington	4.00	1120	1084	330	13.8
93	9MM	125	JSP	Speer	4.00	1120	1058	322	9.9
10	.357 MAG	96	Safety Slug	Deadeye Assoc	2.75	1120	1615	492	46.0
4	.357 MAG	96	Safety Slug	Deadeye Assoc	4.00	1120	1725	525	50.0
29	.357 MAG	110	JHP	Smith & Wesson	4.00	1800	1226	373	24.0
63	.357 MAG	110	JHP	Smith & Wesson	2.75	1800	1044	318	13.9
21	.357 MAG	110	JHP	Speer	4.00	1700	1246	379	33.4
30	.357 MAG	110	JHP	Speer	2.75	1700	1178	359	23.3
35	.357 MAG	110	JHP	Western Sup-X	4.00	1500	1309	398	21.0
36	.357 MAG	110	JHP	Western Sup-X	2.75	1500	1258	383	20.2
32	.357 MAG	125	JHP	Smith & Wesson	4.00	1775	1227	373	22.1
45	.357 MAG	125	JHP	Smith & Wesson	2.75	1775	1188	362	17.7
12	.357 MAG	125	JHP	Speer	4.00	1900	1301	396	44.4
22	.357 MAG	125	JHP	Speer	2.75	1900	1161	353	30.6
14	.357 MAG	125	JHP	Remington	4.00	1675	1366	416	42.5
19	.357 MAG	125	JHP	Remington	2.75	1675	1173	357	37.1
13	.357 MAG	140	JHP	Speer	4.00	1780	1221	372	44.4
20	.357 MAG	140	JHP	Speer	2.75	1780	1125	342	34.4
57	.357 MAG	158	JHP	Smith & Wesson	4.00	1050	1116	340	14.4
84	.357 MAG	158	JHP	Smith & Wesson	2.75	1050	982	299	11.1
33	.357 MAG	158	JSP(HI-VEL)	Federal	4.00	1550	1255	382	21.1
41	.357 MAG	158	JSP(HI-VEL)	Federal	2.75	1550	1195	364	18.7
47	.357 MAG	158	JSP	Smith & Wesson	4.00	1500	1168	356	17.2
48	.357 MAG	158	JSP	Smith & Wesson	2.75	1500	1091	332	17.0
23	.357 MAG	158	JSP	Speer	4.00	1625	1156	352	28.0
46	.357 MAG	158	JSP	Speer	2.75	1625	1030	313	17.5
50	.357 MAG	158	LRN(Lubaloy)	Western Sup-X	4.00	1410	1230	374	16.6
58	.357 MAG	158	LRN(Lubaloy)	Western Sup-X	2.75	1410	1169	356	14.4
91	.357 MAG	158	SWC	Remington	4.00	1410	1088	331	10.2
97	.357 MAG	158	SWC	Remington	2.75	1410	958	291	9.3
141	.38 SPEC	64	Short Stop	MBA	4.00	####	738	224	0.9
142	.38 SPEC	64	Short Stop	MBA	2.00	####	671	204	0.4
68	.38 SPEC	90	JSP(HEMI)	Smith & Wesson	4.00	1350	1158	352	12.4
107	.38 SPEC	90	JSP(HEMI)	Smith & Wesson	2.00	1350	1053	320	7.2
83	.38 SPEC	90	JSP	Smith & Wesson	4.00	1350	1118	340	11.8
112	.38 SPEC	90	JSP	Smith & Wesson	2.00	1350	975	297	6.5
38	.38 SPEC	90	MP	KTW	4.00	1030	922	281	19.6
52	.38 SPEC	90	MP	KTW	2.00	1030	734	223	15.6
24	.38 SPEC	95	JHP(+P)	Remington	4.00	985	1187	361	28.0

* - Advertised Velocity
- Velocity not available

TABLE 2 (CONTINUED)
Performance of Commercially Available Handgun Ammunition

Bullet ID No.	Caliber	Weight (grains)	Bullet Type	Manufacturer	Barrel Length (in)	Velocity Nominal* (fps)	Velocity Measured (fps)	Velocity Measured (mps)	RI Index
60	.38 SPEC	95	JHP(+P)	Remington	2.00	985	1019	310	14.0
15	.38 SPEC	96	Safety Slug	Deadeye Assoc	4.00	1800	1585	483	41.8
18	.38 SPEC	96	Safety Slug	Deadeye Assoc	2.00	1800	1496	455	37.5
69	.38 SPEC	110	JHP	Smith & Wesson	4.00	1380	1014	309	12.4
109	.38 SPEC	110	JHP	Smith & Wesson	2.00	1380	888	270	6.8
89	.38 SPEC	110	JHP	Speer	4.00	1245	857	261	10.5
106	.38 SPEC	110	JHP	Speer	2.00	1245	789	240	7.7
27	.38 SPEC	110	JHP	Super Vel	4.00	1370	1159	353	25.1
28	.38 SPEC	110	JHP	Super Vel	2.00	1370	1148	349	24.8
40	.38 SPEC	110	JHP(LOT-Q4070)	Winch-Western	4.00	####	1106	337	19.3
61	.38 SPEC	110	JHP(LOT-Q4070)	Winch-Western	2.00	####	956	291	14.0
39	.38 SPEC	110	JSP	Super Vel	4.00	1370	1202	366	19.4
62	.38 SPEC	110	JSP	Super Vel	2.00	1370	1076	327	14.0
115	.38 SPEC	125	JHP	Smith & Wesson	4.00	1350	900	274	5.9
136	.38 SPEC	125	JHP	Smith & Wesson	2.00	1350	716	218	3.0
96	.38 SPEC	125	JHP	Smith & Wesson	4.00	1350	1002	305	9.6
100	.38 SPEC	125	JHP	Smith & Wesson	2.00	1350	899	274	8.9
37	.38 SPEC	125	JHP(+P)	Speer	4.00	1425	1006	306	19.9
53	.38 SPEC	125	JHP(+P)	Speer	2.00	1425	931	283	15.5
31	.38 SPEC	125	JSP(+P)	Speer	4.00	1425	1047	319	22.5
66	.38 SPEC	125	JSP(+P)	Speer	2.00	1425	983	299	13.2
56	.38 SPEC	125	JSP	Smith & Wesson	4.00	1350	1064	324	14.5
117	.38 SPEC	125	JSP	Smith & Wesson	2.00	1350	896	273	5.6
51	.38 SPEC	125	JSP	3-D	4.00	1085	1091	332	16.5
92	.38 SPEC	125	JSP	3-D	2.00	1085	957	291	10.1
26	.38 SPEC	125	JHP	Remington	4.00	1160	1108	337	25.5
108	.38 SPEC	125	JHP	Remington	2.00	1160	911	277	7.0
42	.38 SPEC	140	JHP(+P)	Speer	4.00	1200	978	298	18.6
43	.38 SPEC	140	JHP(+P)	Speer	2.00	1200	897	273	18.5
71	.38 SPEC	148	WC	Browning	4.00	770	731	222	12.3
81	.38 SPEC	148	WC	Browning	2.00	770	618	188	11.9
70	.38 SPEC	148	WC	Remington	4.00	770	741	225	12.4
74	.38 SPEC	148	WC	Remington	2.00	770	700	213	12.2
72	.38 SPEC	148	WC	Federal	4.00	770	737	224	12.3
75	.38 SPEC	148	WC	Federal	2.00	770	674	205	12.1
73	.38 SPEC	148	WC	Smith & Wesson	4.00	800	726	221	12.3
76	.38 SPEC	148	WC	Smith & Wesson	2.00	800	662	201	12.1
77	.38 SPEC	148	WC	Speer	4.00	825	679	206	12.1
80	.38 SPEC	148	WC	Speer	2.00	825	652	198	12.0
78	.38 SPEC	148	WC(Clean Cutting)	Western	4.00	770	696	212	12.1
82	.38 SPEC	148	WC(Clean Cutting)	Western	2.00	770	618	188	11.9
67	.38 SPEC	158	JHP	Smith & Wesson	4.00	1050	1047	319	13.0
88	.38 SPEC	158	JHP	Smith & Wesson	2.00	1050	950	289	10.6
137	.38 SPEC	158	JSP	Smith & Wesson	4.00	1050	828	252	2.9
140	.38 SPEC	158	JSP	Smith & Wesson	2.00	1050	730	222	2.0
105	.38 SPEC	158	LRN	Winchester	4.00	855	919	280	8.0
119	.38 SPEC	158	LRN	Winchester	2.00	855	780	237	4.6
99	.38 SPEC	158	LRN(+P)	Federal	4.00	1090	999	304	9.0
103	.38 SPEC	158	LRN(+P)	Federal	2.00	1090	947	288	8.2
118	.38 SPEC	158	LRN	Federal	4.00	855	795	242	5.0
127	.38 SPEC	158	LRN	Federal	2.00	855	632	192	4.2
120	.38 SPEC	158	LRN	Remington	4.00	855	749	228	4.5

* - Advertised Velocity
- Velocity not available

TABLE 2 (CONTINUED)
Performance of Commercially Available Handgun Ammunition

Bullet ID No.	Caliber	Weight (grains)	Bullet Type	Manufacturer	Barrel Length (in)	Velocity Nominal* (fps)	Velocity Measured (fps)	Velocity Measured (mps)	RI Index
124	.38 SPEC	158	LRN	Remington	2.00	855	694	211	4.4
121	.38 SPEC	158	LRN	Speer	4.00	975	749	228	4.5
125	.38 SPEC	158	LRN	Speer	2.00	975	635	193	4.4
126	.38 SPEC	158	LRN	Smith & Wesson	4.00	910	708	215	4.4
135	.38 SPEC	158	LRN	Smith & Wesson	2.00	910	626	190	3.5
44	.38 SPEC	158	LHP	Winch-Western	4.00	855	915	278	18.4
88	.38 SPEC	158	LHP	Winch-Western	2.00	855	805	245	11.0
86	.38 SPEC	158	SWC	Federal	4.00	855	823	250	10.9
101	.38 SPEC	158	SWC	Federal	2.00	855	796	242	8.5
131	.38 SPEC	158	SWC	Smith & Wesson	4.00	1060	875	266	4.0
138	.38 SPEC	158	SWC	Smith & Wesson	2.00	1060	678	206	2.5
87	.38 SPEC	158	SWC	Smith & Wesson	4.00	850	1006	306	10.8
132	.38 SPEC	158	SWC	Smith & Wesson	2.00	850	870	265	4.0
102	.38 SPEC	158	SWC	Speer	4.00	975	803	244	8.5
116	.38 SPEC	158	SWC	Speer	2.00	975	640	195	5.7
59	.38 SPEC	158	SWC	Winchester	4.00	855	924	281	14.3
104	.38 SPEC	158	SWC	Winchester	2.00	855	799	237	8.2
122	.38 SPEC	200	LRN	Remington	4.00	730	647	197	4.5
133	.38 SPEC	200	LRN	Remington	2.00	730	593	180	4.0
123	.38 SPEC	200	LRN	Speer	4.00	850	710	216	4.5
129	.38 SPEC	200	LRN	Speer	2.00	850	598	182	4.1
128	.38 SPEC	200	LRN (Lubaloy)	Western Sup-X	4.00	730	626	190	4.2
130	.38 SPEC	200	LRN (Lubaloy)	Western Sup-X	2.00	730	592	180	4.1
134	380 AUTO	95	FJ	Western Sup-X	3.86	955	948	288	4.0
3	.41 MAG	210	JSP	Remington	4.00	1500	1260	384	51.9
65	.41 MAG	210	SWC	Remington	4.00	1050	944	287	13.7
16	.44 MAG	180	JSP	Super Vel	4.00	1995	1495	455	41.6
1	.44 MAG	200	JHP	Speer	4.00	1675	1277	389	54.9
8	.44 MAG	240	JHP	Browning	4.00	1330	1257	383	47.9
9	.44 MAG	240	JHP	Remington	4.00	1470	1229	374	46.7
11	.44 MAG	240	JSP	Speer	4.00	1650	1203	366	45.7
6	.44 MAG	240	SWC	Browning	4.00	1470	1311	399	49.8
7	.44 MAG	240	SWC	Remington	4.00	1470	1286	391	48.9
5	.44 MAG	240	SWC	Winch-Western	4.00	1470	1330	405	50.0
114	.44 SPEC	246	LRN	Remington	3.00	755	640	195	6.3
34	.45 AUTO	185	JHP	Remington	5.00	950	895	272	21.1
55	.45 AUTO	185	WC(Targetmaster)	Remington	5.00	775	821	250	14.7
95	.45 AUTO	185	WC	Federal	5.00	775	751	228	9.7
110	.45 AUTO	230	FJ	Remington	5.00	855	839	255	6.7
113	.45 AUTO	230	FJ	Winch-Western	5.00	850	740	225	6.5
111	.45 LC	255	LRN	Winch-Western	7.50	860	821	250	6.6

* - Advertised Velocity
- Velocity not available

The relative incapacitation index given in these tables is primarily determined by the size and shape of the maximum temporary cavity produced in a block of ordnance gelatin when the bullet strikes the block with the measured velocity. The distribution of impact points, the aiming error, and the point of aim—all of which are used to compute the averaged vulnerability of the human target and which enter into the computation of RII—were assumed to be the same for all cartridges listed. This is not to say that these data cannot be tailored to the specific cartridge; e.g., it has been suggested that the caliber .44 Magnum is a more difficult round to shoot accurately than is the .38 Special. A specific averaged vulnerability can be determined for any caliber or loading; it was not done in generating these tables. A given degree of proficiency, that depicted in figure 7, has also been assumed.

The measured velocities are those produced by factory-loaded cartridges from new handguns of the stated barrel lengths; a specific revolver cartridge will therefore appear more than once. The nominal velocities listed are those advertised by the cartridge manufacturers.

While it is difficult at this time to recommend any single cartridge for law enforcement use, these tables are quite useful in their present form. For example, if a department wishes to use a more effective cartridge than it currently issues, it needs only to move higher on the RII scale. To estimate the relative effectiveness of the two cartridges, a simple division of the smaller RII into the larger will yield an approximate comparison of the two rounds.

There is a significant need for research to determine the minimum RII needed to reliably produce the required degree of incapacitation or effectiveness. In the absence of such research, one must estimate.

At the present time, an RII of approximately 10 appears to be the lowest index which should be considered. Probably, the selection of a cartridge whose RII is between 20 and 25 represents the upper limit required for reasonable reliability. This statement should not be construed to indicate, on an absolute basis, that an RII either higher than 25 or lower than 10 is unsuitable, undesirable, or unnecessary. It has been shown, many times over, that a hit in a vital spot by any bullet, whatever its RII, can cause death or incapacitation and should not be underestimated. RII deals with probabilities rather than absolutes, as is true with all biological measures of this type.

If an RII of 10 is selected as a lower limit, a number of cartridges which fall below this value as well as above it, are sure to raise questions. For example, Nos. 110 and 113 (Cal. .45 ACP-FMJ), and No. 95 (Cal. .45 ACP-SWC) fall at 6.5, 6.7 and 9.7, while a similar 185 gr. SWC in cal. .45 (No. 55) has an RII of 14.7. The position on the RII scale is primarily due to the size and shape of the temporary cavity formed in the gelatin block. A change in velocity or construction can have considerable effect on RII, as is shown in figure 2. Many of the 9mm cartridges place high because of their high velocity, and not necessarily because they expand. This does not apply totally to bullet No. 17, which, although it has a high velocity, also has a highly deformable jacket; this combination produces a larger temporary cavity.

In conclusion, the full report of this project will describe in detail the methods, models, data, and conclusions summarized here. Interested readers are directed to the full report for the full data, full analysis, and some suggestions as to how to proceed in the absence of detailed guidelines and a standard for police handgun ammunition.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1976 0—201-572

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