PROFESSIONAL WEAPONS TRAINING AND BALLISTIC TESTING SINCE 2011

VIPER WEAPONS TRAINING™

SPECIAL PISTOL AMMUNITION REPORT II

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FOREWORD

The 2025 Special Pistol Ammunition Report II (SPAR 2) is a compilation analysis containing data from terminal wound ballistics and armor testing of one hundred and sixty rounds in eight calibers, in all five different projectile types. Information on the 9mm, .40S&W, .45ACP, .380, .357 Sig and 10mm are in section two. Sections three and four contain data on the 5.7mm and 4.6mm rounds. This reports information was obtained during ongoing testing from 2016 to present, all following the established protocols and phases used during the 2016/17 Joint Agency Ballistic Test For Defensive Handgun Ammunition (available upon request). Testing was also accomplished using standardized heavy barriers and armor from multiple manufacturers. This document is separated into four sections.

Section One: Presentation which is intended for:

A. List of facts without background information or math. It includes chapter names referencing the location of the complete description in the section two report.

B. Academics to present to a group with pictures and talking points.

C. Used as a review and synopsis.

D. An executive summary with less descriptions.

E. It does not include armor data that is included in section two or most of the 5.7mm and 4.6mm data that is contained in sections three and four.

Section Two: The full report which includes all the facts, explanations, math and references.

Section Three: Information and data for the 5.7mm and 4.6mm ammunition tested.

Section Four: 5.7mm LE/MIL Armor Test Presentation.

All testing was conducted by Viper Weapons Training LLC and included ballistics experts and testers from multiple agencies to include the FBI, DHS, CBP, DoD, US Air Force Research Laboratories (AFRL), NASA, Marshalls, and multiple state DPS's and local police, sheriff and constables' offices. No employees or representatives from any ammunition manufacturer were present for any of the testing or influenced any measurements, results or information included in this report. The training and testing company ensured continuity, consistency and accuracy of all tests and generated this final report which is only intended to be released to Law Enforcement, Military (LE/Mil) and the ammunition/armor manufacturers. We implore all agencies and manufacturers who receive this report to treat it as proprietary and not release it. Information on LE/Mil only rounds and data on armor capability is not to be openly released. This is our 52nd published report. A list of all reports and presentations is available on our website.

The comparison of ammunition for federal, state and local agencies is critical and complex. Representative data of a real target is needed for instruction and selection. Terminal wound ballistics tests must have four key features.

1. They must have a large sample size to minimize anomalies and get true averages. This report contains the combined test data and results from multiple previous federal wound ballistics tests, built upon and verified those results with a sample size of at least twenty measured shots per round and over four thousand total shots.

2. The tests and phases must be consistent from round to round. Our standardized protocols and phases have been in place since 2015 and all data comes from tests that comply with those standards.

3. All results must be quantifiable and measurable. The data must stand alone without opinion or subjectivity. Also, all data must describe rounds in the four terminal wound ballistics criteria of penetration, reliability/consistency, barrier performance and permanent wound cavity.

4. The target media must be realistic and standardized to come closer to describing ammunition potential in real-world targets. This test used industry standard International Wound Ballistics Association (IWBA) calibrated FBI gelatin; not clear ballistics gel. Also, medically recommended animal tissue media IAW DoD testing protocols, was used to document relevant realistic data. The tissue test results have been compared to forensics reports from actual shootings and the measured results are very similar, more so than any other media used.

Lastly, many of the rounds were tested vs common armor available. Different levels and product designs were used to get a better picture of ammunition capability vs armor.

Compilation data sheets are included to better compare shot results and averages. The first set of sheets includes all the data for the terminal wound ballistics results and the second includes all the results from the armor testing. The data contained in this report is current and up to date as of September 2025. As ongoing testing is always being accomplished the data is being updated and changes constantly. Any data from our previous reports is valid but encompasses a smaller sample size and therefore may be different.

No conclusions or choices have been made and none will be included in this report. All testing is conducted only to produce and record raw data and describe rounds in regards to the four terminal wound ballistics criteria. Data from rounds failing to function as designed on target were not thrown out as has been done in other tests. Projectile failures to function on target are all included thereby allowing reliability and consistency to be determined. Any ammunition failures in the weapon or failure to fire were recorded but are not described in this report as the weapons were not being tested.

Special Pistol Ammunition Report II

SECTION ONE

PROFESSIONAL WEAPONS TRAINING AND BALLISTIC TESTING SINCE 2011

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SUMMARY

- This presentation is a concise version of the September 2025 Special Pistol Ammunition Report II (SPAR2). Please see that report (section 2) for more detailed explanations, math and references
- Featured here is information compiled from multiple tests performed between 2016 and present. The tests were conducted by Viper Weapons Training LLC, and selected ballistics experts from multiple agencies, who ensured continuity, consistency and accuracy of all tests and generated this report and presentation
- All testing uses the same protocols, media, test phases and grading criteria. 160 rounds in 8 calibers are included. Each round was tested $\geq$20 shots with a total of over 4,000 shots. See sections 3 and 4 for 5.7mm and 4.6mm
- Test results, briefings and reports will only be distributed to Law Enforcement, Military (LE/Mil) and ammunition / armor manufacturers involved
- All data and testing is current as of September 2025
- For a list of the included tests please see our websites Ballistics Testing page.

https://viperweapons.us/ballistics-testing-1

OVERVIEW

- Test Purpose
- Tactical Realities
- Mechanics Of Projectile Wounding
- The Human Target
- Test Protocols, Media And Phases
- Five Types Of Handgun Projectiles
- Four Grading Criteria
- Volume of Wound Index (VWI)
- Terminal Wound Ballistic Test Data Sheets
- Projectile Wound Profiles
- Test Results vs Real World Forensics
- Summary / Additional Comments
- Acknowledgements

TEST PURPOSE

- Each wound ballistics test since 2016 was accomplished for specific agencies or departments as a comparative study of different types of duty and defensive ammunition, conducted in 6 separate phases, using 4 grading criteria
- Testing all 5 bullet types
  - Hollow Points (HP), Full Metal Jackets (FMJ), Fluted-Fluid Transfer, Frangible and Tumbling rounds
- 8 Calibers were tested
  - 9mm, .40 S&W, .45 ACP, .357 Sig, 10mm, .380, 5.7mm and 4.6mm
- No conclusions, rank ordering or selections
  - Raw data from each shot was averaged together for the data sheets and may be used independently depending on the criteria desired by the receiving agency

TACTICAL REALITIES

There are four determinants involved in stopping a human target

- Wound placement
  - Most important determinant in stopping or incapacitating a human target
  - Shot placement is NOT wound placement (barriers, deflection, failures)
- Number of hits
  - Doubling the amount of hits on a target generally doubles the amount of damage depending on the wound placement
- Bullet capability
  - Measured and documented in terminal wound ballistic testing
  - Described by: Penetration Depth, Reliability/Consistency, Barrier Performance and Permanent Wound Cavity (PWC) size
- The target being shot
  - The health and physical condition of the target
  - Age, sex, size, health and outside influences such as drugs and alcohol

PROJECTILE WOUNDING

"There are four components of projectile wounding." FBI's Firearms Training Unit (FTU)

- Penetration Depth
  - A projectile must penetrate deep enough to reach the large vital organs
  - "A penetration of 18 inches is preferable." Federal Standard is 15-21 inches
- Permanent Cavity
  - The volume of the cavity that is destroyed tissue
  - Calculated by multiplying the depth (penetration) of the wound by the area (not diameter) of the hole. Measured in cubic inches of volume
- Temporary Cavity
  - Tissue being stretched away from the permanent cavity by a pressure wave
  - Projectile velocity must exceed roughly 2,000 fps to cause tissue damage
  - "Pistols rounds all travelling significantly slower do not produce a temporary cavity that creates any wounding effects"
- Fragmentation
  - "Fragmentation does not reliably occur in soft tissue handgun wounds…" "When fragmentation does occur, pieces are within one centimeter (.39 inch) of the permanent cavity"
  - "Fragmenting rounds eliminate any reasonable penetration. Such a bullet will break up too fast to penetrate to the vital organs."

THE HUMAN TARGET

The three physical causes of incapacitation from Gun Shot Wounds

- Severing or destroying of the Central Nervous System (CNS)
  - Sufficient damage to the brain and or spine
- Damage to vital organs
  - Heart, lungs and liver. Sufficient damage to these organs may cause immediate incapacitation
  - The larger the hole and more damage to the organs, the greater the chance of incapacitation
- Bleeding
  - Large amount of blood loss or a large enough drop in blood pressure which is required for muscular and systems function
  - The human body has a positive internal pressure and external holes depressurize the system and allow for more blood loss than internal holes. The more or bigger the holes the greater the amount of blood loss and increased incapacitation

TEST PROTOCOLS

All phases and tests were conducted with numerous testers for quality control and multiple measurements. All ammunition was tested with at least 4 rounds fired per phase and at least 20 total measured shots. All failures are included in the data with no "flyers" being removed

All phases mirrored what was accomplished during the 2016/17 Joint Agency Ballistic Test For Defensive Handgun Ammunition (available upon request).

Phases are duplicates of the FBI and DoD series of tests using their standardized and accepted protocols

TARGET MEDIA

1. Calibrated FBI International Wound Ballistics Association (IWBA) 10% ordnance gelatin (Phase 2 and 3)
   - Proper temperature verified and BB depth calibration accomplished immediately prior to shot
   - Two 16x6x6 inch blocks. 32 inches of penetration can be measured
2. Single ¾ inch thick AA fir plywood panel IAW FBI / DoD protocols (Phase 3 and 5) as a light domestic barrier
3. Denim (16 oz) barrier consisting of layers of standardized material (Phases 2-5)
4. Animal Tissue - 2 boneless hanging briskets

   7-8" thick (Average human male is 10" thick), 36±2 pounds, fat side out, back-to-back (Phase 4 and 5)
5. Heavy Barriers - Auto glass, solid wood and metal car doors as well as armor products (Phase 6)

MEDIA DESCRIPTION

Calibrated IWBA FBI 10% ordnance gelatin (Phase 2 and 3)

- Gel is consistent and easy to use/measure. It allows for a comparative study to take place with results that can be replicated
- Gel is not a simulation of human tissue. Gel is a fluid and is non-compressible unlike human or animal tissue which is compressible. Density and resistance are not similar to human tissue (as noted by 3 inches of BB penetration depth at calibration). The tensile strength and resistance of ballistic gelatin is .8 to 1.0 MPa, vs 1.0-4.0 MPa for human soft tissue. It is close to simulating low density human tissue, but it is only 20% that of high-density muscular tissue and organs.
- Temporary Stretch Cavity does not represent any damaged or destroyed material
- Permanent cavity in gel may be exaggerated by rounds causing compression such as fluid transfer or tumbling rounds
- Recovered bullet diameter doesn't equal gel wound diameter because of rounds turning or fragmenting (which happens frequently) and some rounds cut through material while others push allowing the gel to recover, unlike results in actual tissue
- Using gel as a standardized material for comparison is valid and comparing penetration depths is valuable but does not produce results similar to tissue penetration depths
- Using gel for wound diameter size and volumes is extremely artificial and next to impossible to measure accurately

MEDIA DESCRIPTION

Animal tissue consisting of 2 boneless cow briskets (Phase 4 and 5)

- Chosen after discussions with a forensic pathologist, other medical doctors and a butcher
  - The two tissue phases replicate tissue testing accomplished by the DoD
  - Cow brisket closely represents human muscle tissue and organs
- It is a compressible realistic consistent media. However, there is less fluid in the brisket and no blood pressure like live tissue
- 7-8" thick (Average human male is 10" thick), total weight 36±2 pounds, hanging fat side forward, back-to-back. Point side up on one and down on the other to provide equal thickness
- The exit wounds from each of the 2 briskets are measured for min and max diameter. Those four measurements are averaged and then converted to a hole area

6 PHASES

All Wound Ballistics Tests were conducted in 6 phases.

1. All rounds chronographed
2. Calibrated 10% ordnance gelatin IAW IWBA standards with a standard denim barrier (FBI test event 2)
3. Calibrated 10% ordnance gelatin with a single ¾ inch thick AA fir plywood panel and a standard denim barrier (FBI test event 5)
4. Animal Tissue with a standard denim barrier
5. Animal Tissue with a single ¾ inch thick AA fir plywood panel and a standard denim barrier
6. Heavy barrier and armor testing

PHASE 1-Chronograph

- All rounds fired at least 4 times and chronographed
- Testing actual vs. advertised velocities, consistency and reliability
- All velocities averaged
- Noted in data tables as
  - **Box Velocity** (provided by manufacturer)
  - **Phase 1 Average Velocity** (tested)

PHASE 2- IWBA 10% ordnance gelatin with a 4-layer denim barrier

1. FBI Test Event 2 duplicate
2. All rounds fired at least 4 times into calibrated IWBA 10% ordnance gelatin with a standard 4-layer denim barrier
3. Recovered rounds inspected for failures, retained weight and overall dimensions
4. Testing Overall Penetration Depth
   - Noted in data tables as **Penetration** in inches
5. Testing Overall Permanent Wound Cavity (**PWC**)
   - Measured in cubic inch volume. Wound diameter (noted in tables as **Diameter**) converted to area and multiplied by penetration depth in inches
   - Noted in data tables as **PWC**

PHASE 3- IWBA 10% ordnance gelatin with Plywood & 4 layers of denim

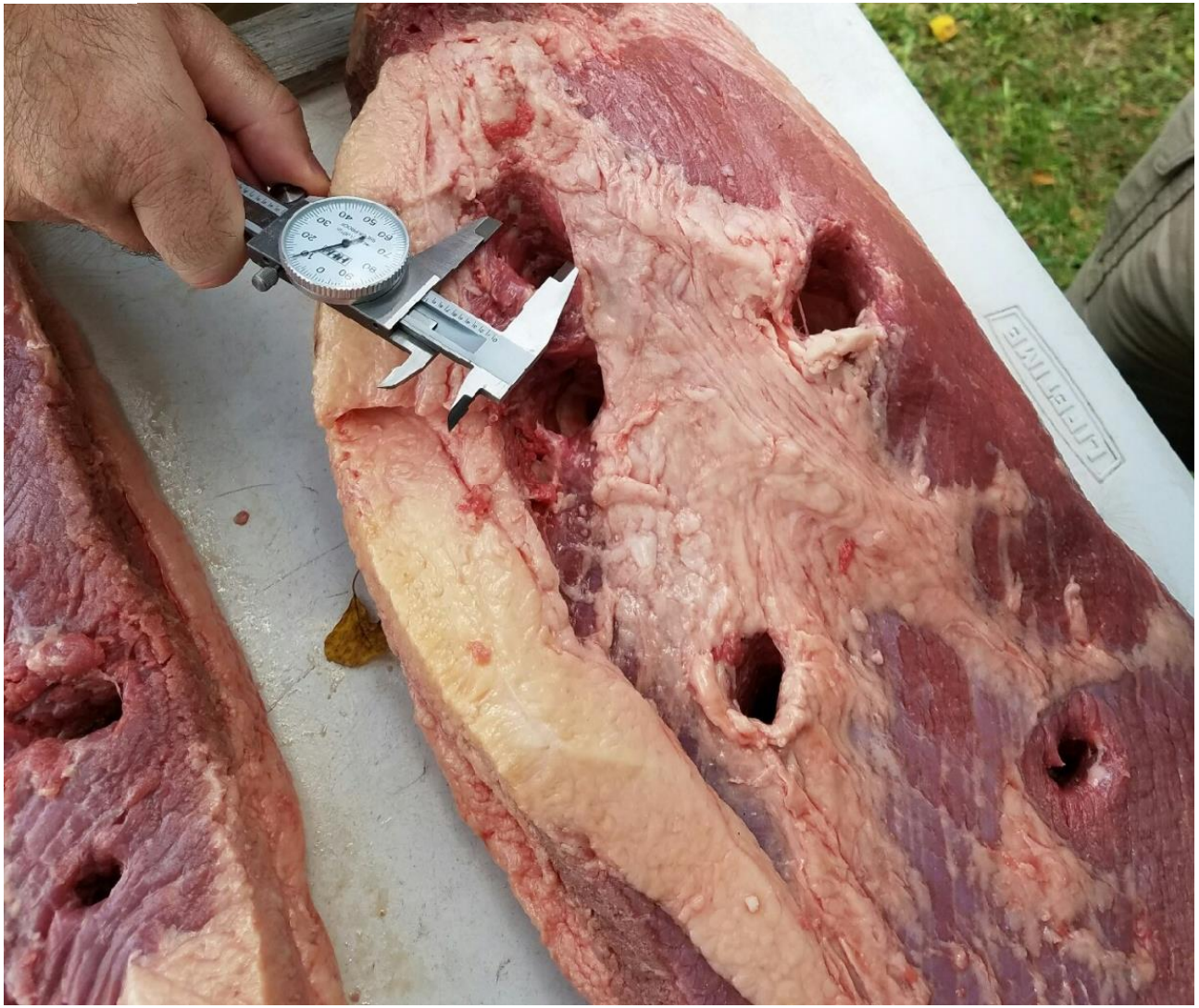
1. FBI Test Event 5 duplicate
2. All rounds were fired at least 4 times into media
3. Calibrated IWBA 10% ordnance gelatin with a single ¾ inch thick AA fir plywood panel IAW FBI / DoD protocols and a standard 4 layers of denim barrier
4. Recovered rounds inspected for failures, retained weight and overall dimensions
5. Testing Overall Penetration Depth after a light domestic barrier
6. Testing Overall Permanent Wound Cavity
   - Measured in cubic inch volume
7. Testing Barrier Performance and Consistency

PHASE 4-Animal Tissue with a 4-layer denim barrier

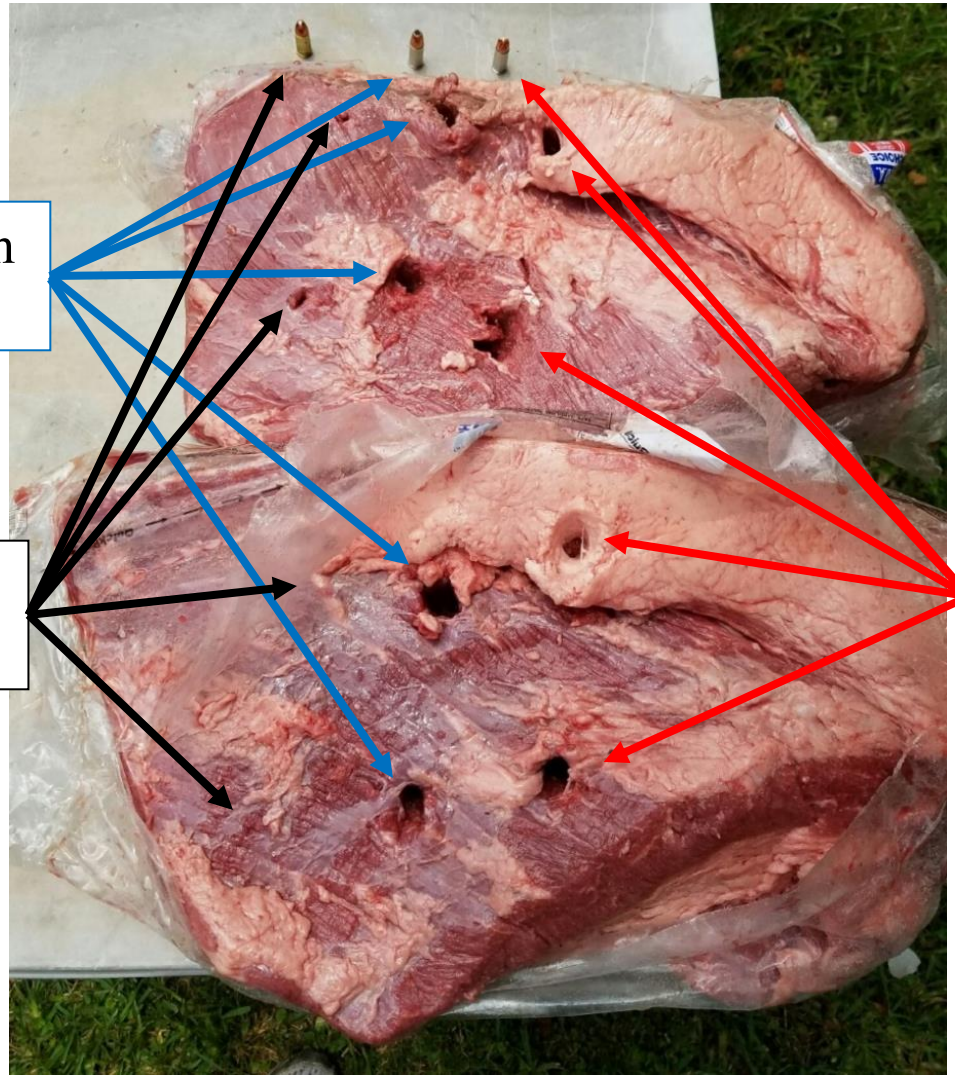
1. All rounds fired at least 4 times into Animal Tissue with a denim barrier
2. Rounds not recovered
   - No Penetration depths measured in this phase
3. Measuring Overall Wound dimensions
   - Exit wound channels from each of the two back-to-back briskets measured for min and max diameter then averaged. (4 measurements). Average diameter converted to hole area
   - Noted in data tables as **Av Hole Area**

PHASE 4 EXAMPLE

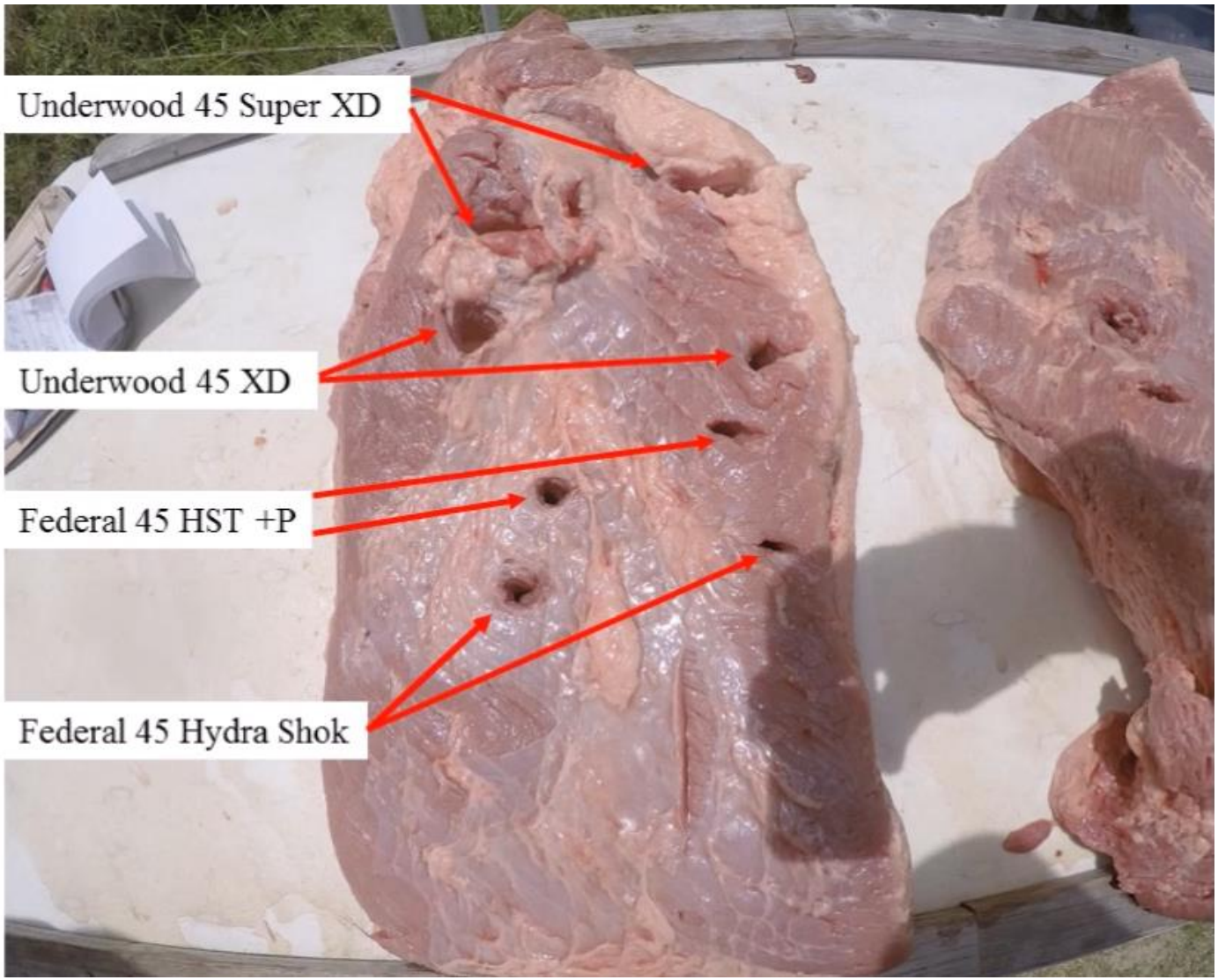
PHASE 4 Measuring .40 S&W



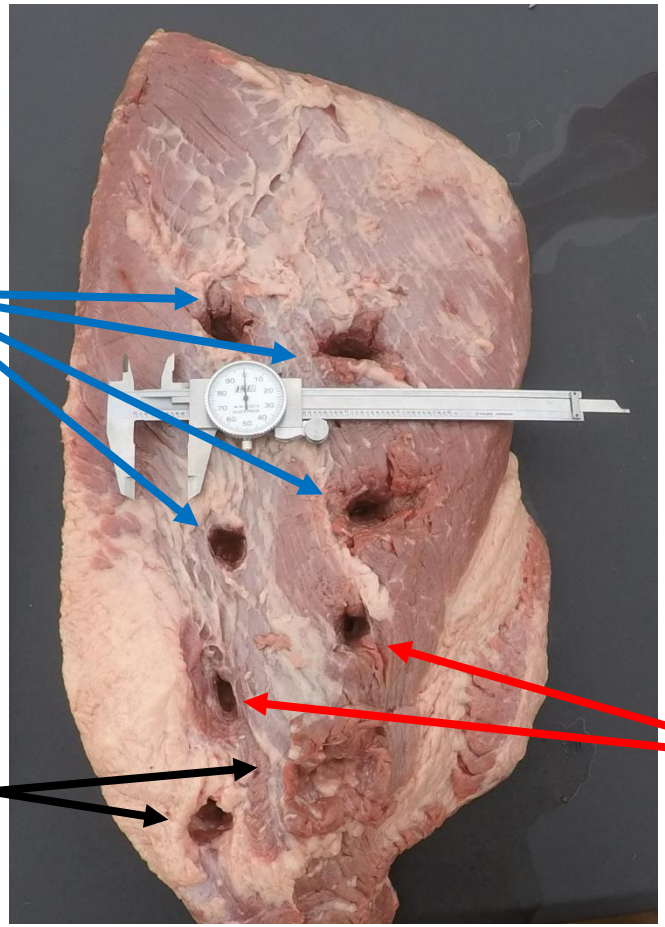
PHASE 4, Brisket 1&2, 9mm



PHASE 4, Brisket 1&2, .45



PHASE 4, Brisket 1, 5.7mm

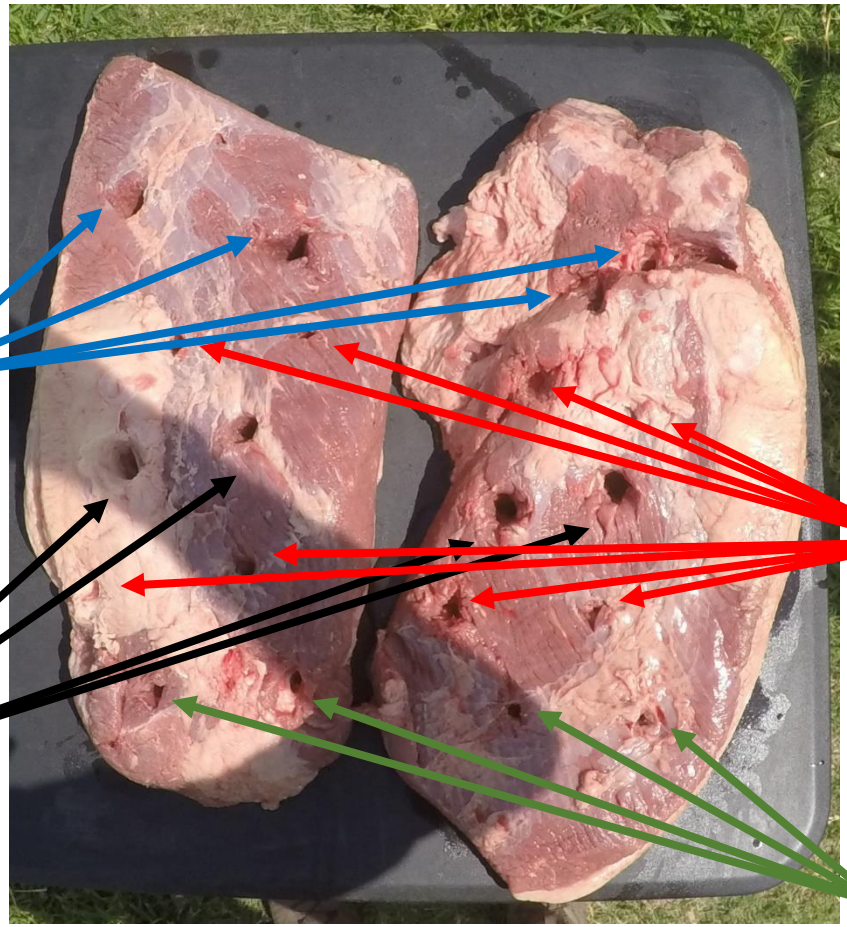


Vanguard
Black Fang
34 grain

Vanguard
Barnes TSX HP
50 grain

Vanguard
Combined Technology
50 grain

PHASE 4, Brisket 1&2



Vanguard
5.7mm 34 grain
Black Fang
Note non-linear path thru the tissue

Underwood
9mm
XD 90 grain

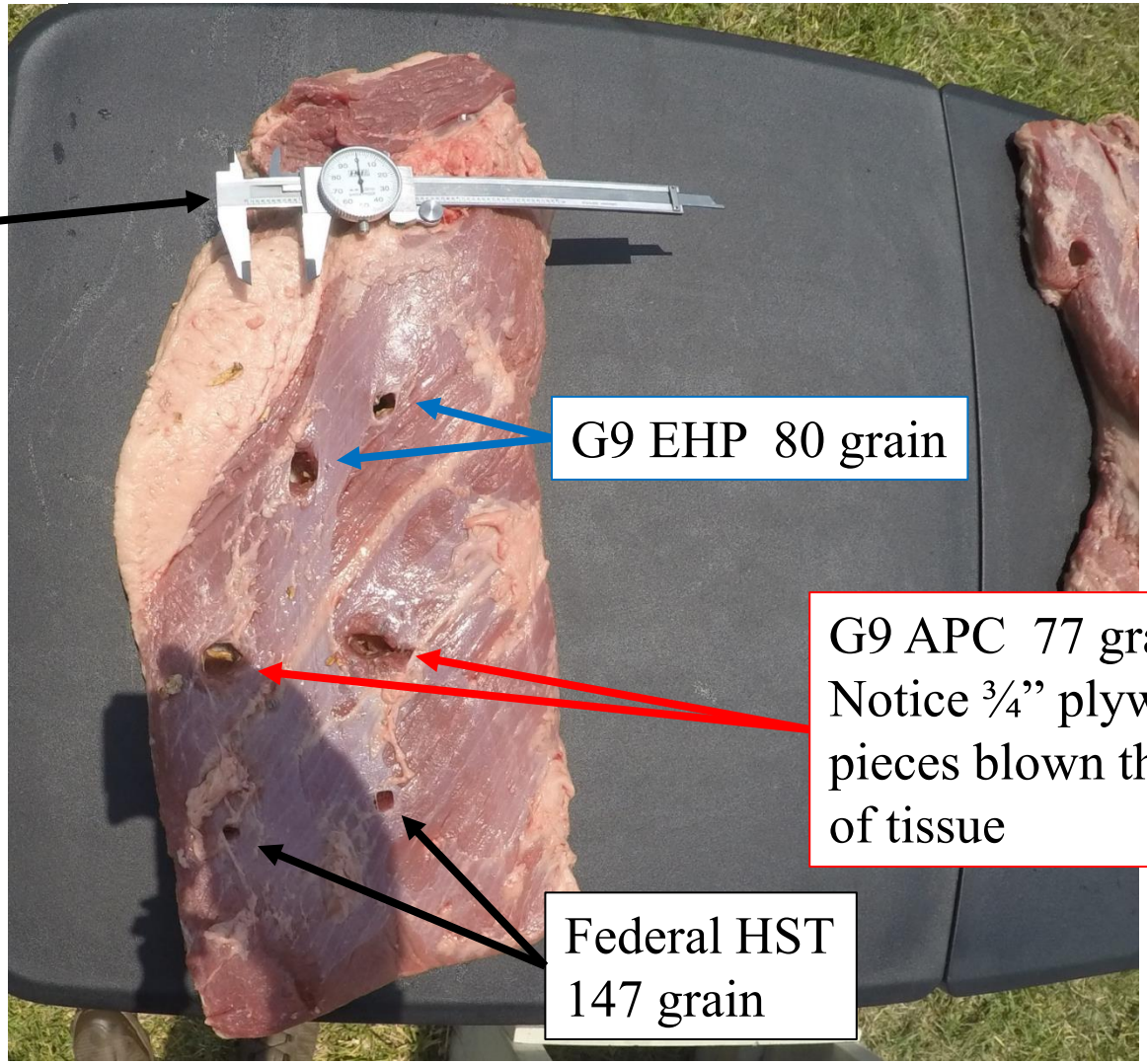
Fort Scott
9mm 80 grain

Winchester FMJ
9mm 124 grain

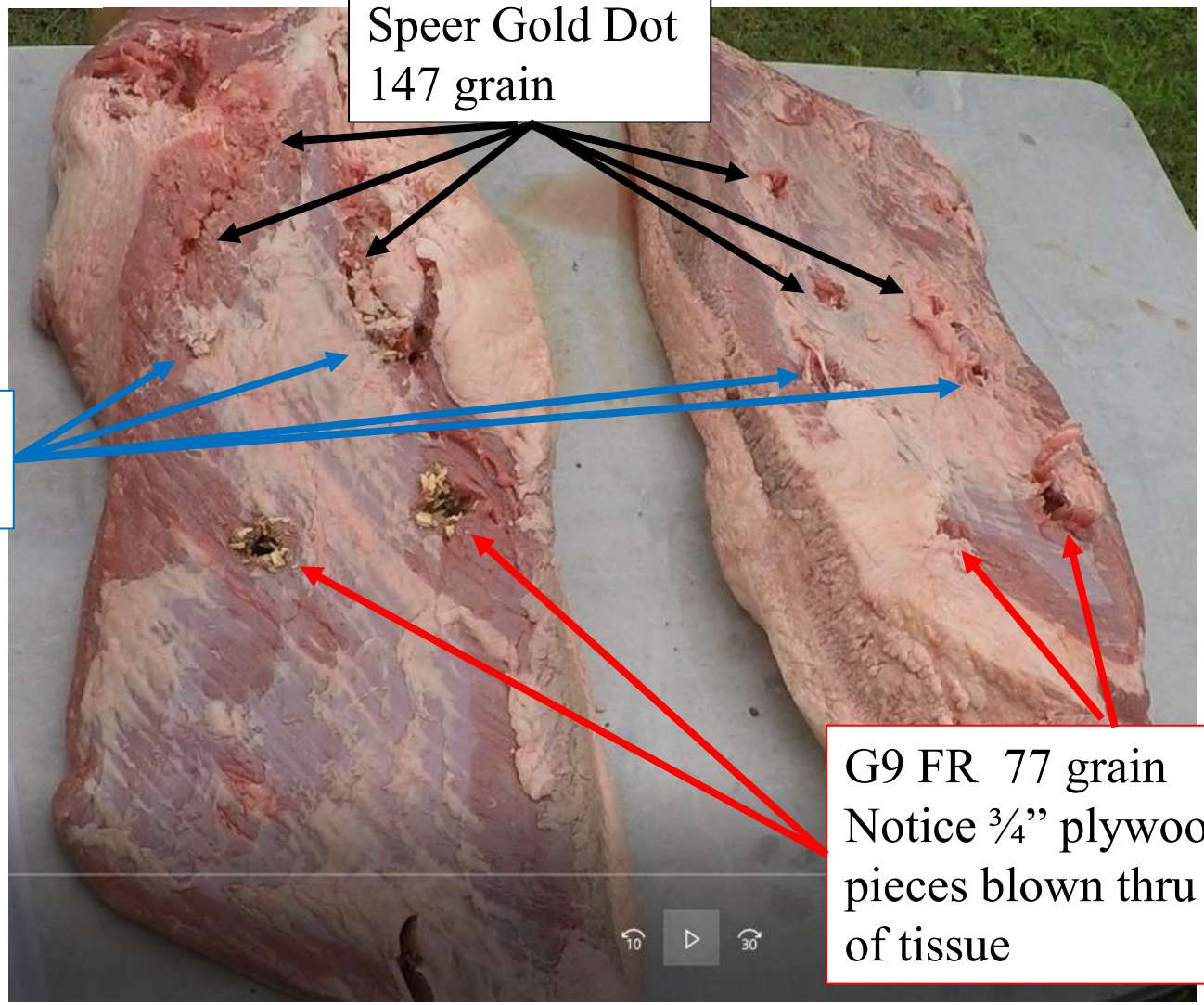
PHASE 5-Animal Tissue with a plywood and 4-layer denim barrier

1. All rounds were fired at least 4 times into Animal Tissue with a single ¾ inch thick AA fir plywood panel and a denim barrier
2. Rounds not recovered
   - No Penetration depths measured in this phase
3. Measuring Overall Wound dimensions
   - Exit wound channels from each of the two back-to-back briskets measured for min and max diameter then the 4 measurements are averaged. Average diameter converted to hole area and recorded
   - Noted in data tables as **Av Hole Area**
4. Testing Barrier Performance and Consistency

PHASE 5, Brisket 1&2, 9mm



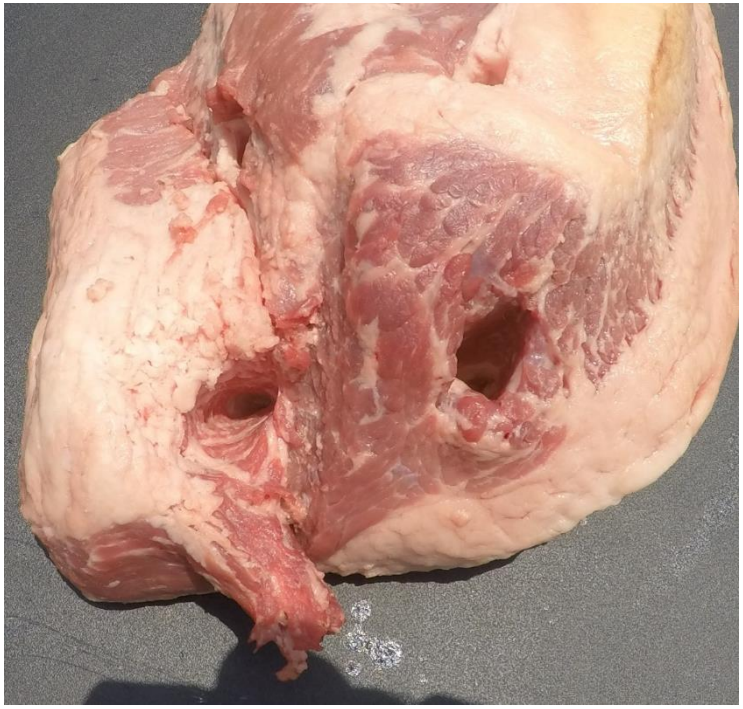
PHASE 5, Brisket 1&2, 9mm



PHASE 5, 5.7mm

During measurement wood chips from the light barrier were noted in the wounds of both briskets from the Black Fang and the Combined Tech.

More wood was found entirely thru the wounds during post test dissection.



PHASE 6-Heavy Barriers

- Testing vs heavy barriers (auto glass, solid wood and metal)
  - Phase 6 data is recorded separately and is not found on the primary Phase 1-5 datasheets
  - Please reference the individual round summaries in section 2 for this information
- Armor testing is accomplished with products from multiple manufacturers and different NIJ armor levels
  - Armor testing is not accomplished for every round
  - Reference the follow-on sections including Armor Test Description and Armor Test Data Sheets for exact product information and results of ammunition vs armor

5 TYPES OF BULLETS

1. Hollow Points (HP)
   - Expand on impact to increase frontal area
2. Full Metal Jacket (FMJ)
   - Designed to create small diameter wounds that penetrate deep without expanding tumbling or fragmenting
3. Fluted-Fluid Transfer
   - Contact tearing and fluid transfer through the Venturi Effect
   - Exhibiting duty penetration depths and the largest wound area and volume
4. Frangible
   - Designed to break apart and fragment upon striking a target or a barrier either immediately at the surface or after minimal penetration
   - Create large diameter wounds that do not penetrate deep
4. Tumbling (see section 2 report for description and sections 3 and 4)
   - Only works on long, high speed rounds like rifle, 5.7mm and 4.6mm

4 GRADING CRITERIA

1. Penetration-Phase 2 data
   - Desired: 15-21” (Federal Standard), 16-24” (DoD Standard)
2. Reliability and Consistency
   - Failure to function (Tumble, Failure to open, fragmentation and jacket separation)
   - Standard Deviation calculated for each bullet in each phase
3. Barrier Performance
   - Ability to function through a light domestic barrier
   - % lost from non-barrier shots to barrier shots from Phase 2/3 and Phase 4/5
4. Permanent Wound Cavity and Volume of Wound Index (VWI)
   - Measured in cubic inches for the Ballistics gel tests of Phase 2 and 3
   - Measured as average hole size in Phase 4 and 5, expressed in Area
   - Calculations made to produce a Volume of Wound Index (VWI)

PENETRATION

Penetration can be divided into four distinct depths

1. Shallow (<10 inches)
   - Frangible
2. Low (10-15 inches)
   - FBI Minimum 12 inches
   - Hollow Points, Tumbling
3. Duty (15-24 inches)
   - FBI Optimum 18 inches (15-21 inches desired), DoD Optimum 16-24 inches
   - Common 5.56mm rounds penetrate 15-24 inches (M193 & M855)
   - Fluted-Fluid Transfer, Hollow Points, Tumbling
4. Deep (roughly >24 inches)
   - FMJ, Fluted-Fluid Transfer

BARRIER PERFORMANCE

Barriers Performance can be divided into four categories

1. Penetration through no barriers
2. Light domestic barriers (plywood, drywall, thick clothing and bone)
   - Used in phase 3 and 5. The results in comparison to the non-barrier phases give barrier results. Average degradation noted in last column marked Light Domestic Barrier Degradation Percentage (LDBD%)
3. Heavy barriers (hardwood 2x4's, auto glass and metal car doors)
   - Heavy barrier testing yields data on deflection, destruction (failures) and degradation of the bullet and properties after contact with the barriers. Also, terminal performance for the rounds that pass through the heavy barrier
4. Armor products using the NIJ levels (listed in the armor data sheet)
   - Testing with armor products from multiple manufacturers and protection levels

Volume of Wound Index (VWI)

- Due to ballistics gel being a fluid and non-compressible, gel test results do not mimic forensic examinations for permanent wound cavity. To better understand and grade/compare rounds a realistic compressible media is used
- IWBA gel (Phase 2 and 3) is a very consistent media for measuring penetration depths
- Animal Tissue (Phase 4 and 5) is a very consistent and realistic compressible media for measuring the wound area
- VWI is created by averaging the penetration results from IWBA gel in Phases 2/3 and multiplying it by the hole area from the tissue tests in Phases 4/5 (averaged together)
- VWI represents the best calculation for comparative purposes by incorporating consistent and realistic medias with barrier and non-barrier data

RESULTS

- All our wound ballistics tests documented raw data from each shot in all 6 phases. Averages were calculated and are reported on the data sheets organized by caliber
- No conclusions, rank ordering or choosing was accomplished
- All data was graded using the aforementioned 4 grading criteria
- For phase 6 heavy barrier and armor testing please see the section 2 report

DATA SHEET DEFINITIONS

- **Round**- All rounds tested. Listed by caliber with grain weight included
- **Velocity**- From manufacturer and Phase 1 tested velocity
- **Penetration**- Average inches of penetration thru gel (Phase 2/3)
- **Diameter**- Largest permanent diameter in gel (Phase 2/3) Averaged over all shots for that round in that phase
- **PWC**- Permanent Wound Cavity volume converting **Diameter** to area ($A = \pi r^2$) and multiplied by **Penetration** (average penetration depth)
- **Av Hole Area**- Phase 4/5 tissue test measurements of average diameter of exit wound from each brisket averaged together and then converted to area ($A = \pi r^2$)
- **VWI**- Volume of Wound Index (slide 31) Average Area from Phase 4/5 multiplied by average Penetration from Phase 2/3
  - Includes data from realistic tissue, consistent to measure gel penetration and barriers
- **LDBD%**- Light Domestic Barrier Degradation Percentage
  - Degradation to each round caused by the barrier. Differences between phase 2/3 for gel and phase 4/5 with tissue.
  - Low % indicates that round was less affected by passing through a light domestic barrier

9mm RESULTS

9mm 42 Rounds

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TERMINAL WOUND BALLISTICS DATA, CAO AUGUST 2025

	Caliber Type	Round (160)	Box Velocity	Weapon	PHASE 1 Average Velocity	PHASE 2 Gelatin / Denim Penetra.	Diam	PWC	PHASE 3 Gelatin / Plywood / Denim Penetra.	Diam	PWC	PHASE 4 Tissue / Denim Av Hole Area	PHASE 5 sue / Plywood / Denim Av Hole Area	VWI Av Pen x Av Area	LDBD%
	9mm	42 rounds													
1	FMJ	Winchester NATO 124 gr	1140	Sig P 226 / Glock 17	1140	28.1	0.35	2.7 ci	27.0	0.35	2.6 ci	0.14	0.12	3.6	10%
2	FMJ	Win. M1152 Active Duty 115 gr	1320	Glock 17	1305	>32	0.35	N/A	>32	0.35	N/A	0.14	0.13	N/A	5%
3	Frangible	G2 RIP 92 gr	1265	Glock 17	1295	4/14	0.4	1.8 ci	3.5/12.5	0.35	1.7 ci	0.15	0.13	1.85	10%
4	Frangible	Glaser Blue +P 80 gr	1500	Glock 17	1465	6.0	Frag	N/A	5.5	Frag	N/A	Did Not Exit (DNE)	Did Not Exit (DNE)	undet Area	>95%
5	Frangible	Interceptor ARX +P 65 gr	1695	Glock 17	1680	12.5	0.9	7.9 ci	12.5	0.8	6.3 ci	0.60	0.50	6.9	17%
6	Frangible	Lehigh Dfense CF +P 115 gr	1100	Glock 17	1126	15.2	Frag	N/A	14.2	Frag	N/A	0.13	0.15	2.0	6%
7	Frangible	Liberty Civil Defense 50 gr	2040	Glock 17	1980	10.5	Frag	N/A	9.8	Frag	N/A	Did Not Exit (DNE)	Did Not Exit (DNE)	undet Area	10%
8	Frangible	Sim-X Defensecore 45 gr	2250	Glock 17	2228	7.0	Frag	N/A	4.8	Frag	N/A	Did Not Exit (DNE)	Did Not Exit (DNE)	undet Area	33%
9	Frangible	Sinterfire RHA 100 gr	1300	Glock 17	1265	9.5	Frag	N/A	9.0	Frag	N/A	Did Not Exit (DNE)	Did Not Exit (DNE)	undet Area	>95%
10	Hollow Pt	American Mun. Sierra 115 gr	1250	Glock 17	1230	9.0	0.5	1.8 ci	10.0	0.4	1.3 ci	0.30	0.25	2.6	21%
11	Hollow Pt	CorBon DPX +P 115 gr	1250	Glock 17	1262	15.3	0.64	4.9 ci	14.2	0.57	3.6 ci	0.38	0.32	5.16	22%
12	Hollow Pt	CorBon Self Defense +P 115 gr	1350	Glock 17	1300	9.5	0.6	2.7 ci	7.0	0.5	1.4 ci	0.30	0.16	1.9	48%
13	Hollow Pt	Federal HST 147 gr	1000	Sig P 226 / Glock 17	1005	15.2	0.65	5.2 ci	15.5	0.5	3.0 ci	0.42	0.35	5.9	30%
14	Hollow Pt	G9 Hardened HP 101 gr	1370	Glock 17	1340	11.5	0.65	3.8 ci	13.7	0.5	2.7 ci	0.23	0.20	2.7	21%
15	Hollow Pt	Hornandy C Duty +P 135 gr	1115	Glock 17	1120	13.8	0.5	2.7 ci	13.1	0.48	2.4	0.35	0.31	4.4	15%
16	Hollow Pt	Lehigh Defense ME +P 115 gr	1100	Glock 17	1135	8.4	0.9	5.3 ci	7.1	0.88	4.3 ci	0.62	0.53	4.5	16%
17	Hollow Pt	OATH Tango 110 gr	1200	Glock 17	1150	5.3	0.8	2.7 ci	4.6	0.75	2.0 ci	Did Not Exit (DNE)	Did Not Exit (DNE)	undet Area	20%
18	Hollow Pt	Remington GS +P 124 gr	1180	Glock 17	1170	13.0	0.6	3.7 ci	12.0	0.5	2.4 ci	0.25	0.17	2.6	33%
19	Hollow Pt	Remington GS 147 gr	990	Glock 17	980	17.0	0.6	4.8 ci	16.0	0.5	3.1 ci	0.30	0.25	4.5	26%
20	Hollow Pt	Sig Sauer V 124 gr	1165	Sig P 226 / Glock 17	1150	13.8	0.6	3.9 ci	16.5	0.45	2.6 ci	0.40	0.35	5.7	24%
21	Hollow Pt	Speer GD +P 124 gr	1150	Glock 17	1112	14.8	0.5	2.9 ci	13.8	0.4	1.7 ci	0.23	0.16	2.8	37%
22	Hollow Pt	Speer GD 147 gr	985	Glock 17	970	15.5	0.6	4.4 ci	14.6	0.5	2.9 ci	0.36	0.32	5.1	23%
23	Hollow Pt	Underwood Max Exp 105 gr	1175	Glock 17	1160	10.3	0.8	5.2 ci	11.0	0.7	4.2 ci	0.50	0.41	4.8	19%
24	Hollow Pt	Winchester RA9TA +P+ 127 gr	1250	Glock 17	1225	14.5	0.65	4.8 ci	19.0	0.4	2.4 ci	0.38	0.28	5.5	38%
25	Hollow Pt	Winchester Ranger T 147 gr	990	Glock 17	1000	14.5	0.6	4.1 ci	16.0	0.4	2.0 ci	0.30	0.25	4.2	35%
26	Hollow Pt	Win. M1153 Active Duty 147 gr		Glock 17	982	15.2	0.55	3.6 ci	13.8	0.5	2.7 ci	0.22	0.20	3.0	15%
27	Tumbling	Fort Scott 80 gr	1350	Sig P 226 / Glock 17	1405	19.5	0.4	2.5 ci	18.8	0.4	2.4 ci	0.27	0.25	5.0	6%
28	Fluted FT	Black Hills HB +P 100 gr	1300	Glock 17	1310	16.5	0.7	6.3 ci	14.8	0.7	5.7 ci	0.47	0.41	6.9	11%
29	Fluted FT	Black Hills Subsonic 125 gr	1050	Glock 17	1040	17.5	0.6	4.9 ci	17.0	0.6	4.8 ci	0.41	0.37	6.7	6%
30	Fluted FT	G9 EHP 80 gr	1480	Glock 17	1512	16.2	1.1	15.4 ci	16.0	1.0	12.6 ci	0.65	0.65	10.5	1%
31	Fluted FT	G9 EHP +P 80 gr	1520	Glock 17	1602	16.8	1.1	15.9 ci	16.4	1.1	15.6 ci	0.67	0.68	11.2	1%
32	Fluted FT	G9 First Response 77 gr	1550	Glock 17	1540	19.5	1.2	22.0 ci	19.0	1.1	18.1 ci	0.73	0.71	13.9	3%
33	Fluted FT	G9 APC 77 gr	1550	Glock 17	1555	19.5	1.2	22.0 ci	19.2	1.2	21.7 ci	0.73	0.72	14.0	1%
34	Fluted FT	G9 APC Subsonic 123 gr	1040	Glock 17	1034	18.8	0.55	4.7 ci	18.4	0.55	4.4 ci	0.42	0.40	7.6	2%
35	Fluted FT	G9 EHP Subsonic 126 gr	1020	Glock 17	1028	17.1	0.6	4.8 ci	16.7	0.6	4.7 ci	0.45	0.42	7.4	5%
36	Fluted FT	G9 Woodsman +P 124 gr	1250	Glock 17	1260	34.0	0.7	13.1 ci	33.0	0.7	12.7 ci	0.42	0.46	14.7	1%
37	Fluted FT	Lehigh Defense XD 90 gr	1300	Glock 17	1328	15.1	0.75	6.7 ci	14.2	0.7	5.5 ci	0.55	0.48	7.5	6%
38	Fluted FT	Lehigh Defense XP 115 gr	1100	Glock 17	1153	38.0	0.45	6.1 ci	38.0	0.45	6.1 ci	0.21	0.19	7.6	0%
39	Fluted FT	Underwood XD +P 65 gr	1800	Glock 17	1760	16.5	1.1	15.7 ci	15.5	1.0	12.2 ci	0.65	0.63	10.2	8%
40	Fluted FT	Underwood XD 90 gr	1400	Sig P 226 / Glock 17	1480	16.0	0.8	8.0 ci	15.2	0.7	5.8 ci	0.60	0.47	8.3	25%
41	Fluted FT	Underwood XD +P 90 gr	1475	Sig P 226 / Glock 17	1505	16.7	0.9	10.6 ci	16.0	0.8	8.0 ci	0.60	0.60	9.8	12%
42	Fluted FT	Underwood XD +P+ 90 gr	1550	Glock 17	1585	17.5	1.0	13.7 ci	17.0	0.9	10.8 ci	0.65	0.65	11.2	11%

.380 & .357 SIG RESULTS

.380 5 Rounds

VIPER WEAPONS TRAINING LLC

TERMINAL WOUND BALLISTICS DATA, CAO AUGUST 2025

	Caliber / Type	Round (160)	Box Velocity	Weapon	PHASE 1 Average Velocity	PHASE 2 Gelatin / Denim Penetra.	PHASE 2 Gelatin / Denim Diam	PHASE 2 Gelatin / Denim PWC	PHASE 3 Gelatin / Plywood / Denim Penetra.	PHASE 3 Gelatin / Plywood / Denim Diam	PHASE 3 Gelatin / Plywood / Denim PWC	PHASE 4 Tissue / Denim Av Hole Area	PHASE 5 Tissue / Plywood / Denim Av Hole Area	VWI Av Pen x Av Area	LDBD%
	.380	5 rounds													
1	FMJ	Winchester FMJ 95 gr	955	Glock 42	940	25.5	0.35	2.5 ci	24.2	0.35	2.3 ci	0.12	0.12	3.0	5%
2	Hollow Pt	Hornady XTP 90 gr	1000	Glock 42	1010	12.5	0.4	1.6 ci	11.2	0.38	1.3 ci	0.32	0.25	3.4	18%
3	Hollow Pt	Speer GD 90 gr	1040	Glock 42	1055	11.2	0.42	1.5 ci	12.5	0.35	1.2 ci	0.32	0.20	3.1	25%
4	Fluted FT	G9 First Response 77 gr	1140	Glock 42	1130	15.2	0.75	6.7 ci	14.8	0.7	5.7 ci	0.52	0.45	7.3	9%
5	Fluted FT	Underwood XD +P 65 gr	1400	Glock 42	1370	12.5	0.7	4.8 ci	12.0	0.6	3.4 ci	0.42	0.38	4.9	7%

.357 Sig 9 Rounds

VIPER WEAPONS TRAINING LLC

TERMINAL WOUND BALLISTICS DATA, CAO AUGUST 2025

	Caliber / Type	Round (160)	Box Velocity	Weapon	PHASE 1 Average Velocity	PHASE 2 Gelatin / Denim Penetra.	PHASE 2 Gelatin / Denim Diam	PHASE 2 Gelatin / Denim PWC	PHASE 3 Gelatin / Plywood / Denim Penetra.	PHASE 3 Gelatin / Plywood / Denim Diam	PHASE 3 Gelatin / Plywood / Denim PWC	PHASE 4 Tissue / Denim Av Hole Area	PHASE 5 Tissue / Plywood / Denim Av Hole Area	VWI Av Pen x Av Area	LDBD%
	357 SIG	9 rounds													
1	FMJ	Winchester FMJ 125 gr	1350	Glock 22 conv barl	1370	32.1	0.4	4.0 ci	30.8	0.4	3.9 ci	0.15	0.15	4.7	10%
2	Hollow Pt	Federal HST 125 gr	1360	Glock 22 conv barl	1375	17.2	0.6	4.9 ci	19.7	0.5	3.9 ci	0.46	0.37	7.6	20%
3	Hollow Pt	Hornady C Duty 135 gr	1225	Glock 31	1277	14.6	0.55	3.5 ci	12.6	0.5	2.5 ci	0.36	0.26	4.2	28%
4	Hollow Pt	Sig Sauer V 125 gr	1356	Glock 22 conv barl	1375	17.0	0.6	4.8 ci	22.0	0.4	2.8 ci	0.44	0.32	7.4	35%
5	Hollow Pt	Speer GD 125 gr	1350	Glock 22 conv barl	1385	17.5	0.6	4.9 ci	14.5	0.5	2.8 ci	0.28	0.16	3.5	43%
6	Hollow Pt	Winchester Defender 125 gr	1350	Glock 31	1327	15.0	0.55	3.6 ci	12.4	0.45	2.0 ci	0.41	0.25	4.5	47%
7	Fluted FT	G9 APC 77 gr	1750	Glock 31	1740	20.2	1.4	31.1 ci	19.8	1.4	30.5 ci	0.86	0.83	16.9	1%
8	Fluted FT	Underwood XD 65 gr	2100	Glock 22 conv barl	2060	17.5	1.0	13.7 ci	16.5	1.0	13.0 ci	0.78	0.71	12.7	7%
9	Fluted FT	Underwood XD 90 gr	1700	Glock 22 conv barl	1690	18.3	1.0	14.4 ci	17.4	1.0	13.7 ci	0.78	0.68	13.0	9%

.40 S&W RESULTS

.40 S&W 27 Rounds

VIPER WEAPONS TRAINING LLC

TERMINAL WOUND BALLISTICS DATA, CAO AUGUST 2025

	Caliber / Type	Round (160)	Box Velocity	Weapon	PHASE 1 Average Velocity	PHASE 2 Gelatin / Denim Penetra.	Diam	PWC	PHASE 3 Gelatin / Plywood / Denim Penetra.	Diam	PWC	PHASE 4 Tissue / Denim Av Hole Area	PHASE 5 Tissue / Plywood / Denim Av Hole Area	VWI Av Pen x Av Area	LDBD%
	40 S&W	27 rounds													
1	FMJ	Winchester FMJ 180 gr	1020	Glock 22	1005	31.0	0.4	3.9 ci	29.5	0.4	3.7 ci	0.14	0.16	4.5	3%
2	Frangible	G2 RIP 115 gr	1080	Glock 22	1100	5/11.5	0.5	2.6 ci	5/11.2	0.4	1.4 ci	0.20	Did Not Exit (DNE)	undet Area	
3	Frangible	Glaser Blue 115 gr	1400	Glock 22	1355	7.0	Frag	N/A	6.5	Frag	N/A	Did Not Exit (DNE)	Did Not Exit (DNE)	undet Area	>95%
4	Frangible	Liberty Civil Defense 60 gr	2000	Glock 22	1965	11.2	Frag	N/A	10.5	Frag	N/A	Did Not Exit (DNE)	Did Not Exit (DNE)	undet Area	
5	Frangible	Sinterfire RHFP 125 gr	1350	Glock 22	1330	10.75	Frag	N/A	10.0	Frag	N/A	Did Not Exit (DNE)	Did Not Exit (DNE)	undet Area	>95%
6	Hollow Pt	Federal HST 180 gr	1000	Glock 22	988	18.0	0.6	5.1 ci	17.6	0.6	5.0 ci	0.49	0.43	8.2	7%
7	Hollow Pt	Hornady C Duty 175 gr	1010	Glock 22	1020	17.9	0.6	5.0 ci	17.2	0.6	4.9 ci	0.40	0.40	7.0	2%
8	Hollow Pt	OATH Tango 125 gr	1250	Glock 22	1225	8.0	0.8	4.0 ci	6.7	0.8	3.4 ci	Did Not Exit (DNE)	Did Not Exit (DNE)	undet Area	
9	Hollow Pt	Remington GS 165 gr	1150	Glock 22	1145	15.3	0.5	3.0 ci	17.2	0.4	2.2 ci	0.30	0.20	4.1	25%
10	Hollow Pt	Remington GS 180 gr	1015	Glock 22	1020	17.2	0.6	4.9 ci	16.4	0.5	3.9 ci	0.44	0.36	6.7	19%
11	Hollow Pt	Sig Sauer V 165 gr	1090	Glock 22	1100	16.5	0.6	4.7 ci	16.1	0.6	4.6 ci	0.45	0.41	7.0	7%
12	Hollow Pt	Speer Gold Dot 165 gr	1050	Glock 22	1060	14.3	0.7	5.5 ci	16.0	0.5	3.1 ci	0.30	0.24	4.1	32%
13	Hollow Pt	Speer Gold Dot 180 gr	1025	Glock 22	1040	16.0	0.6	4.5 ci	15.1	0.6	4.3 ci	0.45	0.41	6.7	7%
14	Hollow Pt	Underwood Max Exp 140 gr	1050	Glock 22	1060	8.5	1.0	6.7 ci	9.5	0.9	6.0 ci	0.69	0.58	5.7	13%
15	Hollow Pt	Winchester Ranger T 180 gr	990	Glock 22	1000	13.5	0.7	5.2 ci	12.7	0.6	3.6 ci	0.42	0.36	5.1	23%
16	Tumbling	Fort Scott 125 g	1320	Glock 22	1290	22.0	0.5	4.3 ci	20.8	0.4	2.6 ci	0.20	0.28	5.1	15%
17	Fluted FT	G9 EHP Range Limiter 80 gr	1625	Glock 22	1640	19.0	1.3	25.2 ci	18.5	1.2	20.9 ci	0.78	0.76	14.4	10%
18	Fluted FT	G9 EHP 95 gr	1460	Glock 22	1445	19.0	1.0	14.9 ci	18.7	0.9	11.9 ci	0.70	0.66	12.8	8%
19	Fluted FT	G9 First Response 77 gr	1680	Glock 22 Sig 320	1670	19.3	1.5	34.1 ci	19.2	1.5	33.9 ci	0.90	0.85	16.8	4%
20	Fluted FT	G9 First Response 90 gr	1450	Glock 22	1450	19.2	1.1	18.2 ci	19.0	1.0	14.9 ci	0.75	0.74	14.2	9%
21	Fluted FT	G9 First Response 100 gr	1500	Glock 22	1536	20.5	1.2	23.2 ci	20.7	1.2	23.4 ci	0.82	0.81	16.8	0%
22	Fluted FT	G9 First Response 115 gr	1420	Glock 22	1454	21.4	1.1	20.3 ci	21.1	1.1	20.0 ci	0.74	0.77	16.0	1%
23	Fluted FT	G9 APC 77 gr	1700	Glock 22	1670	19.5	1.5	34.5 ci	19.5	1.5	34.5 ci	0.88	0.86	17.0	1%
24	Fluted FT	G9 APC 90 gr	1450	Glock 22	1460	19.2	1.1	18.2 ci	19.1	1.1	18.2 ci	0.75	0.75	14.4	0%
25	Fluted FT	G9 Woodsman 130 gr	1300	Glock 22 Sig 320	1315	33.0	0.8	15.8 ci	32.0	0.8	16.1 ci	0.55	0.52	17.4	3%
26	Fluted FT	Underwood XD 100 gr	1500	Glock 22	1510	18.0	1.0	14.1 ci	17.6	0.9	11.2 ci	0.69	0.64	11.8	14%
27	Fluted FT	Underwood XD 115 gr	1400	Glock 22	1425	18.5	0.9	11.8 ci	18.1	0.9	11.5 ci	0.63	0.58	11.1	5%

10mm & 4.6mm RESULTS

10mm 11 Rounds

VIPER WEAPONS TRAINING LLC

TERMINAL WOUND BALLISTICS DATA, CAO AUGUST 2025

	Caliber / Type	Round (160)	Box Velocity	Weapon	PHASE 1 Average Velocity	PHASE 2 Gelatin / Denim Penetra.	PHASE 2 Gelatin / Denim Diam	PHASE 2 Gelatin / Denim PWC	PHASE 3 Gelatin / Plywood / Denim Penetra.	PHASE 3 Gelatin / Plywood / Denim Diam	PHASE 3 Gelatin / Plywood / Denim PWC	PHASE 4 Tissue / Denim Av Hole Area	PHASE 5 Tissue / Plywood / Denim Av Hole Area	VWI Av Pen x Av Area	LDBD%
	10mm	11 rounds													
1	FMJ	Winchester FMJ 200 gr	1050	Glock 20	1020	22+	0.4	N/A	22+	0.4	N/A	0.16	0.16	undet Pen	
2	Hollow Pt	Federal Hydra Shok 180 gr	1030	Glock 20	1005	16.6	0.6	4.7 ci	17.4	0.5	3.4 ci	0.54	0.44	8.3	23%
3	Hollow Pt	Federal HST 200 gr	1130	Glock 20	1106	17.8	0.65	5.9 ci	16.8	0.62	5.1 ci	0.51	0.47	8.5	11%
4	Hollow Pt	Hornady C Duty 175 gr	1160	Glock 20	1180	22.0	0.5	4.3 ci	16.0	0.6	4.5 ci	0.44	0.42	8.2	5%
5	Hollow Pt	Sig Sauer 180 gr	1250	Glock 20	1200	16.0	0.6	4.5 ci	15.0	0.6	4.2 ci	0.60	0.36	7.4	23%
6	Hollow Pt	Speer Gold Dot 200 gr	1100	Glock 20	1043	15.7	0.5	3.1 ci	14.6	0.45	2.3 ci	0.48	0.51	7.5	12%
7	Hollow Pt	Winchester SX 175 gr	1290	Glock 20	1300	14.8	0.6	4.2 ci	18.5	0.5	3.6 ci	0.50	0.40	7.5	17%
8	Fluted FT	G9 EHP 95 gr	1720	Glock 20 / FN 510	1705	19.6	1.1	18.6 ci	19.7	1.1	18.7 ci	0.84	0.79	16.0	3%
9	Fluted FT	G9 First Response 100 gr	1750	Glock 20 / FN 510	1776	22.3	1.7	50.2 ci	22.1	1.7	49.9 ci	1.03	0.97	22.2	3%
10	Fluted FT	G9 Woodsman 145 gr	1450	Glock 20	1315	41.0	0.8	20.6 ci	40.0	0.8	20.1 ci	0.66	0.66	26.7	1%
11	Fluted FT	Underwood XD 115 gr	1700	Glock 20	1750	19.2	1.0	15.1 ci	18.7	1.0	14.7 ci	0.78	0.72	14.2	5%

4.6 x 30mm 9 Rounds

VIPER WEAPONS TRAINING LLC

TERMINAL WOUND BALLISTICS DATA, CAO AUGUST 2025

	Caliber / Type	Round (160)	Box Velocity	Weapon	PHASE 1 Average Velocity	PHASE 2 Gelatin / Denim Penetra.	PHASE 2 Gelatin / Denim Diam	PHASE 2 Gelatin / Denim PWC	PHASE 3 Gelatin / Plywood / Denim Penetra.	PHASE 3 Gelatin / Plywood / Denim Diam	PHASE 3 Gelatin / Plywood / Denim PWC	PHASE 4 Tissue / Denim Av Hole Area	PHASE 5 Tissue / Plywood / Denim Av Hole Area	VWI Av Pen x Av Area	LDBD%	TVWI Av PTL x Av Area
	4.6mm	9 rounds														
1	Training	Fiocchi 40 gr	1900	HK MP7	1875	18.2			16.5			0.29	0.25	4.7	5%	
2	Soft Pt	Fiocchi 40 gr Soft Point	1900	HK MP7	1912	16.2			13.8			0.27	0.32	4.4	10%	
3	Training	Sellier & Bellot 40 gr	2067	HK MP7	2020	20.5			18.8			0.34	0.33	6.6	3%	
4	Tumbling	Hornady Black V-Max 38 grain	2100	HK MP7	2048	14.9			14.1			0.39	0.38	5.6	3%	
5	Tumbling	Vanguard Solid Penetrator 31 gr	2250	HK MP7	2125	15.75			15.2			0.41	0.38	6.1	6%	
6	Tumbling	Vanguard SP LE 31 gr	2375	HK MP7	2247	16.9			16.2			0.45	0.48	7.7	1%	
7	Hollow Pt	Barnes TSX 31 gr	2328	HK MP7	2328	15.2	0.8		13.5			0.30	0.33	4.5	3%	
8	Hollow Pt	Vanguard EXP 31 gr	2250	HK MP7	2130	14.2	0.7		13.1			0.35	0.31	4.5	9%	
9	Hollow Pt	Vanguard EXP LE 31 gr	2375	HK MP7	2240	14.8	0.7		13.3			0.28	0.40	4.8	1%	

.45 ACP RESULTS

.45 ACP 24 Rounds

VIPER WEAPONS TRAINING LLC

TERMINAL WOUND BALLISTICS DATA, CAO AUGUST 2025

	Caliber / Type	Round (160)	Box Velocity	Weapon	PHASE 1 Average Velocity	PHASE 2 Gelatin / Denim Penetra.	Diam	PWC	PHASE 3 Gelatin / Plywood / Denim Penetra.	Diam	PWC	PHASE 4 Tissue / Denim Av Hole Area	PHASE 5 Tissue / Plywood / Denim Av Hole Area	VWI Av Pen x Av Area	LDBD%
	45 ACP	24 rounds													
1	FMJ	Winchester FMJ 230 gr	835	Sig P227E / Glock 21	865	27.5	0.45	4.4 ci	27.0	0.45	4.3 ci	0.18	0.22	5.5	2%
2	Frangible	G2 RIP 162 gr	960	Glock 21	995	4.5/16	0.5	3.1 ci	8.8 FTE	0.6	2.5 ci	0.18	0.24	2.6	20%
3	Frangible	Glaser Blue +P 145 gr	1350	Glock 21	1330	7.2	Frag	N/A	7.0	Frag	N/A	Did Not Exit (DNE)	Did Not Exit (DNE)	undet Area	>95%
4	Frangible	Liberty Civil Defense 78 gr	1900	Glock 21	1885	11.5	Frag	N/A	10.8	Frag	N/A	Did Not Exit (DNE)	Did Not Exit (DNE)	undet Area	
5	Frangible	Sinterfire Special Duty 155 gr	1150	Glock 21	1125	13.75	Frag	N/A	12.5	Frag	N/A	0.15	Did Not Exit (DNE)	undet Area	
6	Hollow Pt	Federal HST +P 230 gr	950	Sig P227E / Glock 21	950	15.5	0.7	6.0 ci	16.0	0.7	6.2 ci	0.55	0.45	7.9	9%
7	Hollow Pt	Federal Hydra Shok 230 gr	900	Sig P227E / Glock 21	860	15.0	0.7	5.8 ci	17.2	0.6	4.9 ci	0.31	0.32	5.1	8%
8	Hollow Pt	Hornady C Duty +P 220 gr	975	Glock 21	960	16.0	0.7	6.5 ci	17.2	0.6	4.9 ci	0.52	0.44	8.0	20%
9	Hollow Pt	OATH Tango 163 gr	1100	Glock 21	1105	9.0	0.9	5.7 ci	11.3	0.7	4.3 ci	0.61	0.53	5.8	19%
10	Hollow Pt	Remington GS 185 gr	1140	Glock 21	1115	15.1	0.7	5.8 ci	13.8	0.6	3.9 ci	0.40	0.36	5.5	21%
11	Hollow Pt	Sig Sauer V 230 gr	830	Glock 21	850	15.1	0.7	5.8 ci	16.2	0.7	6.2 ci	0.50	0.42	7.2	8%
12	Hollow Pt	Speer Gold Dot 230 gr	890	Glock 21	810	17.5	0.7	6.7 ci	16.5	0.6	4.7 ci	0.50	0.44	8.0	21%
13	Hollow Pt	Underwood Max Exp 174 gr	1050	Glock 21	1035	9.0	1.2	10.2 ci	7.5	1.1	7.1 ci	0.79	0.79	6.5	15%
14	Hollow Pt	Winchester Ranger T 230 gr	880	Glock 21	910	16.5	0.7	6.3 ci	15.4	0.6	4.4 ci	0.48	0.48	7.7	15%
15	Tumbling	Fort Scott 180 gr	989	Glock 21	1000	22+ FTT	0.5	N/A	22+ FTT	0.48	N/A	0.20	0.28	undet Pen	
16	Fluted FT	G9 EHP 117 gr	1400	Glock 21	1315	17.9	0.9	11.4 ci	17.2	0.9	10.9	0.67	0.65	11.6	3%
17	Fluted FT	G9 EHP +P 117 gr	1480	Glock 21	1410	19.0	1.0	14.9 ci	18.7	0.9	11.9 ci	0.72	0.71	13.5	2%
18	Fluted FT	G9 APC 110 gr 2022	1550	Glock 21	1490	18.8	1.4	28.9 ci	18.5	1.3	24.5 ci	0.84	0.80	15.3	4%
19	Fluted FT	G9 First Response 117 gr	1500	Glock 21	1495	19.5	1.4	30.0 ci	19.5	1.4	30.0 ci	0.80	0.85	16.1	1%
20	Fluted FT	G9 APC 117 gr 2023	1500	Glock 21	1470	19.7	1.4	30.3 ci	19.6	1.4	30.2 ci	0.83	0.82	16.2	2%
21	Fluted FT	G9 Woodsman 165 gr	1230	Glock 21	1215	30.0	0.8	15.1 ci	28.5	0.7	11.0 ci	0.58	0.55	16.5	6%
22	Fluted FT	Underwood XD 120 gr	1320	Sig P227E / Glock 21	1400	18.5	0.9	11.8 ci	17.6	0.8	8.8 ci	0.60	0.42	9.2	28%
23	Fluted FT	Underwood XD +P 120 gr	1420	Sig P227E / Glock 21	1460	19.0	0.9	12.1 ci	18.4	0.9	11.7 ci	0.65	0.61	11.8	5%
24	Fluted FT	Underwood XD Super 120 gr	1600	Sig P227E / Glock 21	1550	19.5	1.0	15.3 ci	19.0	0.9	12.1 ci	0.825	0.71	14.8	17%

5.7mm RESULTS

5.7 x 28mm 33 Rounds

VIPER WEAPONS TRAINING LLC

TERMINAL WOUND BALLISTICS DATA, CAO AUGUST 2025

	Caliber / Type	Round (160)	Box Velocity	Weapon	PHASE 1 Average Velocity	PHASE 2 Gelatin / Denim Penetra.	PHASE 2 Diam	PHASE 2 PWC	PHASE 3 Gelatin / Plywood / Denim Penetra.	PHASE 3 Diam	PHASE 3 PWC	PHASE 4 Tissue / Denim Av Hole Area	PHASE 5 Tissue / Plywood / Denim Av Hole Area	VWI Av Pen x Av Area	LDBD%	TVWI Av PTL x Av Area
	5.7mm	33 rounds														
1	Training	American Eagle 40 gr	1655	FN 5.7	1575	12.5			11.5			0.30	0.20	3.0	20%	3.0
2	Frangible	Fiocchi Frangible HP 35 gr	1750	FN 5.7	1715	13.2			10.5			0.18	0.12	1.8	25%	ND
3	Training	Fiocchi Hyperformance 40 gr	1750	FN 5.7	1735	13.5			12.8			0.22	0.24	3.0	0%	ND
4	Tumbling	Fiocchi Subsonic 62 gr		FN 5.7	950	10.5			9.0			0.25	0.23	2.3	10%	ND
5	AP Tumbling	FNH SS190 31 gr	2130	FN 5.7	2130	12.0			11.2			0.39	0.39	4.5	3%	ND
6	Hollow Pt	FNH SS192 28 grain		FN 5.7	2046	9.7			9.1			0.35	0.32	3.2	7%	3.4
7	Tumbling	FNH SB193 Subsonic 60 grain	984	FN 5.7	1042	13.5			13.8			0.22	0.21	2.9	0%	3.2
8	Training	FNH SS195LF 28 gr	2000	FN 5.7	1900	9.1			8.3			0.29	0.27	2.4	9%	2.6
9	Training	FNH SS197SR 40 gr	1700	FN 5.7	1620	13.8			12.7			0.22	0.20	2.8	9%	2.9
10	Tumbling	FNH SS198LF 28gr	2150	FN 5.7	2092	10.2			9.6			0.38	0.34	3.6	10%	3.9
11	Hollow Pt	FNH SS200 DFNS 30 gr	1894	FN 5.7	1817	12.2			9.5			0.36	0.28	3.5	22%	ND
12	Training	Hornady Black V-Max 40 gr	1810	FN 5.7	1794	13.2			11.7			0.24	0.31	3.4	0%	3.5
13	Hollow Pt	Hornady Critical Defense 40 gr	1810	FN 5.7	1835	12.5			11.8			0.49	0.35	5.1	15%	5.1
14	Hollow Pt	Speer Gold Dot HP 40 gr orig.	1800	FN 5.7	1775	14.5			15.0			0.51	0.42	6.9	9%	6.9
15	Hollow Pt	Speer Gold Dot HP 40 gr v2 2024	1800	FN 5.7	1705	13.8			13.5			0.39	0.44	5.7	5%	5.8
16	Tumbling	Elite S4M 28gr	2650	FN 5.7	2410	12.5			11.9			0.44	0.50	5.7	3%	6.4
17	Tumbling	Elite T6B 27 gr	2570	FN 5.7	2230	15.1			14.7			0.54	0.51	7.8	2%	8.9
18	Tumbling	Elite PenetraTOR 40 gr	1900	FN 5.7	1905	17.2			15.9			0.35	0.10	3.7	37%	ND
19	Frangible	Elite ProtecTOR 40 gr	2100	FN 5.7	1910	16.5			15.3			0.13	0.12	2.0	8%	ND
20	Tumbling	Elite DevastaTOR 37 gr		FN 5.7	2005	18.7			18.3			0.62	0.58	11.1	4%	12.0
21	Tumbling	Elite DevastaTOR 3.0 27 gr		FN 5.7	2310	19.9			19.7			0.66	0.66	13.0	1%	14.9
22	Tumbling	Vanguard Black Fang 34 gr	2150	FN 5.7	2130	18.9			18.7			0.63	0.51	10.6	8%	12.2
23	Tumbling	Vanguard BDF LE 34 gr	2150	FN 5.7	2200	19.2			19.0			0.57	0.55	10.7	2%	ND
24	Tumbling	Vanguard BDF HVP LE 34 gr	2150	FN 5.7	2190	19.3			19.2			0.55	0.56	10.7	1%	ND
25	Tumbling	Vanguard Longfang SE 34 gr	2125	FN 5.7	2188	17.7			18.2			0.63	0.65	11.5	0%	13.4
26	Tumbling	Vanguard Lightning Fang 25 gr	2350	FN 5.7	2305	17.5			17.7			0.61	0.57	10.4	3%	ND
27	Hollow Pt	Vanguard Barnes HP 50 gr	1725	FN 5.7	1590	16.8			15.0			0.56	0.40	7.6	20%	ND
28	Tumbling	Vanguard Comb Tech 50 gr		FN 5.7	1635	17.0			16.2			0.59	0.50	9.0	10%	ND
29	Frangible	Vanguard GPMI 40 gr		FN 5.7	1970	20.5			19.5			0.48	0.43	9.1	9%	ND
30	Frangible	Vanguard GPMI DF 35 gr	2150	FN 5.7	2140	16.2			15.0			0.50	0.40	7.0	14%	ND
31	Frangible	Vanguard Low Collateral 35 gr	2025	FN 5.7	2076	13.9			13.1			0.54	0.55	7.4	4%	7.5
32	Frangible	Vanguard FRAG HP 32 gr	2225	FN 5.7	2134	11.2			10.0			0.28	0.31	3.1	10%	ND
33	Tumbling	Vanguard EXP Subsonic 64 gr		FN 5.7	1030	13.2			12.4			0.28	0.24	3.3	10%	ND

PISTOL PROJECTILE WOUND PROFILES

All five pistol projectile types are represented. This information is designed to highlight the effects of different projectile types. It is not intended to highlight any differences between calibers as only averages are provided.

- Full Metal Jacket (FMJ)
- Hollow Point (HP)
- Fluted-Fluid Transfer
- Frangible
- Tumbling (5.7mm and 4.6mm)

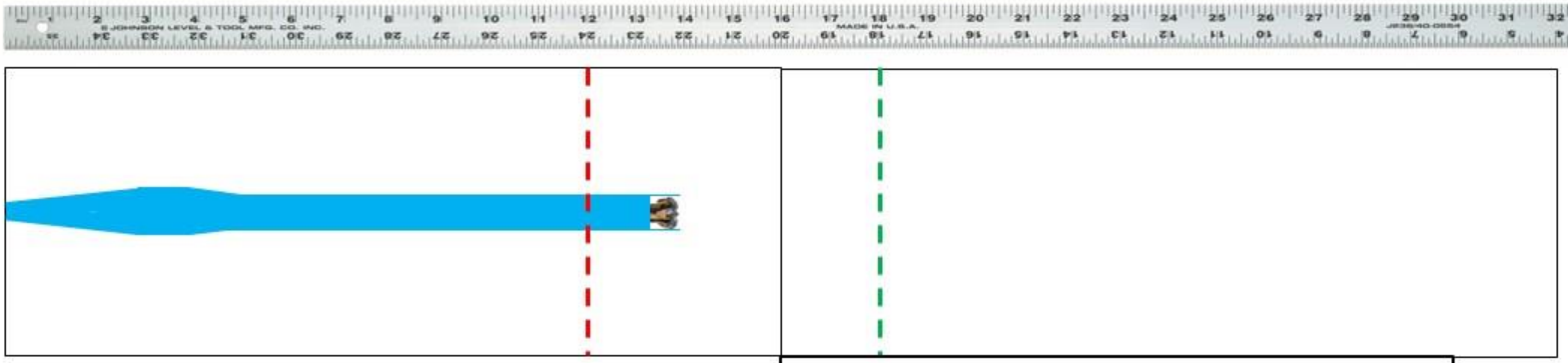
Yardstick and profile picture is to scale and is 36 inches.
Rectangle is two 16x6x6 IWBA gel blocks (FBI/DoD standard). Broken in half since its two blocks. The rectangle is to scale. Denim Barrier not shown. Federal Standard penetration minimum 12 inch and optimum 18 inch lines included.

Wound Profile picture derived from the following:

- Wound shape comes from gel testing, forensic reports and testing in animal tissue
- Wound diameter comes from forensic reports and testing in animal tissue. It is an average of the three listed calibers
- Wound penetration depth comes from IWBA gelatin tests by multiple agencies. It is an average of the three listed calibers

Average Wound Dimension table shows the average of all the rounds tested in that caliber and bullet type. For a list of all the rounds tested and included here, please see the data tables, which includes the individual dimensions used for the averages. CAO September 2025

HOLLOW POINT (HP) WOUND PROFILE

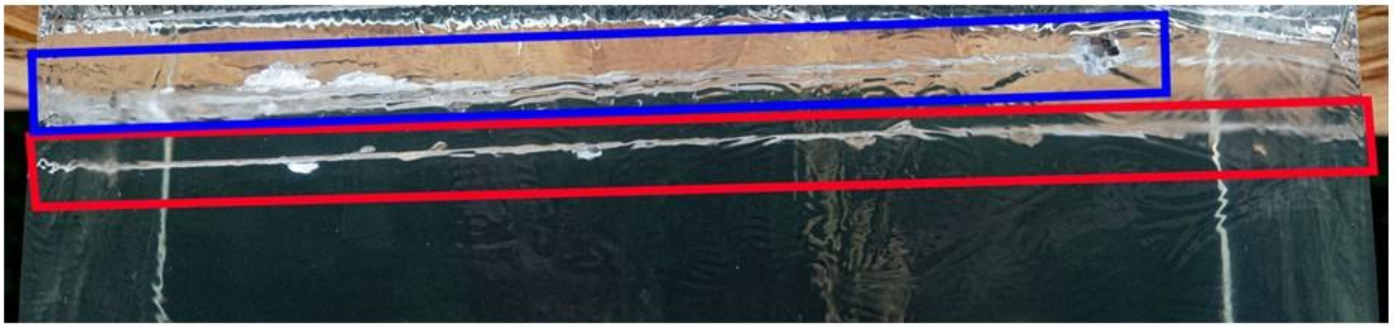


AVERAGE HP WOUND DIMENSIONS

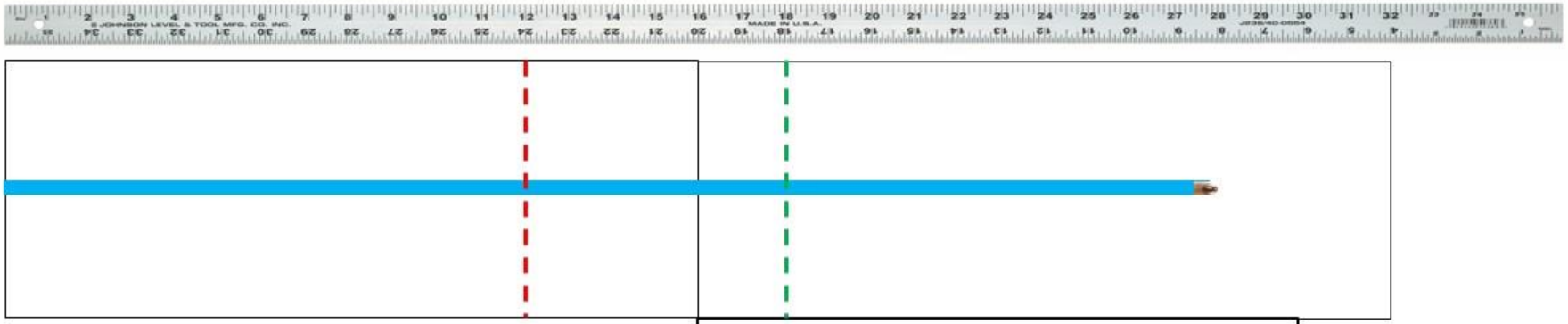
Caliber	Diameter x Penetration Depth
9mm	.58" x 12.8"
40 S&W	.64" x 14.5"
45 ACP	.73" x 14.3"

Light Domestic Barrier Degradation Percentage. Skin, light clothing, plywood, drywall and bones. 15-48% loss

Top blue = HP
Bottom red = FMJ



FULL METAL JACKET (FMJ) WOUND PROFILE

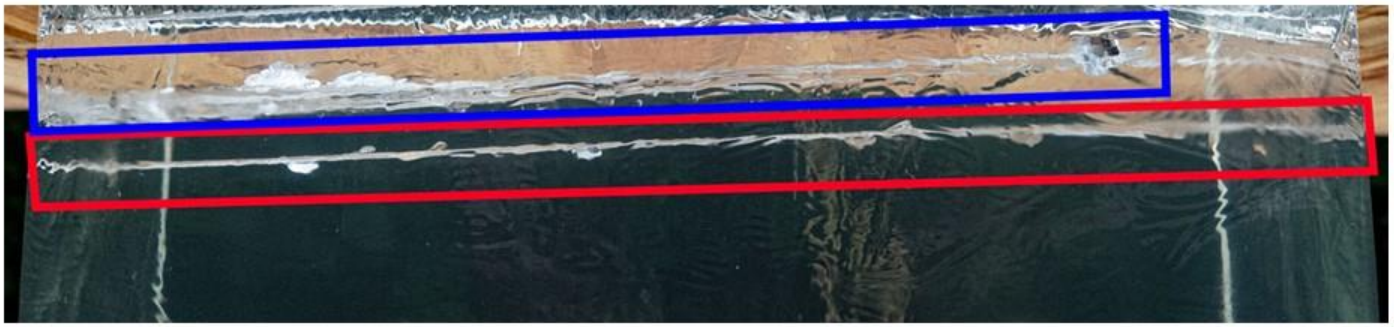


AVERAGE FMJ WOUND DIMENSIONS

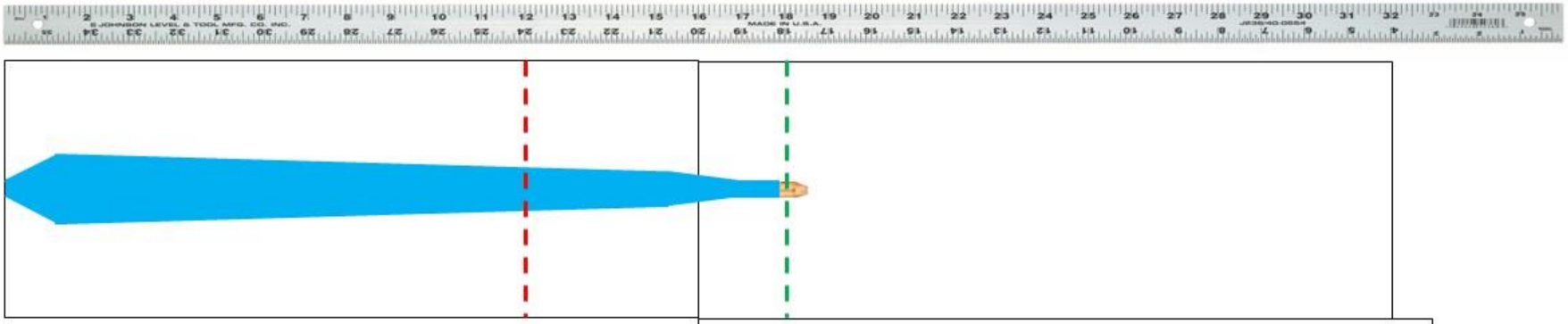
Caliber	Diameter x Penetration Depth
9mm	.35” x 30”
40 S&W	.4” x 31”
45 ACP	.45” x 27.5”

Light Domestic Barrier Degradation Percentage. Skin, light clothing, plywood, drywall and bones. 2-10% loss

Top blue = HP
Bottom red = FMJ



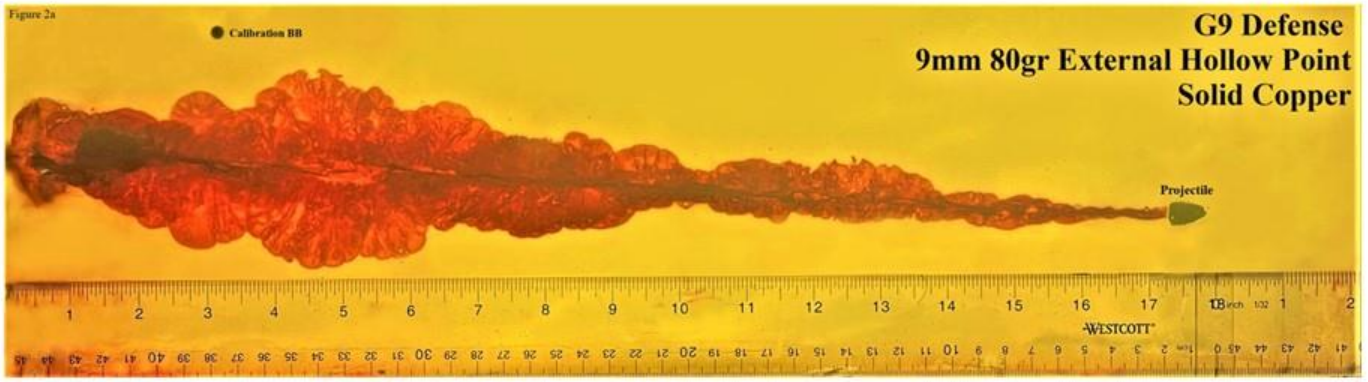
FLUTED - FLUID TRANSFER WOUND PROFILE



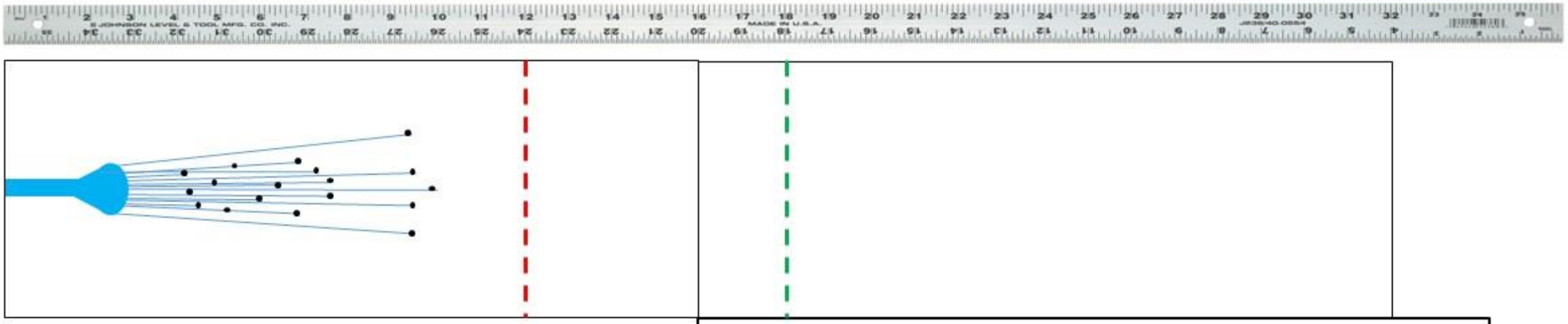
AVERAGE FLUTED WOUND DIMENSIONS

Caliber	Diameter x Penetration Depth
9mm	.83" x 17.1"
40 S&W	1.12" x 18.9"
45 ACP	1.05" x 19.2"

Light Domestic Barrier Degradation Percentage
Skin, light clothing, plywood and bones: 0-28% loss



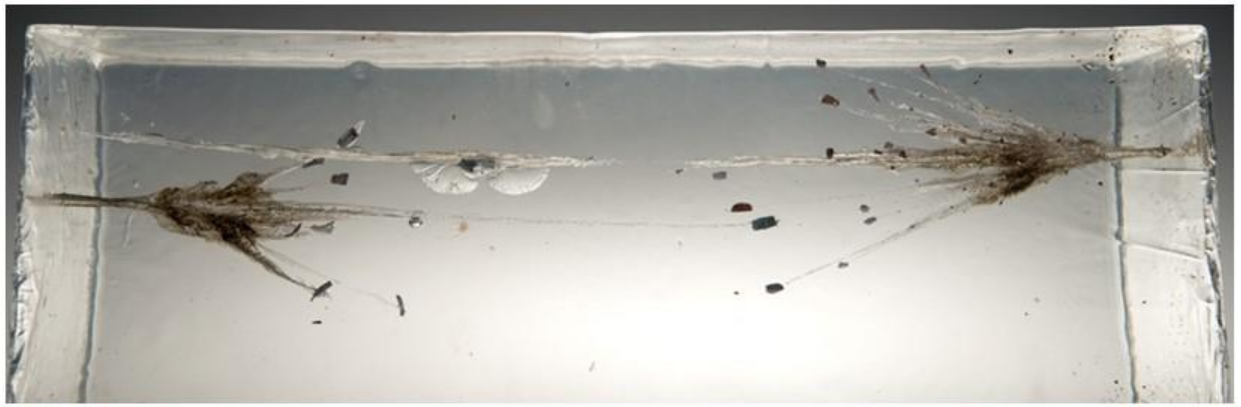
FRANGIBLE WOUND PROFILE



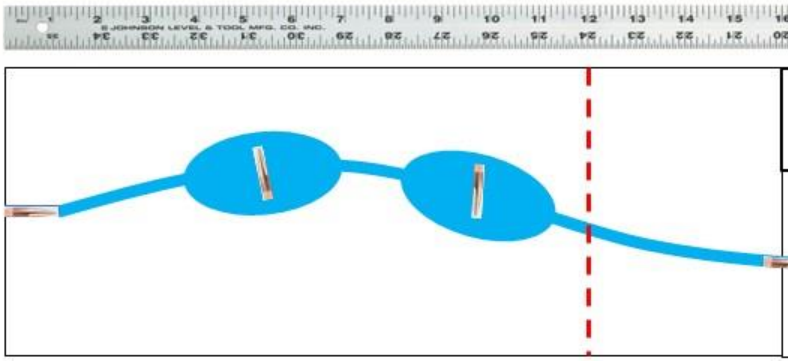
AVERAGE FRANGIBLE WOUND DIMENSIONS

Caliber	Penetration Depth
9mm	9.6”
40 S&W	9.7”
45 ACP	10.8”

Light Domestic Barrier Degradation Percentage. Skin, light clothing, plywood, drywall and bones. 15-100% loss



TUMBLING WOUND PROFILE

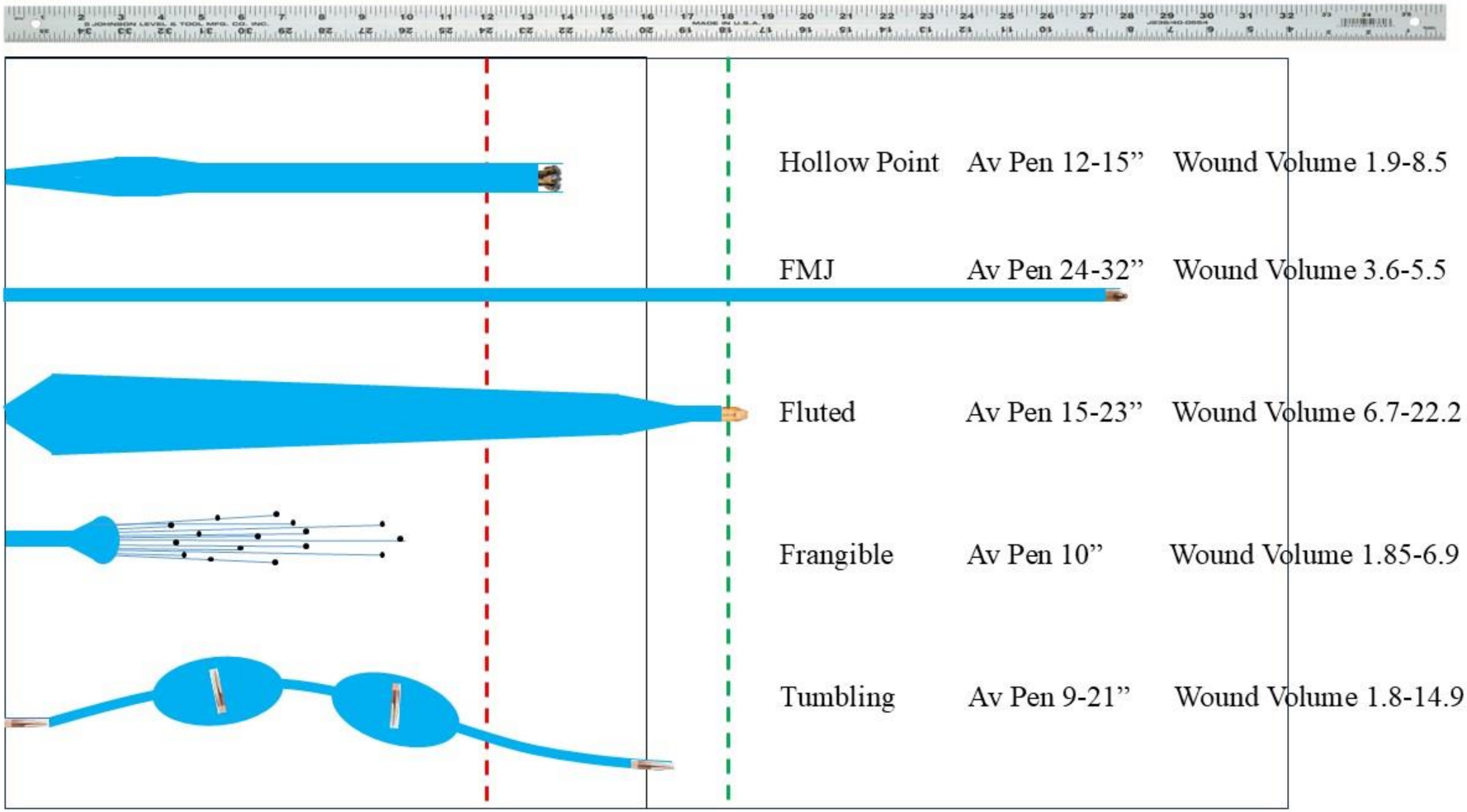


Light Domestic Barrier Degradation Percentage. Skin, light clothing, plywood, drywall and bones. 0-37% loss

AVERAGE TUMBLING WOUND DIMENSIONS

Caliber	Penetration Depth
4.6mm	15.8”
5.7mm	15.9”

COMPOSITE WOUND PROFILES



PROJECTILE CHARACTERISTIC SUMMARY

	4 CHARACTERISTICS			
BULLET TYPE	PENETRATION GEL INCHES	RELIABILITY	BARRIERS PENETRATED	PWC VWI
HOLLOW POINT	9-18 12-14 average	65%	LIGHT DOMESTIC	1.9-8.3
FMJ	24-32	95%	HEAVY	3.6-5.45
FLUTED	15-23	90%	HEAVY-ARMOR	6.7-22.2
FRANGIBLE	4-16	85%	NONE-LIGHT	1.85-6.9
TUMBLING	9-21	85%	NONE-ARMOR	1.8-14.9

PROJECTILE AVERAGES

PENETRATION / WOUND VOLUME

BULLET TYPE	9mm	.380	.357 Sig	.40	10mm	.45	5.7mm	4.6mm
HOLLOW POINT	12.8” 4.1”	11.9” 3.25”	16.2” 5.44”	14.5” 6.1”	17.2” 7.9”	14.3” 6.85”	14.0” 5.8”	14.7” 4.6”
FMJ	30.0” 3.6”	25.5” 3.0”	32.1” 4.7”	31.0” 4.5”		27.5” 5.5”		
FLUTED	17.1” 9.83”	13.9” 6.1”	18.7” 14.2”	18.9” 14.8”	20.4” 17.5”	19.2” 13.6”		
FRANGIBLE	9.6” 3.6”			9.1”		10.8”	15.3” 5.1”	
TUMBLING							15.9” 7.9”	15.8” 6.5”

TEST RESULTS vs REAL WORLD FORENSICS

- Test results in calibrated FBI International Wound Ballistics Association (IWBA) 10% ordnance gelatin (Phase 2 and 3) are vastly different from medical measurements taken post real-world shootings
  - 5 case studies of non-barrier shots to the thoracic cavity with two fluted-fluid transfer rounds that each produce 17-20 inches of penetration in gel. None of the 5 shots exited through the real-world targets.
  - 7 case studies of non-barrier shots to the thoracic cavity with a certain popular 9mm duty hollow point that averages 13-14 inches of penetration in gel, as tested by the FBI, DHS and us. None of the shots hit bone or penetrated >5 inches into the targets.
- Test results from animal tissue (Phase 4 and 5)
  - Only measuring wound diameter and corresponding wound hole area. Penetration depth not accomplished due to the requirement do measure the exit holes through the tissue during testing.
  - Hunting shots into live animals exhibit the same wound channel diameter and area as testing on dead animal tissue with all 5 projectile types.
  - 5 case studies of non-barrier shots to the thoracic cavity with two fluted-fluid transfer rounds mentioned above. All 5 real-world wound diameters matched tissue test results.

SUMMARY

- Pistol ammunition is graded by four characteristics
  - Penetration, Reliability, Barrier Performance and Permanent Wound Cavity Volume
- There are five types of pistol projectiles each with there own generalized characteristics, abilities and purpose
  - Hollow Points, FMJ, Fluted- Fluid Transfer, Frangible and Tumbling
- Standardized testing from the FBI and DoD is used to quantify the four characteristics
  - FBI tends to use IWBA gelatin and several different types of barriers
  - DoD uses IWBA gel and tissue and multiple barriers to include armor
- There is a vast difference between results from test media gel and real-world shootings
  - IWBA gel has a tensile strength and resistance of .8-1.0 MPa vs the average human soft tissue tensile strength of 2.5 MPa. IWBA gel penetration depths are significantly deeper than forensic analysis of penetration depths on human targets
- There are several factors that do not represent a bullets wounding capability
  - Energy, Temporary Stretch Cavity and Fragmentation

HOW TO CHOOSE A ROUND

1. Understand the 4 projectile characteristics
   - Penetration, Reliability/Consistency, Barrier Performance and Permanent Wound Cavity (PWC)
2. Determine your desired values for each characteristic
   - Those effects must match mission requirements
   - Compare your desires with forensic data for validation
3. Understand the different projectile types
   - Most rounds of the same type have very similar characteristics in regards to penetration and barrier performance
   - By first choosing which bullet type most closely matches your needs you can easily narrow down your search and achieve your desired results
4. Use data sheets to match your desired characteristics to actual test results
   - There is no best projectile, just one that most closely matches your needs

ADDITIONAL COMMENTS

- Information concerning other critical elements of ammunition was noted
  - Recoil
  - Feed reliability
  - Not related to Terminal Wound Ballistics, but still essential in ammunition testing and selection
- Minimal testing was done with non-standard barrel lengths
  - Data not included in the data sheets
  - Calculating velocity gain or loss
  - Requested specifically for certain weapons, barrels and ammunition
- Minimal testing was done with suppressors on subsonic ammunition
  - Information on velocity changes, sound effects and weapon / ammunition function was noted
- Please contact us for specifics

ACKNOWLEDGEMENTS

- There are so many people to credit with the amount of data that was measured and calculated in this report presentation. People involved in this test came from multiple federal and state agencies, police departments, local gun stores and 2 training schools. One local grocery store chain gave a great discount on the brisket used in Phases 4 and 5. The tests were accomplished at multiple ranges
- No ammunition manufacturers were allowed to attend any test. They were only allowed to provide ammunition and nothing else
- A very special thanks to all the volunteers who helped set up, tear down, measure, re-measure, document, calculate and check all the data. Only through their diligent thorough work could this much accurate data be generated
- Information and measurements taken from actual medical forensic reports has been invaluable. We sincerely wish to express our gratitude for all who have provided that critical data
- There are no conclusions in this report. Testing was accomplished only to provide quantifiable raw data on a large scale with an enormous sample size on multiple realistic media

CONTACT US

Please contact us for questions or follow-on testing

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SPECIAL PISTOL AMMUNITION REPORT II SECTION 2

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SPECIAL PISTOL AMMUNITION REPORT II

SECTION TWO

TABLE OF CONTENTS

TACTICAL REALITIES

There are four main determinants involved in stopping a human target. Wound placement, number of hits, bullet capability and the target being shot.

1. Wound placement: The location of the wound is the most important determinant in stopping or incapacitating a human target. However, shot placement is NOT wound placement and where a projectile impacts the target does not always determine the path of the bullet through the target due to bullet performance, failures and barriers (clothes, bones and outside items). Many common defensive rounds do not penetrate deep enough, are easy to defeat or vector away from the original path of the bullet. Barrier performance is extremely important in judging whether a round will continue its original path or be deflected / defeated. "Shot placement is an important and often cited consideration regarding the suitability of weapons and ammunition. However, considerations of the projectile are equally important and cannot be ignored. For example, a bullet passing through the central nervous system with any caliber of ammunition is likely to be immediately incapacitating. Even a .22 rimfire penetrating the brain will cause immediate incapacitation in most cases. But no one is stating that a .22 is preferred for defensive purposes."[1] Bullets that fail, break apart, don't go through bone, don't penetrate deep enough or get deflected off line, don't do what people expect or need. Also, all rounds can be fired accurately, that doesn't change the wounding ability of the projectile. Lastly, why aren't the people saying shot placement is the only thing, shooting 22s, and why are they using expanding bullets to make a bigger hole? Wound location is critically important, but does not change or affect wound dimensions or projectile effectiveness. The critical point is that the important body parts are deep, requiring penetration and they may be covered by bone or other intervening items which raises the importance of barrier performance. Hit what you are aiming at and then do more damage. Two separate events. This determinant is a factor of the shooter's accuracy and the projectile capability.

2. Amount of hits on target: Simply doubling the amount of hits on a target generally doubles the amount of damage depending on the wound placement. "A review of law enforcement shootings clearly suggests that regardless of the number of rounds fired in a shooting, most of the time only one or two solid torso hits on the adversary can be expected. The probability of multiple hits with a handgun is not high." "The handgun is the primary weapon for defense against unexpected attack. Given the idea that one or two torso hits can be reasonably expected in a handgun shooting incident, the ammunition used must maximize the likelihood of immediate incapacitation."[2] This determinant is simply the shooter taking multiple shots and achieving multiple hits.

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[1] Wound Ballistics Workshop: "9mm vs .45 Auto". FBI Academy, Quantico, VA, September, 1987. Conclusion of the workshop.

[2] US Department of Justice: "Handgun Wounding Factors and Effectiveness". FBI Firearms Training Unit (FTU), Quantico, VA, September, 1989.

3. Bullet capability: The wound ballistic profile of that exact ammunition is what is measured and documented in terminal wound ballistic testing. Test data must provide measurable results that answers questions in regards to how the projectile performs in relation to desired characteristics witnessed in real world shootings. Bullet capability is a quantifiable measurement of the performance of a single round in regards to the four terminal wound ballistics criteria.

1. Penetration Depth
2. Reliability and Consistency
3. Barrier Performance
4. Permanent Wound Cavity (PWC) size.

This is the most complex determinant and must occur in four steps. It starts with understanding wound ballistics, then determining what your requirements are for a bullet in regards to the above criteria, finding the data that is quantifiable and relevant to your expected target and finally, matching your requirements to the test data to find the best fit. "The critical wounding components for handgun ammunition are penetration and permanent cavity."[3] "The incidence of failure to incapacitate will vary with the severity of the wound inflicted. Severity is a function of location, depth and the amount of tissue destroyed."[4] In summation.... caliber is meaningless.... weight is meaningless, velocity is meaningless, same with momentum, energy, sectional density, ballistic coefficient and power factor. Those are all simply descriptions of what the bullet is and not what the bullet does. How the bullet functions in the real world is all that matters. Testing must use methods that show a correlation to real world forensic studies of projectile wounding, so that when we compare two or more rounds the characteristics in testing describe (not match) reality.

4. The Target Being Shot: The health and physical condition of the target is extremely important in determining the results of a shooting. Age, sex, size, health and outside influences such as drugs and alcohol greatly affect the targets capability to stay active or be incapacitated. This last determinant is completely out of the control of the shooter.

[3] Wound Ballistics Workshop: "9mm vs .45 Auto". FBI Academy, Quantico, VA, September, 1987. Conclusion of the workshop.

[4] US Department of Justice: "Handgun Wounding Factors and Effectiveness". FBI Firearms Training Unit (FTU), Quantico, VA, September, 1989.

MECHANICS OF PROJECTILE WOUNDING

"There are four components of projectile wounding."[5] From the FBI's Firearms Training Unit at Quantico: "The wounding factors, in order of importance, are as follows:"

1. Penetration: Required penetration depth is based solely on the target regardless of weapon or ammunition. "A projectile must penetrate deeply enough into the body to reach the large vital organs, namely heart, lungs, aorta, vena cava and to a lesser extent liver and spleen, in order to cause rapid blood loss. It has long been established by expert medical professionals, experienced in evaluating gunshot wounds, that this equates to a range of penetration of 12-18 inches, in tissue, depending on the size of the individual and the angle of the bullet path (e.g., through arms, shoulder, etc.)." "A penetration of 18 inches is preferable."[6] The 18 inch mark is considered "optimum", not maximum. The current Federal Standard for penetration depth is a 12 inch minimum and 15-21 inches desired in gel (see chapter "Test Purpose, Protocols, Media, Phases and Grading Criteria", The Federal Standard). "Choosing a bullet with relatively shallow penetration will seriously compromise weapon effectiveness. No one has lost their life because a bullet over penetrated his adversary and virtually none have ever been sued for hitting an innocent bystander through an adversary. On the other hand, tragically large numbers have been killed because their bullets did not penetrate deeply enough."[7] Other than long range capability, accuracy and armor penetration potential, rifle rounds are more effective than handgun rounds because they produce greater penetration, with the projectile reaching or going through important body parts. The US Army judged their 5.56x45mm M193 ammunition to be: A. under penetrator vs soft targets and B. poor vs heavy barriers and light armor. It was found in medical and forensic exams to not penetrate deeply enough to be effective under normal circumstances. In gel testing the M193 penetrated between 15-18 inches (17 inch average) and in a final comparison test of 7 shots all penetrated >17 inches in gel. It was replaced by the M855 which was deemed to have optimum penetration (more than the M193 and less than the 7.62x51mm NATO M80) and in gel testing exhibited an average of 22 inches and did not exceed 24 inches when functioning properly.

2. Permanent Cavity: "The destroyed tissue which is in direct contact with the projectile and any material coming off the bullet such as metal, bone fragments or other material projected away from the path of the bullet by the projectile itself."[8] "It is measured in cubic inches of volume and calculated by multiplying the depth (penetration) of the wound and the area (not diameter) of the

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[5] Josselson, A., MD, Armed Forces Institute of Pathology, Walter Reed Medical Center, Washington, D.C., lecture series to FBI

[6] US Department of Justice, "Handgun Wounding Factors and Effectiveness", FBI Firearms Training Unit, Quantico, VA, September, 1989

[7] Ibid US Department of Justice, "Handgun Wounding Factors and Effectiveness"

[8] FBI's Firearms Training Unit at Quantico

hole left by the passage of the bullet." This volume is extremely difficult to measure in the case of fragmenting rounds, Fluted-Fluid Transfer rounds which create holes larger than their caliber and tumbling bullets that have holes that vary greatly at different depths. Simply measuring recovered bullet diameter is worthless as fragmenting or turning of the projectile completely changes the actual hole size and fluid transfer or tumbling rounds create holes vastly larger than the bullet diameter. Actual measurement of the hole in the media is required. "Given adequate (and equal) penetration, a larger diameter bullet (wound area) will have an edge in wounding effectiveness. Any bullet which will not penetrate through vital organs from less-than-optimal angles is not acceptable. Of those that will penetrate, the edge is always with the bigger hole."[9]

3. Temporary Cavity: "The temporary cavity is caused by tissue being stretched away from the permanent cavity by a pressure wave."[10] If the temporary cavity is large enough, or produced rapidly enough in elastic tissue, the tensile strength of the tissue can be exceeded resulting in tearing of the tissue. This effect is seen with very high velocity projectiles such as in rifle caliber, but is not seen with handgun caliber. In general, "The heavier, slower bullet crushes more tissue but induces less temporary cavitation. Most of the wounding potential of the lighter, faster bullet is likely to be used up forming a larger temporary cavity, but this bullet leaves a smaller permanent cavity. The heavier, slower bullet causes a more severe wound in elastic tissue than the lighter, faster bullet, which uses up much of its potential producing tissue stretch (temporary cavitation). This tissue stretch may be absorbed with little or no ill effect by elastic tissue such as lung or muscle. In nonelastic tissue, such as liver or brain, the temporary cavity produced by the lighter, faster bullet can produce a more severe wound."[11] "For the temporary cavity of most handgun projectiles to have an effect on wounding, the velocity of the projectile needs to exceed roughly 2,000 fps."[12] Temporary cavity effects in human tissue looks like slightly mushy tissue with less resistance or rebound. During testing in animal tissue, that property was never seen until the projectiles exceeded 2,300 fps at impact. It might be present in small amounts slower than that, but not noticeable. "At the lower velocities of handgun rounds, the temporary cavity is not produced with sufficient velocity to have any wounding effect; therefore any difference in temporary cavity noted between handgun caliber is irrelevant."[13] High speed (>2,300 fps) rifle rounds were tested at some of our events and the animal tissue media was dissected and showed

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[9] US Department of Justice, "Handgun Wounding Factors and Effectiveness", FBI Firearms Training Unit, Quantico, VA, September, 1989

[10] Emergency Medicine Practice article. "Ballistic Injuries In The Emergency Department (Trauma CME)", 2022

[11] "Gunshot Wounds: 1.Bullets, Ballistics and Mechanism of Injury" Jeremy J Hollerman, Douglas Coldwell

[12] Emergency Medicine Practice article. "Ballistic Injuries In The Emergency Department (Trauma CME)", 2022

[13] FBI Firearms Training Unit, Quantico, VA,

tearing outside of the permanent wound cavity which was never present in any of the handgun rounds, further confirming that temporary stretch cavity has no effect on wounding a target with <2,000 fps projectiles. Also, recent testing has showed that the actual projectile velocity required for the temporary cavity to have a wounding effect from tearing human tissue is nearer to 2,200 fps.[14] The real velocity (2,000 or 2,200) does not matter and is probably variable due to tissue density differences. What is important is that pistol rounds all travelling significantly slower than these figures do not produce a temporary cavity that creates any wounding effects. Unfortunately, it is still used by non-experts during handgun ammunition assessment. When evaluating high speed rifle rounds the temporary cavity may have significant impact on a target and may increase the amount of damaged and destroyed tissue. (See chapter "The Human Target" for forensic results and combat evaluation of high velocity rifle projectile temporary cavities.)

Energy transfer is often quoted and is completely immaterial. First, the transfer of energy is represented by the temporary stretch cavity and as stated is insufficient in low-speed pistol rounds to cause wounding. The human body can absorb a great amount of energy without being damaged (a baseball hit in a game, or a hockey puck has approximately half the energy of a 9mm bullet being shot). Also, the human body is not one solid mass where energy is easily transferred throughout the body, as changes in tissue density and space between organs nullifies a vast amount of transfer of energy. The human body is compressible which absorbs energy and the pressure wave unlike ballistics gelatin, which is an uncompressible liquid. Finally, in bullets like hollow points, well over half the energy the bullet has at impact is used by the bullet to bend and reshape. The idea of "energy dump" into the target does not make sense. It takes energy for the hollow point to mushroom. That comes from the kinetic energy the projectile has at impact. That energy is staying in the bullet to cause the metal to bend, not being dumped into the target. Picture an automobile driving and having a certain amount of energy. Regardless of what it hits, the energy it has is fixed based on the weight and velocity of the vehicle. If the vehicle hits a shed and the impact slows the car to a stop and the shed is destroyed and the car has zero damage, then the shed absorbed all the energy. If the vehicle hits a brick wall and is demolished and the wall is unmoved and undamaged, then the vehicle absorbed all the energy. In both cases the shed and the wall contained no kinetic energy as both were fixed and not moving. When a hollow point hits a target, most of the energy is used to reshape the bullet, the rest is used to crush the tissue in front of the bullet and a very small portion creates an insignificant pressure wave that is seen as the temporary stretch cavity that does not destroy any tissue.

Energy vs Momentum: Comparing hollow points during our tests and the six other major federal handgun ballistics tests it was conclusively found that the heaviest hollow point bullets in each caliber average larger Permanent Wound Cavities (PWC) than lighter bullets in the same caliber. (See Ballistic Ratio in the chapter "Test Protocols." "Increased bullet mass will increase penetration."[15] "Increasing velocity does not increase expansion as almost all hollow points

[14] Johann Boden: Federal Ammunition, Technical Lead, Law Enforcement Division

[15] US Department of Justice, "Handgun Wounding Factors and Effectiveness", FBI Firearms Training Unit, Quantico, VA, September, 1989

regardless of velocity wrap back on themselves. In fact, increased velocity typically increases failure rate." In 6 of 7 tests the heaviest hollow point 9mm (147 grain) bullets averaged the largest PWC over any other weight 9mm. In 5 of 6 tests the heaviest .40 S&W bullets averaged the largest PWC over any other weight 40. In 7 of 7 tests the heaviest .45 ACP (230 grain) hollow point bullets averaged the largest PWC over any other weight 45 hollow point. In all cases the heavier bullets in any caliber have less energy than the lightweight bullets in that caliber that have the highest energy. Several companies make the exact same projectile in different weights within the same caliber. This allows us to be very specific and not just use averages in evaluating energy and momentum tradeoffs when the pressures are the same and weight is changed resulting in a change in velocity. Below is a table of four examples where the results show that when a heavier projectile of the exact same design is compared to the lighter / faster bullet, we see that the heavier projectile has a higher weight, higher momentum, deeper penetration and larger overall permanent wound cavity size, yet the velocity and energy are lower. This is for the following reasons: 1. There is not an equal tradeoff when you make a bullet lighter by a certain percentage you do not gain the same percentage of velocity, because with the lighter / faster bullet it exits the barrel faster (less barrel burn time) resulting in a smaller percentage increase in velocity. This results in a lower momentum of faster bullets vs heavier bullets at the same pressure. 2. The faster bullet has a huge increase in drag, as drag goes up at the square of velocity and this causes a decrease in penetration depth.

	ROUND	WEIGHT	VELOCITY	ENERGY	PENETRATION	VWI
9mm	Rem GS+P	124 grains	1180	383	13.0"	2.6"
9mm	Rem GS	124 grains	1125	349		
9mm	Rem GS	147 grains	990	320	17.0"	4.5"
9mm	Speer GD +P	124 grains	1150	364	14.8"	2.8"
9mm	Speer GD	147 grains	985	317	15.5"	5.1"
.40	Rem GS	165 grains	1150	485	15.3"	4.1"
.40	Rem GS	180 grains	1015	412	17.2"	6.7"
.40	Speer GD	165 grains	1050	404	14.3"	4.1"
.40	Speer GD	180 grains	1025	420	16.0"	6.7"

Notice in every example, the heavier version of the same projectile penetrates farther and has a larger permanent wound cavity (Volume of Wound Index). Of additional note, after making this chart we went back and looked at the reliability of each round and the heavier rounds in each and every example had a lower failure rate. As noted in the next paragraph, higher velocities in hollow points tend to increase fragmentation and asymmetric expansion resulting in turning. Specifics for each round, to include the failure rates, can be found in the round summaries and the data sheets. Lastly, the information listed in the table is matched by the data from the Federal Bureau of Investigation (first the "1989 Ammunitions Tests" and the second was "1990 FBI Ammunitions Tests"). The above discussion of weight and velocity vs wound cavity size is for hollow points only as their destructive mechanism is specific to them. Other bullet types will yield different weight vs velocity results. See chapter "Five Types of Handgun Projectiles." So, does that mean that momentum is more important? Well, the heaviest rounds do have more momentum, but in actuality what it proves is that **energy calculations have no bearing or indicators to bullet performance**. Otherwise, the fastest bullets in any particular weight / caliber would be the best and that simply is not the case. Energy and momentum calculations are simply mathematical formulas that have no bearing on projectile capability. "Kinetic energy does not wound. Temporary cavity does not wound. 'Knock down' power is a myth."[16] No emergency room surgeon ever said "I need to repair the energy dump that my patient experienced." Dr's only repair actual wounds from the permanent wound cavity. Furthermore, with a hollow point, the energy the projectile contains at impact is mostly used to deform the bullet and bend / tear the metal to form the mushroom shape. Only a small portion is transferred to the tissue and that energy is what tears the impacted tissue forming the permanent cavity. "Temporary cavity is frequently and grossly overrated as a wounding factor when analyzing pistol wounds."[17]

4. Fragmentation: Fragmentation can be defined as projectile pieces which are impelled outward and may sever muscle tissue, blood vessels, etc., and are part of the permanent cavity. "Fragmentation does not reliably occur in soft tissue handgun wounds due to the low velocities of handgun bullets. When fragmentation does occur, fragments are usually found within one centimeter (.39 inch) of the permanent cavity."[18] "For these reasons, wounding effects secondary to any handgun caliber bullet fragmentation are considered inconsequential."[19] "Frangible rounds eliminate any reasonable penetration. Such a bullet will break up too fast to penetrate to the vital organs."[20] Frangible rounds tend to create large wound diameters but shallow wound penetration.

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[16] Smith, O'Brien C., M.D., presentation to the Wound Ballistics Workshop, Quantico, VA,

[17] Lindsay, Douglas, MD: "The Idolatry of Velocity, or Lies, Damn Lies, and Ballistics", Journal of Trauma 20, 1980.

[18] DiMaio, V.J.M.: "Gunshot Wounds", Elsevier Science Publishing Company, NY, NY

[19] US Department of Justice, "Handgun Wounding Factors and Effectiveness", FBI Firearms Training Unit, Quantico, VA, September, 1989

[20] US Department of Justice, "Handgun Wounding Factors and Effectiveness", FBI Firearms Training Unit, Quantico, VA, September, 1989

Since most critical body parts reside deep inside of the thoracic cavity a superficial wound that does not encounter and destroy critical organs / blood vessels and Central Nervous System (CNS) tissue does little in the way of incapacitation. This is why penetration is the most important characteristic of projectile wounding. Quoting the FBI Firearms Training Unit: "Effective pistol rounds thus need to be able to penetrate a minimum of 12 inches into a human target to offer the best chance of striking a major artery or organ." "A penetration of 18 inches is preferable." Given that the FBI and DoD standards call for a minimum gel penetration of 12 inches with a goal of 15-21 inches, low penetrating fragmenting rounds do not qualify because of minimal penetration depths. Each fragment path must be included in the calculation of the Permanent Wound Cavity (PWC). The overall PWC is generally much less than a non-fragmenting round due to the smaller mass of each fragment and larger surface area after fragmentation resulting in greatly increased drag and reduced penetration depths.

The physics of fragmentation is generally misunderstood. In fact, the US Army originally believed it to be beneficial and requested their new ammunition to have frangible effects. That was the 5.56mm M193 round from 1964. It is a high speed 55 grain Full Metal Jacket (FMJ) that is designed to fragment upon impact. In the 1970s, after years of combat use, forensic research into its combat effectiveness showed that the fragmentation greatly limited the overall wounding ability due to decrease in penetration depth vs soft targets and the inability to go through heavy barriers.[21] [22] This necessitated the introduction of a more effective round, the M855. When a bullet or sphere breaks into two pieces, several fluid-dynamic effects are noticed. First, the inner surface that was not exposed to drag, is now part of the surface area. "Splitting a sphere in half and exposing the flat, split side to a fluid flow will generally lead to an increase in drag compared to the intact sphere. This phenomenon is primarily due to a significant increase in pressure drag, also known as form drag." [23] If a sphere has a diameter of .355 inches (9mm), its surface area would be .4 inches. If that sphere broke into two parts, each half would have a surface area of .3 inches. That's right, its not .2 for each because the inner area that was covered is now part of the surface area which is now exposed to form drag. Therefore, total drag on both pieces jumped up 50% from.4 to .6 inches. Also, if the bullet or sphere breaks again into 4 pieces that increase in drag goes up again exponentially. Given that fragmentation almost always, whether intentional or unintentional, breaks the projectile into three or more pieces, it is easy to see a huge increase in surface area drag. Second, the shape of each piece has a much higher coefficient of drag (C_d). "For example, studies have shown that a half-sphere with the open side exposed has a drag coefficient of 1.42, which is notable higher than the drag coefficient of a sphere, which can range from .4 to .5 depending on the Reynolds number."[24] That means that each piece not only has more

[21] US Army. "Gunshot Wounds: 1.Bullets, Ballistics and Mechanism of Injury"
Jeremy J Hollerman, Douglas Coldwell

[22] US Army Wound Data and Munitions Effectiveness Team (WDMET) study

[23] NASA: Glenn Research Center. "Drag of a Sphere."

[24] NASA: Glenn Research Center. "Drag of a Sphere."

surface area drag but the shape is around 3 times less aerodynamic. Third, the momentum of each piece decreases by an equal percentage to the number of pieces created. Penetration depth can be described as: Power Over Drag ratio (POD) (weight x muzzle velocity / area / 7000) in foot pounds. Each time the original shape breaks in two the weight is cut in half, the velocity stays the same and the area of each piece is only reduced by 25%, not 50% as seen above. As a result, the POD goes down, which limits penetration depth. This enormous increase in drag and decrease in momentum decreases penetration depth by a very large percentage. You would think that by having multiple holes the increase in surface area would increase the wound diameter, which it does, but there are now three additional issues. First, the increase in surface area wounding is not as large as the decrease in penetration depth, so the overall wound volume is less after fragmentation. Second, All the important body parts are deep, so low penetration means that even if the wound area is large, only less important tissue was destroyed. Third, many of the fragments follow the path of least resistance and stay in the channel of the main bullet piece, or other fragments and do not create their own wound channel. Remember, there is no force actually propelling the pieces away from the original path of the bullet into adjacent tissue, in fact the laws of physics say that after breaking apart the pieces will stay in a straight line until acted upon by an outside force and there is no outside force.

Fragmentation occurs either intentionally using frangible rounds or accidentally by the unintentional breaking apart of the bullet. Accidental fragmentation is most common with hollow point ammunition over any other bullet type. Two distinct characteristics increase accidental fragmentation with hollow points. First, velocity. Hollow point rounds travelling over 1,200 fps have an alarmingly high rate of accidental fragmentation. Between 1,100-1,200 fps the rate was abnormally high, but not as catastrophic as over 1,200 fps. Rounds below 1,100 fps had a relatively low fragmentation rate, until barriers were encountered. Second, thickness of the metal of the sidewall of the hollow point projectile. Smaller caliber rounds have less thick walls. This makes them less strong and increased the rate of fragmentation. At the same velocity the smaller the caliber of the hollow point the higher the accidental fragmentation rate across the board with no exceptions.

Fragmentation greatly reduces the penetration depth, barrier performance and overall permanent wound cavity size. Accidental fragmentation also reduces the reliability and consistency of the round. Lastly, in the cases where fragmentation occurs the pieces are generally very close to, or inside the permanent wound cavity track which limits additional wounding effects.

Projectiles incapacitate by destroying or seriously damaging Central Nervous System (CNS) tissue, causing organ failure or causing blood loss. All projectile wounds combine the above four components to a greater or lesser degree. "The critical wounding components for handgun ammunition are penetration and permanent cavity."[25]

[25] US Department of Justice, "Handgun Wounding Factors and Effectiveness", FBI Firearms Training Unit, Quantico, VA, September, 1989

THE HUMAN TARGET

There are four main kinds of human tissue.

1. Epithelial: Covers the body surface (skin) and forms the lining of most internal cavities and organs. "The skin is tough and flexible. Experiments have shown that it has the same resistance to bullet passage as approximately four inches of muscle tissue."[26] Normal testing using IWBA gel does not take into account this protective layer, which severely limits penetration ability.

2. Nervous: Thin nerve tissue which constitutes the smallest percentage of human tissue. The neural network of the Central Nervous System (CNS), including the brain, spine and neurons.

3. Connective: Tissue providing a variety of functions to include support and protection. Bone, cartilage and blood vessels are the most common types of connective tissue. Bone is an excellent protective barrier and is similar but stronger than the plywood that is used in two phases of testing as a consistent barrier IAW IWBA and FBI/DoD standards.

4. Muscular: Muscles and internal organs are the most common type of human tissue in the thoracic cavity which is the target area or center of mass. During phase 4 and phase 5 the testing media is animal tissue to as closely as possible, consistently replicate human muscular and organ tissue. "The tensile strength of muscle is from 1 to 4 MPa (145 to 580 lb.f/in2), and minimal damage will result if the pressure exerted is below this amount. IWBA gelatin and other less elastic media have much lower tensile strengths, exhibiting more damage after being struck with the same amount of force. Handgun bullets create temporary cavities with much less than 1 MPa of pressure, and are incapable of causing damage to elastic tissues that they do not directly contact."[27] The tensile strength of ordnance gelatin is approximately .8 to 1.0 MPa, vs 1.0-4.0 MPa for actual human tissue, so gel is close to simulating low density human tissue, but it is only 20% that of high-density muscular tissue and organs.

"The mechanism of formation of the injury includes the compression of tissue by the projectile impact and their disruption when these compressive forces exceed the elasticity of the tissue."[28] Objects pushed away from the wound track, to include projectile fragments, bone fragments and

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[26] Fackler, M.L., M.D., Director, Wound Ballistics Laboratory, letter: "Bullet Performance Misconceptions", International Defense Review 3, 1987

[27] National Library of Medicine, National Center for Biotechnology Information. "Experimental evaluation of fiber orientation based material properties of skeletal muscle in tension. "Kuthe CD, Uddanwadiker RV, Ramteke A. Mol Cell Biomech. 2014 Jun;11.

[28] National Library of Medicine, National Center for Biotechnology Information. "Gunshot Wounds Forensic Pathology." Shrestha R, Kanchan T, Krishan K. Updated 2023 Apr 17

the compressed destroyed tissue from impact, contact and can destroy adjacent tissue not directly impacted by the bullet.

There are three physical causes of incapacitation from Gun Shot Wounds (GSW).

1. Severing / destroying parts of the Central Nervous System (CNS). Sufficient damage to the brain and or spine will incapacitate a human.

2. Extreme damage to a vital organ required for immediate activity (heart, lungs and liver). Sufficient damage to these organs may cause immediate incapacitation. The larger the hole and the more the damage the greater the chance of elimination of body activity. "Structures that are less dense and have elasticity may sustain less damage than structures with greater density and more rigidity. For example, lung tissue has low density with high elasticity and tends to be less damaged than muscle with higher density and some elasticity. The liver, spleen, brain and adipose tissue have little elasticity and are easily injured. Organs that are fluid-filled, such as the bladder, heart, great vessels and bowel, may rupture due to the pressure waves from extremely high velocity projectiles (>2,000 feet per second)[29] even without direct contact by the missile."[30] "Temporary cavitation can also cause the tearing of tissues if a very large amount of force is involved. That force must exceed the tensile strength of muscle and organ fibers, which ranges from 1 to 4 MPa (145 to 580 lb.f/in2)." "Minimal damage will result if the pressure exerted by the temporary cavitation is below this." "At typical handgun velocities (<2,000 fps), bullets will create temporary cavities with much less than 1 MPa of pressure, and are incapable of causing damage to elastic tissues that they do not directly contact."[31] Test gel blocks have much lower tensile strengths (<1 MPa) and exhibit more damage after being struck with the same amount of force than human or animal tissue. Not only is the pressure wave to slow to damage tissue, the pressure wave that causes the temporary cavity in gel does not flow through a human target as it does in gel. Visceral fat and air space between muscle and organs absorb the disturbance.

3. Large amount of blood loss or a large enough drop in blood pressure which is required for muscular and systems function. The human body has a positive internal pressure and external holes depressurize the system and allow for more blood loss than only internal holes. Large loss

[29] Emergency Medicine Practice article. "Ballistic Injuries In The Emergency Department (Trauma CME)", 2022

[30] EMSworld, article "Shootings-What Emergency Medical Service Providers Need To Know". hmpgloballearningnetwork.com, 2010

[31] National Library of Medicine, National Center for Biotechnology Information. "Experimental evaluation of fiber orientation based material properties of skeletal muscle in tension". Kuthe CD, Uddanwadiker RV, Ramteke A. Mol Cell Biomech. 2014 Jun;11.

of blood or excessively low blood pressure will shut down voluntary control.[32] Gun Shot Wounds (GSW) require immediate sterile compression to attempt to stop the bleeding and cause blood clotting. "Open wounds greatly increase the chance of death from blood loss. Multiple openings must all be treated as each will have a significant impact on the survival of the patient." No matter where the wound is, applying steady and firm compression directly over it is the only effective way to slow the blood flow." [33] The larger the intrusion, the greater the blood loss. "Circulatory collapse results from massive bleeding caused by bullet wounds primarily to the heart, other major organs or major blood vessels of the torso. Circulatory collapse will result in significant deprivation of oxygen to the brain. This can take several seconds to several minutes or even longer. There is sufficient oxygen in the brain to support voluntary, life-threatening actions against an officer for 10 to 15 seconds after the heart has been destroyed."[34]

"Incapacitation results from central nervous system (brain or spinal cord) disruption, massive organ destruction and hemorrhage (critical loss of blood and blood pressure)."[35]

Tensile Strength of Human Tissue, Bone and Skin:
"The tensile strength of muscle tissue is significantly lower than that of bone. For example, the ultimate tensile strength of the temporal muscle fascia (a type of connective tissue encompassing muscle) is 3.6 ± 1.7 MPa."[36] This is slightly different than the 2.5 ± 1.5 MPa as tested by the above-mentioned source.
"Bone tensile strength along the length: Bone, particularly cortical (compact) bone, exhibits higher tensile strength along its long axis. For example, the human femur's tensile strength along its length is around 135 MPa.
Bone tensile strength across the width (projectile impact direction):
The tensile strength of cortical bone (such as the rib, sternum or femur) in the transverse direction (across the width) is considerably lower than along the length. The femur's compressive strength along the short axis is (86 MPa) roughly 36% less than along the long axis."[37] Since the testing method from each source may be different and since the strength of tissue is variable from one

[32] Rhee, PM; Moore, EE; Joseph, B; Tang, A; Pandit, V; Vercruysse, G. "Gunshot wounds: A review of ballistics, bullets, weapons, and myths". The Journal of Trauma and Acute Care Surgery, 2016

[33] How to Treat a Gunshot Wound. Jeffrey Luk, MD, is the director of prehospital and disaster medicine at University Hospitals Cleveland Medical Center and an assistant professor of emergency medicine at Case Western University School of Medicine in Ohio. Medically Reviewed by Jennifer Payne, MD. Reviewed: July 7, 2022

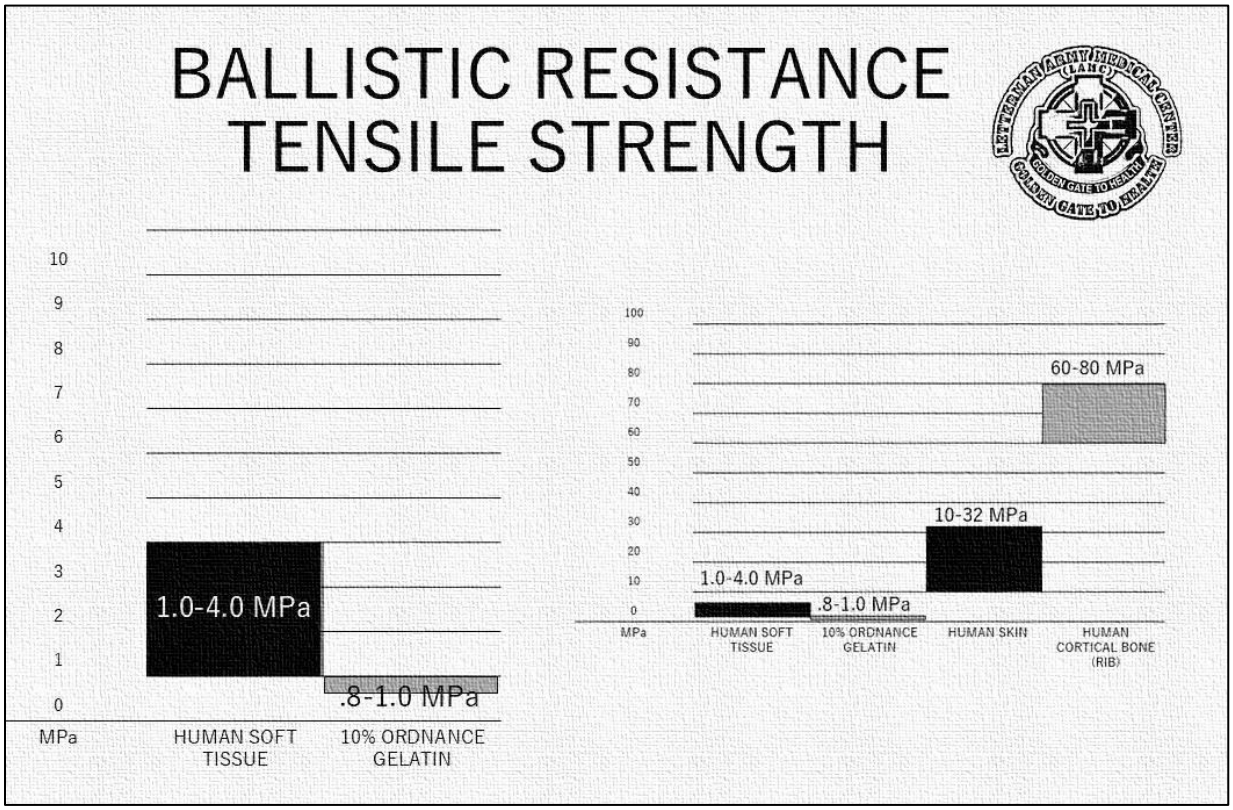
[34] Police-1. "Why bullet size matters in officer-involved shootings". Mike Calahan, 2017

[35] National Library of Medicine: "Ballistics reviews: mechanisms of bullet wound trauma", 2009

[36] Open Oregon "Body Physics: Motion to Metabolism"

[37] Open Oregon "Body Physics: Motion to Metabolism" Chpt 51 Ultimate strength of the human femur.

person and one body part to another, we see variances. From another source we have: "Bone Longitudinal Tensile Strength: Approximately 130-135 MPa. Bone Transverse Tensile Strength: Approximately 50-53 MPa"[38] "The tensile strength of human skin, typically ranges from 10 to 32 MPa (megapascals). The mean ultimate tensile strength (UTS) was 27.2±9.3MPa."[39] Below is yet another source comparing the tensile strength of different human tissues (similar quantities to the above sources and 10% ordnance gelatin.



(U) Comparison of Tensile Strength. Tissue vs Ordnance Gelatin. [40]

"It would require an extremely thick layer of muscle (like 10 inches thick) to stop a 9mm full metal jacket handgun bullet."[41] Given that the average FMJ 9mm projectile penetrates around 30 inches

[38] "Bone Anisotopy" University of Wisconsin. Elastic anisotropy of bone. Tissue Biomechanics Advanced Mechanical Testing Symposium.

[39] Research Council on Biomechanics of Injury, (RCOBI) Conference 2012 "Dynamic Tensile Properties of Human Skin" IRC-12-59. A.J. Gallagher, , A. Ní Anniadh, , K. Bruyere, , M. Otténio, , H. Xie, , M.D. Gilchrist

[40] Wound Ballistics Laboratory. Handout briefing. Circa 1990.

[41] National Institute of Health. "Ballistic Trama of Limbs" Leopold Lama

in ordnance gelatin, we see the contrast between testing media and real-world post gunshot wound forensics.

What happens to the tissue impacted by the projectile?

1. The tissue impacted by the bullet is destroyed and stops functioning. The more the material and the more important the material is, the more incapacitated the target is. The tissue is composed mostly of liquid created by the impact physically breaking the cell membrane, and is also composed of some non-liquid material.

2. With a hollow point the impacted material is trapped inside and in front of the concave bullet. The high viscosity and fibrous nature of human tissue and the compression of the non-liquid material pushes against the bullet with ever increasing drag, continuing to reshape and slow the bullet. In test gelatin the liquid nature of the media may flow around and to the side, but in an actual target the elastic, connected nature of the tissue stacks in front of the bullet highly limiting penetration depth. This is why we see such a huge disparity between penetration depths in gel testing and human forensics with hollow points.

3. With an FMJ the tissue is pushed to the side with no focus at <10% the velocity of the bullet at that depth. It travels outward and pushes against adjacent material causing a slight non noticeable compression on the solid tissue. The material does not stack in front of the projectile and therefore does not limit deep penetration.

4. Tumbling rounds, like the 5.56, 5.7 and 4.6mm exhibit the exact same effect as the FMJ, where the impacted material simply moves out of the way with insufficient force (amount, velocity and focus) to damage adjacent tissue.

5. Fluted-Fluid Transfer rounds use the material impacted by the projectile. It is forced into and down a channel or flute, where the shape causes a constriction which increases the velocity and focuses the material into a jet of high velocity liquefied tissue. This then impacts adjacent material as a physical particle (not a pressure wave) and causes increased permanent wound cavity diameter. The impacted tissue is used profitably as a destructive element instead of either being wasted or it impeding progress.

"The tissue disruption caused by a handgun bullet is limited to two mechanisms. The first, or crush mechanism is the permanent hole the bullet makes after passing through the tissue to include fragments or other material. The second, or stretch mechanism is the temporary cavity formed by the tissues being pushed outward by a pressure wave. The crush mechanism, the result of penetration and permanent cavity, is the only handgun wounding mechanism which damages tissue. Temporary cavity from a handgun has no reliable wounding effects in elastic body tissue and is nothing more than a stretch of the tissues."[42] "Temporary cavity effects in human tissue looks like slightly mushy tissue with less resistance or rebound caused by minor tearing of the

[42] Wound Ballistic Workshop: "9mm vs. .45 Auto", FBI Academy, Quantico, VA, September, 1987. Conclusion of the Workshop.

tissue fibers. It is not recommended by trauma surgeons to remove the spongey material, as it is not destroyed. Blood vessels are usually simply pushed aside and are almost never disrupted by temporary cavitation."[43] The temporary stretch cavity is caused by a pressure wave interacting with muscle and organ tissue. It is not caused by material propelled away from the permanent cavity such as bullet fragments, bone or liquid tissue cast-off. Those materials create a permanent cavity of their own by physically contacting adjacent material which adds to the overall permanent wound cavity caused by the path of the bullet.

"A systematic review of 1,400 rifle wounds sustained in the Vietnamese War and analyzed in the Wound Data and Munitions Effectiveness Team (WDMET) study of: M16 5.56x45mm, muzzle velocity 2,800 fps and AK-47 7.62x39mm, muzzle velocity 2,350 fps: Military rifle bullets have clearly disproved the assertion that all tissue exposed to temporary cavitation is destroyed."[44] Further studies also show that the 14-cm-diameter temporary cavity produced by the AK-74 (5.45x39mm, muzzle velocity 2,900 fps) assault rifle does not destroy a great amount of muscle."[45] The temporary effect only produces a wound above >2,200 fps, so a round which impacts at 3,300 only produces a wounding temporary cavity for 1/3 its penetration distance till the projectile slows below 2,200 fps, then the shock wave only produces minor stretching.

Stretching distance: The average human male is 10" thick. Most human tissue can be stretched as much as 6 times its normal size before overexpansion and tearing occurs. The distance created by the temporary cavity does not exceed the capability of muscular tissue to stretch without tearing.

Stretching velocity: Medical and military studies have shown that human tissue can expand extremely rapidly. A projectile velocity greater than roughly 2,000-2,200 fps may cause the pressure wave to have an outward force velocity exceeding the maximum rate of expansion for most human tissue which in turn causes a tearing wound in muscular or organ tissue. "Most tissue in the human target is 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 tissue in which the temporary cavity forms is no more than one tenth of the velocity of the projectile (unless accelerated). This is well within the elastic limits of tissue."[46] To quote the FBI Firearms Training Unit: "Unlike rifle rounds, there is no temporary wound created by pistol bullets."

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[43] International Wound Ballistics Association (IWBA) "Wound Ballistics Review" vol 5 #2. Multiple authors.

[44] US Army. "Gunshot Wounds: 1.Bullets, Ballistics and Mechanism of Injury" Jeremy J Hollerman, Douglas Coldwell

[45] Ibid: US Army. "Gunshot Wounds: 1.Bullets, Ballistics and Mechanism of Injury"

[46] Fackler, M.L.M.D., Director, Wound Ballistics Laboratory, "Ballistic Injury", Annals of Emergency Medicine 15: 12 December 1986

Hydrostatic shock: A controversial theory that a projectile can produce a pressure wave that causes "remote neural tissue damage" and "rapid incapacitating effects" in living targets.[47] [48] [49] Whereas the temporary stretch cavity is a pressure wave interacting with muscle or organ tissue, hydrostatic shock is that same pressure wave interacting with neural tissue which has completely different density and elasticity.[50] Proposed in 1942 it quickly gained popularity with circumstantial evidence. Later it was debunked by many scientific and medical professionals.[51] [52] Recently it has resurfaced with the increased amount of Traumatic Brain Injuries (TBI) from wartime explosions caused by pressure waves and physical evidence of remote neuron damage caused by high velocity projectiles.[53] The medical research supporting hydrostatic shock has shown that very high velocity projectiles do create a pressure wave fast enough to interact and damage the neural network, but that the amount of damage is unpredictable and difficult to quantify. Their medical results show that with a penetrating projectiles velocity above 2,600-2,800 fps and possibly as low as 2,200fps (different from different sources) the damage to neurons has been witnessed. It is still a highly debatable topic. What we do know is this:

1. Penetrating projectiles do create a shock (pressure) wave.

2. The shock wave does travel throughout the body far in excess to the distance of both the permanent wound cavity and the temporary stretch cavity.

3. The shock wave does interact with nerve tissue. It is unknown whether this causes wounding or incapacitation, but circumstantial evidence supports the claim that it does.

4. The amount of possible wounding is unpredictable and unreliable to calculate, so judging one projectile or another using hydrostatic shock as the determinant is invalid.

5. All sources agree that high velocity is required. Most quote a minimum velocity of between 2,600-2,800 fps although one source says it might be possible to have minimal effects as low as 2,200 fps. The only handgun rounds at this velocity are 5.7mm (see sections three and four).

6. The pressure (shock) waves from wartime explosions causing Traumatic Brain Injuries (TBI) are much more powerful than those caused by firearms projectiles. The highest velocity rifle

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[47] "Scientific Evidence for Hydrostatic Shock". Michael Courtney; Amy Courtney, 2008

[48] Deadly fighting skills of the world, Steve Crawford (1999) pp. 68–69

[49] AK-47: the weapon that changed the face of the war, Larry Kahaner, John Wiley (2007)

[50] Firearms Legal Protection. article, "Hydrostatic Shock: Real Or Myth?" Tom Gulley, 2022

[51] Maneater. article, "IS HYDROSTATIC SHOCK REAL?" Jordan Sillars, 2021

[52] Neurosurgery, article, Dr Marvin Fackler and numerous authors. 2007

[53] Terminal Ballistics Research, article, "Effective Game Killing", 2011

ammunition has velocities around 4,000 fps and creates pressure waves that never exceeds 450 fps. Pressure waves caused by explosions are 4,600-5,400 fps for fuel air explosives and thermobaric weapons, 5,600-9,900 fps for hydrogen, propane, methane, butane and natural gas. Solid explosives like TNT, RDX (H6), ANFO and Tritonal create pressure waves of 13,000-34,000 fps. Therefore, proving pressure waves can cause neurological injuries does not necessarily mean that those injuries could be sustained by a firearms projectile that has at most 10% of the pressure.

7. Discussion of hydrostatic shock in low velocity pistol rounds is unjustified and has no basis in science even among those medical professionals who believe in the controversial theory

The critical element is penetration. "Given desirable and reliable penetration, the only way to increase bullet effectiveness is to increase the severity of the wound by increasing the size of the hole made by the bullet."[54] "Except for penetration into the brain cavity or spinal cord, reliable and consistent immediate incapacitation of the human target by projectile wounding to the torso is extremely unreliable."[55] "Even shots to the heart are not immediate as stored oxygen may allow for voluntary action for 10-15 seconds after functional heart destruction."[56] "Failure of the Central Nervous System (CNS) and / or massive blood loss sufficient to drop blood pressure, cause organ failure or deprive the brain of oxygen is the only way to cause reliable incapacitation."[57] Important tissue destruction equals stopping power. Common "One Shot Stop" and "Knock Down Power" are both myths perpetuated by the uninformed. "The impact of the bullet upon the body is no more than the recoil of the weapon."[58] "A ten-pound weight equals the impact of a 9mm bullet when dropped from a height of .72 inches (velocity attained is 1.96 fps)."[59] Mathematical calculations without shooting are not tests and have no bearing on reality. True bullet performance must be tested and measured in a consistent media. Realistic animal tissue media yields better analysis to real world shootings.

"The incidence of failure to incapacitate will vary with the severity of the wound inflicted. Severity is a function of location, depth and the amount of tissue destroyed."[60]

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[54] Smith, O'Brien C., M.D., presentation to the Wound Ballistics Workshop, Quantico, VA.

[55] Wound Ballistics Laboratory, Letterman Army Institute of Research, letter: "Bullet Performance Misconceptions", International Defense Review 3. Fackler, M.L., M.D., Director

[56] Wound Ballistic Workshop: "9mm vs. .45 Auto", FBI Academy, Quantico, VA

[57] US Department of Justice, "Handgun Wounding Factors and Effectiveness", FBI Firearms Training Unit, Quantico, VA, September, 1989

[58] Ibid US Department of Justice, "Handgun Wounding Factors and Effectiveness"

[59] Ibid US Department of Justice, "Handgun Wounding Factors and Effectiveness"

[60] Josselson, A., MD, Armed Forces Institute of Pathology, Walter Reed Medical Center, Washington, D.C., lecture series to FBI

TEST PURPOSE, PROTOCOLS, MEDIA, PHASES AND GRADING CRITERIA

PURPOSE:

Terminal Wound Ballistics testing is conducted to compare handgun ammunition. Wound Ballistics is the measurement of the effect of projectile and tissue interaction. It is not calculations of ballistic coefficient, sectional density, power rating, momentum, energy or other mathematical ratios. It is the actual biological problem occurring from an object traveling through tissue. Raw data for each of the four grading criteria is averaged and may be used independently depending on the standards of each receiving agency.

All five bullet types and eight calibers will be included.

It will be conducted in six separate phases, two of which exactly match the FBIs testing.

It will be graded using four standardized criteria.

No conclusions, rank ordering or selections shall be made.

PROTOCOLS:

We conduct our own tests and accomplish testing with multiple agencies and departments. All phases and tests are conducted with at least one chief tester and one assistant for quality control and multiple measurements. For each round, no averages are calculated or reported until at least four rounds are fired in each of the first five phases (minimum sample size of 20). All failures to function on target are included in the data with no "flyers" or failures being removed allowing us to measure reliability and consistency. Testing takes place at multiple facilities. If our test team members are present and verify the authenticity of the media, ammunition, weapons and raw data then it is included in our overall test data spreadsheets. If any of the above is not validated then that particular test is used only as a control and verification of previous results, but the raw data is not included in the test data sheets. This takes place when individual agencies conduct tests or demonstrations to compare their chosen rounds and to validate our tests. If our test team members are present and verify their test then that data is included, otherwise the data is only used by the testing agencies. Testing has taken place with the same protocols, media, phases and grading criteria since 2016 and has formed a database. Testing continues to add more rounds and to increase the sample size of previous tested rounds. This continued testing creates changes to data as the sample size grows. We include a Current As Of (CAO) date to each report or presentation. Any old data is valid but simply not up to date with increased sample size. Please contact us for updated information.

PREVIOUS TESTS:

There have been several large scale reliable wound ballistics tests we recommend as reference from the Federal Bureau of Investigation (FBI), the Wound Ballistics Laboratory, the Department of Defense, the North Atlantic Treaty Organization (NATO) and the Federal Firearms Institute. Ours is the first large scale multi-agency test to accomplish two items.

1. The testing of all five different projectile types used in handgun defensive ammunition instead of only testing Hollow Points and Full Metal Jacket (FMJ) rounds.

2. The use in two of the phases of actual animal tissue. This tissue was chosen after consultation with the Department of Defense, to mimic their testing, forensic pathologists, internal medicine doctors and finally butchers. The media chosen was found to be the closest tissue to actual human tissue that was readily available and consistent in size and density.

Prior to our large-scale testing which started in 2016, analysis of the previous major tests was done. Several of the tests seemed to produce very similar results to other tests while two did not. During further analysis of the data, we found that there were specific consistent ratios between all the tests, with most of the differences being due to the media. We produced a report and Power Point presentation with these findings which was made available to many government agencies. A term Ballistic Ratio was coined which described wound ballistics test comparisons in an all-new way.

BALLISTIC RATIO:

Ballistic Ratio (BR) is a mathematical calculation used to compare results from different tests. The tests compared only featured hollow points, as such Ballistic Ratio is only applied to hollow points. BR is calculated separately for each test. All rounds in a test have a Permanent Wound Cavity (PWC) calculated in cubic inch volume. Unfortunately, since the actual media could not be measured after the fact, the recovered bullet diameter was used, which as discussed earlier is inaccurate. Therefore, BR is of limited utility. All 9mm hollow points are analyzed to determine the largest PWC average by weight (147 grain, 124 grain, and 115 grain). In 6 of the 7 tests the average 147 grain had the largest PWC compared to the other 9mm weights. Therefore, the average PWC of the best grain of the 9mm in each test is used as the Ballistic Standard. All Ballistic Ratios are calculated as a ratio of PWC in comparison to the 9mm Ballistic Standard in each test. The largest average PWC 9mm by grain has a BR of 1.0 and is the Ballistic Standard for all comparison of data in that test.

Raw data comparisons from different tests between rounds or calibers cannot be used due to differences in media. Not all tests used the same percentage gel. A Ballistic Ratio must be calculated for each test then BRs can be compared between tests.

Example:

Average all the PWCs for each 9mm grains separately (115, 124, 147 grain)

All 115 grain 9mm are tested and have an average PWC of 2.8 cu inches (example)

All 124 grain 9mm are tested and have an average PWC of 2.9 cu inches (example)

All 147 grain 9mm are tested and have an average PWC of 3.0 cu inches (example)

The largest average PWC of those three grains becomes the Ballistic Standard which all rounds are compared to (3.0 in this example) in this one test.

In this example the 147 grain 9mm with an average PWC of 3.0 cu inches is the Ballistic Standard and has a Ballistic Ratio of 1.0. If a round tested had a PWC of 4.5 ci than its BR would be 1.5 (4.5 ÷ 3.0). That would signify that exact round as having 1.5 times the PWC of the Ballistic Standard 9mm in that test. Now any two rounds BR can be compared from any test.

Seven large scale tests from US Federal Government agencies and independent organizations have been analyzed to produce this concept. Each of the seven tests, compared terminal ballistics for pistol hollow points. Permanent Wound Cavities were calculated for every shot in each test. Each test calculated separately PWC and BR.

SEVEN PRIOR FEDERAL HOLLOW POINT TEST RESULT OBSERVATIONS:

The following results are a composite from the multiple tests and reports from the Federal Bureau of Investigation (first the "1989 Ammunitions Tests" and the second was "1990 FBI Ammunitions Tests"), Federal Firearms Institutes, the Army Research Laboratory (ARL), Wound Ballistics Laboratory and third-party testing for federal agencies.

All caliber Ballistic Ratios were fairly consistent across all 7 tests. All overall calculated Permanent Wound Cavity (PWC) volumes were within 5%.

The average 147 grain 9mm won 6 of 7 competitions for largest 9mm PWC size.

The average 230 grain 45ACP won all 7 competitions for largest PWC in 45ACP.

The 45ACP won all 7 competitions for largest average PWC between all calibers in all of the referenced tests.

As stated earlier only the 9mm and .45 ACP were in all 7 tests. The Ballistic ratios shown below are the average for that caliber regardless of how many tests that caliber was included in.

CALIBER OF HOLLOW POINT	7 TEST BALLISTIC RATIO (BR) AVERAGE
.45 ACP	1.5
10mm	1.3
.40 S&W	1.22
.357 Sig	1.1
9mm	1.0
.357 Mag	.98
.38 Special	.79
.380	.48

NOTE: In three of the seven tests, rounds which failed on target due to failure to expand and accidental fragmentation were included. The 10mm, .357 Sig and .357 Magnum had an extremely high failure rate due to accidental fragmentation from excessive velocity. This was also verified in our testing. That is why the BR for those calibers is so low. In the other four tests failures on target were thrown out and those calibers results showed artificially better. If a test you are referencing shows better than the above composite results from these seven federal tests, question whether the failures were included.

Our ballistics gel test results were only compared to the above-mentioned tests that used the same IWBA gel, and the results were all very consistent, within 5%-10% for each round in each test. Our Ballistic Ratios were compared to all the above tests and again the results were extremely close. Our duplicated results validated the other tests which in turn validated our testing process. Since our Phase 2 and Phase 3 are exact duplicates of FBI test events, the results are extremely similar as can be seen by doing a direct comparison between results from the same projectiles tested by both parties.

RESULTS / REPORTS / DATASHEETS:

All our testing raw data is added to the database and reflected on our data spreadsheets with short narratives for many rounds that contains reliability, consistency and heavy barrier information and a synopsis of all six phases. Separate data sheets contain information from phase 6 armor testing.

Please note data in Phase 2/3 is:

1. Penetration in inches.
2. Diameter of the wound, as is industry standard.
3. Permanent Wound Cavity (PWC), which is Penetration x Area (NOT DIAMETER)

Please note data in Phase 4/5 is:

1. Average hole AREA (NOT DIAMETER). Do not confuse the diameter listed in Phase 2/3 data with area listed in Phase 4/5 data.

Please see the next chapter for an entire description of Volume of Wound Index (VWI).

The last column is marked LDBD%. This is Light Domestic Barrier Degradation Percentage. Phases 3 and 5 add a light domestic barrier in front of the media. The overall average percentage of degradation from that barrier is calculated and displayed in this column. A low number indicates that particular round was less affected by passing through a light domestic barrier prior to the target media of gel or tissue. A larger number indicates the barrier degraded the round more and the ability of the round to function after the barrier was more diminished.

No conclusions, rank ordering or choosing will be accomplished. All data is graded using the aforementioned four grading criteria that is detailed below in this chapter. Each agency may use the data as they see fit and can calculate any other grades they wish. Any agency desiring help with their ballistics testing, wishing to recreate any of our tests, or wanting information on our rig for tissue testing please make your request and we will help the best we can.

MEDIA USED IN TESTING:

1. IWBA calibrated FBI 10% ordnance gelatin. Temperature and BB depth calibration (by firing a 0.177" steel BB into the gelatin at a velocity of 590 +/- 15 feet per second, and checking for a penetration depth between 2.95–3.74 inches) are measured immediately prior to shooting. Two 16x6x6 inch gel blocks are typically used allowing penetration depth measurements up to 32 inches. Phase 2 and 3

We only use IWBA calibrated gel (FBI/DoD standard), not clear ballistics gel. There is an enormous difference in the consistency and the results between these two gel types.[61]

2. Denim (16 oz) barrier consisting of four layers of standardized material. Phase 2-5

3. Light Domestic Barrier: Single ¾ inch thick AA fir plywood panel IAW FBI / DoD protocols. Phase 3 and 5. The amount of degradation to each round caused by the addition of this barrier is reflected both by analyzing the differences between phase 2 and phase 3 for gel and phase 4 and phase 5 with tissue and also as an average degradation in the last column of the data sheet, marked Light Domestic Barrier Degradation Percentage (LDBD%)

4. Animal Tissue consisting of 2 boneless hanging briskets. Phase 4 and 5 7-8" thick. (Average human male is 10" thick). Total weight 36±2 pounds. Fat side forward, hanging back-to-back. Point side up on one and down on the other to provide equal thickness. The exit wounds from each of the two briskets are measured for min and max diameter. Those four measurements are averaged and then converted to a hole area.

Animal Tissue consisting of two boneless cow briskets was chosen after discussions with other military units that test in animal tissue, a forensic pathologist, other MD's and a butcher. Our tissue tests are similar, but not exact duplicates of the tissue testing accomplished by the DoD. There are four main types of human tissue: muscle/organ, epithelial, connective and nervous. Cow brisket closely represents human muscle tissue and organs. It is a compressible, realistic, consistent media. Results accurately compare to post shooting medical forensic reports which we have access to.

5. Heavy Barriers: Auto glass (both laminated and tempered), solid wood and metal. Phase 6.

6. Armor products: We accomplish testing with armor products including HG2 (formerly Level 3A pistol soft and hard plate), RF1, RF2 and RF3 (formerly Level 3 ICW, Level 3, Level 3+, Level 4) and armored wall board (Level 7) from multiple companies listed on the armor data sheet. All shots IAW FBI/DoD protocols using the NIJ .07 standards listed on the Armor Test Data Sheet page. Phase 6.

[61] Police1. "Ballistic gelatin comparisons: Part I" November 2019

TWO DIFFERENT MEDIA:

International Wound Ballistics Association (IWBA) Calibrated FBI 10% ordnance gelatin has several good and some bad properties.

Ballistics gelatin started being accepted in terminal wound ballistics in the 1970's. There was no standardized recipe used in the different tests leading to very different results and interpretations. "In National Institute of Justice testing, bullets were evaluated and scored on their ability to penetrate between 1.6 and 8.7 inches in the test media (20% gelatin), while US Secret Service testing focused on the 1–5.9 inch range (20% gelatin), US Navy testing focused on the 7–12 inch range (20% gelatin), and US Immigration and Naturalization Service testing favored performance in the 9–12 inch range (10% gelatin). Based on this factor alone, it is easy to see how a bullet that scored highly in one test could fail the test conducted by another agency."[62] The Wound Ballistics Laboratory for the Letterman Army Institute of Research Center standardized the recipe for the gel used by the FBI. The FBI introduced its own standardized testing protocols in December 1988 which quickly became commonly used among US law enforcement agencies. The IWBA used the FBI recipe and calibration techniques as their standard, and now that is the accepted industry standard. The density was designed to replicate soft body tissue, not dense tissue (four times the density and resistance when compared to soft body tissue) and not skin. "Our FBI tests were *absolutely not simulating a human*. We only use gel as a comparative test media and it works great, but ballistic gel doesn't simulate a human body."[63] "To make a good test you have to have: A. a huge sample size to create a real understanding of the round's ability. Other tests throw out failed shots…that doesn't work. You have to include everything so you can determine the failure rate. B. everything must be measurable… a number that can be put on a spreadsheet, otherwise you either have to see it (observational data) or you have an opinion in discussing it…numbers don't have opinions. C. you have to find a media to be used in addition to gel that can more closely replicate human tissue, since gel doesn't do that." [64] Clear ballistics gel is not used during our testing. First, a sample-based calibration guarantee from the manufacturer is given, but FBI protocols require every gel block to pass calibration prior to testing. Second, deviations using IWBA gel hover around 5% and are always less than 10%. Tests have shown that even with calibrated synthetic clear gel, penetration depth increases of >30% are common.[65] Given that penetration is judged as the most important wound characteristic and that handgun ammunition is a notorious under-penetrator this is disastrous. During demonstrations, our clients may use the clear gel because the synthetic product is more easily seen and photographed from outside the block. No data from any demos using the synthetic clear gel is ever added to our database or into

[62] Police1. "Ballistic gelatin comparisons: Part I" November 2019

[63] FBI Firearms Training Unit. Telephone interviews and conference calls with DoD ballistics testers. 2015

[64] FBI Firearms Training Unit. Telephone interviews and conference calls with DoD ballistics testers. 2015

[65] Police1. "Ballistic gelatin comparisons: Part II/III" November 2019

our spreadsheets. Using penetration data from tests incorporating synthetic clear gel is unprofessional and absolutely leads to poor analysis and ammunition decisions.

IWBA gel benefits: "The FBI protocol has been widely accepted by both the law enforcement and manufacturing communities and has given them a standard to work from. The FBI protocol has established a common language, a standardized testing process and standardized benchmarks for performance that have allowed a variety of different agencies, companies and individuals to conduct their own testing and contribute data that is directly comparable to the data derived from other tests and sources."[66] It is consistent, yielding similar results from shot to shot with the same projectile. When inconsistencies exist, it is an indicator of poor bullet design or unreliability. Gel shows what happens as the projectile goes through the media by being clear enough to witness the effects, and are retained post-shot for measuring. Its density and drag does mimic some low-density tissue types so the penetration depth results may be similar to reality, although normally much deeper in gel. Using gel to compare permanent wound cavities works as long as you are comparing only rounds of the same bullet type. It is one of the only media that has all these great factors.

IWBA gel problems: IWBA gel is a non-compressible liquid unlike human or animal tissue which is compressible. Compressibility causes absorption and dissipation that limits the distance the force can travel, and thus the overall size of the wound and the damage inflicted. As the force of the temporary cavity shock wave radiates outward away from the wound track the circumference of the effected tissue increases. The force is spread out over a larger area and the force per square inch is reduced. This is dissipation caused by expansion. Absorption is caused by compression of each cell of tissue stretching and minimizing the effect. Liquids, like ballistic gel are non-compressible and cannot absorb, but can only dissipate. Absorption reduces force by a far greater amount than dissipation. This makes gel a poor tissue simulant as hydraulic effects are completely different than in human or animal tissue. Therefore, the permanent cavity in gel does not replicate or represent human tissue so using it alone does not simulate a real target. Also, in gel the liquid nature of the media may flow around and to the side of the projectile, whereas in actual tissue the elastic, connected nature of the material stacks in front of the bullet increasing drag and highly limiting penetration depth. As such we see such a huge discrepancy between penetration depths in gel testing and human forensics with hollow points. Other projectile types allow for the destroyed material to be either moved aside, or utilized for additional wounding, which is similar to the effects seen in gel. Each bullet type utilizes a different mechanism for destroying tissue and how that mechanism works in different media or tissue is substantially dissimilar. For some projectile designs, like the hollow point that only uses direct contact as its destructive mechanism, the wound diameter is similar in gel as it is in tissue, but the penetration depths are vastly disproportionate, whereas rounds that cause compression create a huge permanent cavity in gel that is not witnessed in actual tissue as seen in testing and forensic reports. "The tensile strength of muscle is from 1 to 4 MPa (145 to 580 lb.f/in2), and minimal damage will result if the pressure exerted by the temporary cavitation is below this. IWBA gelatin and other less elastic media have

[66] Police1. "Ballistic gelatin comparisons: Part I" November 2019

much lower tensile strengths, exhibiting more damage after being struck with the same amount of force. Handgun bullets create temporary cavities with much less than 1 MPa of pressure, and are incapable of causing damage to elastic tissues that they do not directly contact."[67] The tensile strength of ballistic gelatin is approximately .8 to 1.0 MPa, vs 1.0-4.0 MPa for actual human tissue, so it is close to simulating low density human tissue, but it is only 20% that of high-density muscular tissue and organs.

Therefore, it is incorrect to believe that if one round does better in gel then it will do better in tissue. When only testing rounds like hollow points, that cause minimal compression, gel works ok, but when mixing bullet types, the results in gel are impossible to compare. In some tests, measurements of recovered bullet diameter are used which does not equal gel wound diameter because of rounds turning or fragmenting (which happens frequently) and some rounds cut through material while others push allowing the gel to recover. Lastly, with rounds that tumble or cause compression, gel results are artificial and are very different from actual tissue tests or post shooting medical reports.

Consequently, results in gel, while being outstanding for comparative reasons, are very poor at expressing what damage happens to a human target and predicting reality. Using gel as a standardized material for comparison is scientifically valid when comparing penetration depths as drag and momentum are the main components. Using gel for wound diameter size and volumes is extremely artificial and next to impossible to measure. This requires a more realistic media to be used in conjunction with gel. Realistic target media is required exactly the same as realistic barriers to make the results relevant.

Animal tissue is a realistic media that produces results that more closely match forensic reports from real world shootings. Due to the compressibility and absorption of actual tissue, unlike gel, the wound channel effects and dimensions are representative of the destructive properties exhibited by the projectile on a target. Our Phase 4 and 5 use actual animal tissue to make up for the deficiencies in only using gel and getting artificial results. These phases are similar to DoD testing in tissue. By combining two different medias the test data is closer to real world results. Unfortunately, an enormous amount of tissue would be required to measure penetration depths. Furthermore, cutting into tissue to measure penetration depths, changes the size and dimensions of the wound that would make the measurements inaccurate. The rounds must completely go thru the tissue to measure the size of the exit hole. We use back-to-back tissue pieces so we actually get two holes on every shot. a midway hole and an exit hole. Also, using the recovered bullet is meaningless in trying to determine the actual cavity size with any bullet design. Only by measuring the actual cavity on the target will you know the true size and amount of destroyed material. Measuring both the major axis (widest diameter of the hole) and minor axis (narrowest diameter of the hole) yields an accurate wound hole area. Taking these measurements from both the midway exit hole (first tissue piece) and the second exit hole yields four total measurements

[67] National Library of Medicine, National Center for Biotechnology Information. "Experimental evaluation of fiber orientation based material properties of skeletal muscle in tension. "Kuthe CD, Uddanwadiker RV, Ramteke A. Mol Cell Biomech. 2014 Jun;11.

per shot to determine the average hole area for one shot. With increased sample size we can get a true average and create a standard deviation for the measurements to check and see is the results are consistent for each particular projectile. We have a 1-sigma standard deviation on each measurement and achieve a 2-sigma standard deviation on the 4-measurement average, meaning that the data is consistent to a 95% level. Those wound areas are annotated on the data sheets. We compare those average wound areas to medical and forensic reports we obtain and have found the results very comparable and much closer than the results from IWBA calibrated gelatin.

After all of the external measurements of the tissue are complete, agreed upon and recorded, the tissue in some occasions is dissected to inspect for projectile fragmentation, wound channel characteristics and barrier-to-tissue interaction. Three distinct facts have been uncovered.

1. During limited testing with high-velocity rounds (>2,600 fps) using the AR-15 5.56mm and the PS-90 5.7mm, the dissected animal tissue media showed a mushy area including tearing outside of the permanent wound cavity, which was never present in any of the handgun rounds. This is reportedly caused by the high-speed rounds temporary cavity causing stretching at a velocity in excess to what tissue can be stretched without tearing. The thickness of the mushy area was minimal, it did not continue deeply and was never present in the second tissue piece.

2. On several occasions' fragments from the light domestic barrier used in phase 5 (plywood) were carried through both pieces of tissue and were also embedded into the sidewalls of the internal wound track (see pictures in section one presentation). Although, the sideways penetration depth was extremely minimal, it was worth noting.

3. Dissection of the media showed the extent of the veering and change of course caused during penetration from the tumbling rounds (5.7mm, 4.6mm and military rifle rounds) and led to the Penetration Track Length (PTL) vs Penetration Depth (PD) comparison. (See chapter Five Types of Handgun Projectiles for information regarding tumbling rounds). (See section three and four for full description of the 5.7mm and 4.6mm rounds)

SIX TEST PHASES:

Phases 1-5: All shots are 90 degrees to the media and shot at 10 feet IAW FBI protocols.

Phase 1: All rounds fired at least 4 times, chronographed and averaged. Testing actual vs advertised velocities, consistency and reliability.

Phase 2: All rounds fired at least 4 times into IWBA calibrated FBI 10% ordnance gelatin with a standard 4-layer denim barrier. Recovered rounds inspected for failures, retained weight and overall dimensions. Measuring wound dimensions, reliability and consistency. This phase is an exact duplicate of the FBI test used to determine the penetration depth of rounds (FBI test event 2). The FBI standard is 12" minimum and 15-21" desired. The data sheet records penetration depth in inches, average cavity diameter and calculated Permanent Wound Cavity (PWC) volume in cubic inches (ci).

Phase 3: IWBA Calibrated FBI 10% ordnance gelatin with a single ¾ inch thick AA fir plywood panel IAW FBI / DoD protocols and a standard 4-layer denim barrier. All rounds fired at least 4 times. Recovered rounds inspected for failures, retained weight and overall dimensions. Measuring wound dimensions, reliability, consistency and barrier performance. This test is an exact duplicate of the FBI test, which uses plywood as a light domestic barrier (FBI test event 5). The data sheet records penetration depth in inches, average cavity diameter and calculated Permanent Wound Cavity (PWC) volume in cubic inches (ci). To see the average degradation to the round caused by the light domestic barrier, see the last column marked Light Domestic Barrier Degradation Percentage (LDBD%).

Phase 4: Animal Tissue with a standard 4-layer denim barrier. All rounds fired at least 4 times. Rounds not recovered. Measuring wound hole area dimensions. Exit wound channels from each of the two tissue pieces are measured for min and max diameter, then averaged and converted to area. Measuring reliability and consistency. After the external measurements the tissue is dissected to inspect for projectile fragmentation and wound channel characteristics. The data sheet records the average wound hole area.

Phase 5: Animal Tissue with a single ¾ inch thick AA fir plywood panel and a standard 4-layer denim barrier. All rounds fired at least 4 times. Rounds not recovered. Measuring wound hole area dimensions after the projectile interacts with a light domestic barrier. Exit wound channels from each of the two tissue pieces are measured for min and max diameter, then averaged and converted to area. Measuring reliability, consistency and barrier performance. After the external measurements the tissue is dissected to inspect for projectile fragmentation, wound channel characteristics and barrier-to-tissue interaction. The data sheet records average wound hole area. To see the average degradation to the round caused by the light domestic barrier, see the last column marked Light Domestic Barrier Degradation Percentage (LDBD%).

Phase 6: Testing vs heavy barriers (auto glass, solid wood and metal) and armor products. Armor testing is accomplished with products from multiple manufacturers and different NIJ armor levels. This phase is not accomplished for every round. Phase 6 data is recorded separately and is not found on the primary phase 1-5 datasheet.

GRADING CRITERIA:

There are four main criteria in quantitatively grading handgun projectile wounding. Before picking a bullet type or specific ammunition you must understand these criteria and decide what value you desire for each. From there determine the best bullet type and specific round that matches your requirements for each criterion for your application. If your agency believes in putting these characteristics in a particular order and believes that their importance is not equal, use the following test data favoring your requirements. We have tested, measured and reported these characteristics separately so each agency can use the criteria best suited for their purposes.

1. Penetration Depth: The overall distance traveled by the bullet through the target or media. It is measured during the two IWBA gel phases (2 and 3). Phase 2 yields penetration depth numbers used to describe a rounds overall penetration capability. The FBI's Firearms Training Unit states that "Effective pistol rounds must be able to penetrate a minimum of 12 inches, to offer the best chance of striking a major artery or organ." "A penetration of 18 inches is preferable." Currently the desired standard is 15-21 inches in gel (Federal Standard-see below) for non-DoD agencies and 16-24 inches for military. *Originally the FBI used 18-inch gel blocks which created the 18-inch maximum. That depth had nothing to do with over-penetration.* The 18 inch depth is optimum not maximum. Phase 3 adds a plywood barrier to determine the penetration after passing through a light domestic barrier and uncover failure issues. Penetration was judged to be the single most important component of projectile wounding. See "Test Results vs Real World Forensics" below.

The Federal Standard: In 1982 the US Army changed ammunition for their 5.56x45mm M16 rifles adopting the M855 round after an exhaustive combat forensic examination and a long development. It did so for two main reasons. 1. Deeper penetration 2. Better hard target performance (barrier capability). The old M193 from 1963 was replaced which exhibited approximately 15-18 inch (17 inch average) penetration in gel and poor performance vs hard targets such as vehicle glass and doors, solid wood and personnel body armor. Both problems were to be rectified by the new M855 ammunition, which is a spitzer-style projectile with a boat tail rear for better long-range performance and features a copper jacket filled with a lead core and steel tip. It is designed to penetrate lightly armored targets, such as body armor or light vehicles, and provides increased penetration (16-24 inches with a 22 inch average). That 22-24 inch penetration depth average became the desired depth for the military based on a human target and was a driving factor in their development of current calibers, namely the .300 BLK (7.62x35mm) and 6.8 SPC II (6.8x43mm) when designing rounds with that optimum penetration depth. The US military still utilizes the FMJ and SOCOM prefers them over hollow points due to "superior penetration, reliability, feed and function and improved barrier performance."

In 1988 the FBIs Firearms Training Unit (FTU) implemented terminal wound ballistics testing for its pistol ammunition. Penetration depth was judged to be the most important projectile characteristic and stated that 18 inches in gel is optimum and any round that averages <12 inches of gel penetration, is designed to fragment or fails to expand would not be tested. That eliminated many hollow points (under penetration or fragmentation), all FMJ (non-expansion), all frangible rounds (fragmentation) and many smaller calibers (under penetration). Those rules have not been changed or been modified since 1988, which now eliminates the Fluted-Fluid Transfer rounds

(non-expansion). This decision explains why they have not tested the fluted rounds and why they have no data or experience with them. Also, because 18 inches was declared "optimum" the FBI used 18 inch IWBA gel blocks which unfortunately did not allow for calculations of wounding past 18 inches.

In approximately 2019, the FBI, DHS, Border Protection and the US Marshall's all started enquiring about pistol rounds penetrating as deep as 21 inches in line with ammunition used in their rifles, which was the same as used by the US military as described above. This was due to the poor terminal performance caused by under penetration of the duty pistol ammunition. What they referred to as the combined civilian agency "federal standard" was still a minimum of 12 inches penetration in gel to be tested for duty use, 15-21 inches desired and 18 inches still "optimum". However, their requested optimum was 18-21 inches. So as of the time of this report the civilian “optimum” for duty rifle and pistol rounds vs a human target is 18-21 inches in IWBA FBI calibrated ordnance gelatin and the military “optimum” is 22-24 inches. Also, heavy barrier performance was now made a requirement instead of simply a desired capability. Required penetration depth is based solely on the target regardless of weapon or ammunition. Therefore, combining the desired penetration depths from the federal standard and DoD military we see that 15-24 inches is considered “duty”.

Penetration can be divided into four distinct depths:

1. Shallow (<10 inches). Rounds providing this penetration depth: Frangible

2. Low (10-15 inches). Rounds providing this penetration depth: Hollow Points, Tumbling

3. Duty (15-24 inches). Rounds providing this penetration depth: Hollow Points, Fluted-Fluid Transfer, Tumbling

4. Deep (roughly >24 inches). Rounds producing this penetration depth: FMJ, Fluted-Fluid Transfer hunting variants

Hollow Points: Penetrate 9-18 inches with an average of 12-14 inches. The shallower values (9-12 inches) are caused by light-weight rounds and or excessive fragmentation, increasing drag. The deeper values (15-18 inches) are caused by rounds failing by minimally expanding or not expanding at all, accidentally achieving deeper penetration depths due to the lower drag. There are no tested hollow points in any caliber that when functioning properly and attaining full expansion and no turning, average over 16 inches of penetration.

Full Metal Jacket: FMJs penetrate between 24-32 inches.

Fluted-Fluid Transfer: Fluted rounds penetrate between 15-23 inches.

Frangible: Most fragmenting rounds penetrate <12 inches, with an average of 10 inches, except when they fail to break apart. Other types of frangible bullets have sections that penetrate deeper.

Tumbling (5.7mm / 4.6mm): Penetrate 9-21 inches with an average of 16 inches.

Over Penetration Facts:

Definition: A projectile that passes through the targets center of mass (thoracic cavity) and has enough residual wounding potential to travel to another target and cause death or serious bodily damage. Over-penetration occurs when a projectile passes completely through its intended target and out of the other side, with enough remaining kinetic energy to continue flying as a stray projectile and risk causing unintended collateral damage to objects or persons beyond. Over-penetration is not grazing or missing the intended target. Over-penetration can occur from either a fully-functioning projectile or by means of a malfunction. An example of a bullet that functions properly and causes an over-penetration in a human is a hunting rifle round that is designed for deep penetration through a large animal. When encountering a human, a projectile of this type may, as designed, penetrate deeply and go through a thinner human target. Examples of bullets that malfunction and cause over-penetration are projectiles that are designed to expand (hollow point) and fail to do so (Failure To Expand) or a projectile designed to tumble (military rifle anti-personnel, 5.7mm and 4.6mm rounds) and there is insufficient yaw or instability to cause the tumble and the round continues straight through and over-penetrates. Therefore, over-penetration must be considered both by looking at the designed and tested average penetration depth and also looking at the failure rate and typical malfunction effects.

1. 55% of all shots do not hit the target. Worrying about the effects of those rounds that miss is of higher concern.
2. No handgun shot has passed through the center of mass of a human target (thoracic cavity) and then resulted in a law suit or serious injury of a separate individual. Rounds that have done that have not passed through the desired target area. The FBI, US Law Shield and USCCA all report that not a single case in US history has occurred from an over penetrating pistol round.
3. Federal standards require a minimum of 12-inch penetration into the gel to even continue the testing of that round. Federal agencies to include the DoD desire 15-24 inches of overall penetration. That figure is derived from witnessing which rounds penetrate properly in human forensic reports and then witnessing what those rounds do in gel testing. See "Test Results vs Real World Forensics" below.
4. No defensive frangible, fluted, tumbling or non-malfunctioning hollow point rounds penetrate past 23 inches in IWBA gel.
5. Full Metal Jacket (FMJ) rounds in all calibers pass between 24-32 inches in IWBA gel. Simply carrying non FMJ will eliminate excessively deep penetration depths.
6. No Frangible rounds penetrate the minimum required 12 inches, and average <10 inches. Most only create superficial wounding on human targets. All are considered under penetrators. These rounds may be great in apartments or the like, but are typically not considered duty ammunition.
7. Hollow Points (HP) penetrate between 9 and 18 inches. In any specific caliber, weight is the number one determinant in penetration depth. Generally speaking, more weight equals more penetration. Increased velocity does not increase penetration depth. Hollow points that fail (fail to open, fragment, tumble) normally do not fall within the 9-18 inch average. Depending on caliber and design, the failure rate for a hollow point is between 25-40%. Lack of reliability and consistency of even the highest quality HP leads to inconsistent and uncontrollable penetration

depths. When a hollow point has a Failure-To-Expand (FTE) the penetration depths are typically between 18 and 25 inches.
8. Fluted-Fluid Transfer rounds penetrate between 15-23 inches in IWBA gel. Fluted rounds have the highest reliability and consistency of any of the five bullet types tested greatly reducing the chance of penetrating past 23 inches. Post-shooting medical and forensic report analysis shows that so far there have been no incidents of fluted-fluid transfer rounds exiting a human target after hitting the thoracic cavity.
9. Rifle rounds, like the NATO 5.56x45mm and the NATO 7.62x51mm all penetrate deeper than pistol rounds. One of the reasons quoted by the US Army for the switch from 7.62x51mm (M80) to 5.56x45mm was a more controlled penetration, with projectile effects of tumbling or fragmentation happening at a shallower depth, increasing wounding and decreasing over-penetration. The M80 projectile (7.62) tends to tumble by the 9-inch point and penetrate 25-28 inches total.[68] Those figures were not considered as effective in comparison to the 5.56 rounds. This is one of the stated reasons for the switch to the 5.56x45mm M193. The M193 55 grain regularly penetrates 15-18 inches as demonstrated during testing. Unfortunately, the M193 underperformed in combat. "One of the inferiorities (of the M193) is, however, its penetration capability." "…both versus soft targets and heavy barriers, like auto glass."[69] The M193 was replaced by the M855, providing optimum penetration vs soft targets and better performance vs barriers and armor. The M855 5.56mm round (16", 1 in 8 twist barrel) (2,900-3,000 fps) tends to tumble by the 6-inch point and penetrate to 16-24 inches, with a 22 inch average. (US Army optimal penetration depth).[70] Due to the chaotic, unpredictable nature of tumbling and fragmentation, when any of these rounds do not function as designed (failure) they may exceed 24 inches of penetration and both minimize tissue damage and cause an overpenetration.

Handgun ammunition over-penetration summary:

1. No recorded event as reported by the FBI, US Law Shield and USCCA.
2. Duty rifle ammunition penetrates deeper (18-24 inches) than duty handgun ammunition (15-23 inches), yet it is considered standard and acceptable.
3. Hollow points that fail go as deep as FMJ and much deeper than the fluted-fluid transfer rounds, tumbling rounds or frangible rounds.
4. Gel does not replicate human tissue, so assuming that 20 inches deep in gel = 20 inches deep in human is completely wrong. See "Test Results vs Real World Forensics" below and the chapter "The Human Target" for human tissue and ordnance gelatin comparisons.

Pistol ammunition over-penetration is possible, but of minor concern and can be easily mitigated.

[68] Wound Ballistic Review, US Army data on M80 7.62 projectile.

[69] US Army. "Evolution of the M855". Lt. Col. Jeffrey K. Woods (USAASC)

[70] Wound Ballistic Review, US Army data on M193 and M855 5.56 projectiles.

2. Reliability and Consistency: Reliability is a measurement of failure rate. Each of the five handgun bullet types is constructed specifically with separate and different design features. If the round doesn't do what it is designed to do then that is a failure. It is a failure when bullets accidentally fragment (frangible rounds are designed to fragment), accidentally turn sideways (tumbling rounds are designed to turn sideways, yaw and tumble) or in the case of the hollow points Fail To Expand (FTE) and jacket separation. On every single shot we note if there are any failures and what the failures are. When we divide the number of failures by the total quantity of shots, we derive a failure rate and therefore the reliability rate. Please reference the Round Summaries chapter for the description of each of the round's reliability and consistency. "Handgun bullets (hollow points) expand in the human target only 60-70% of the time at best. Damage to the hollow point by hitting bone, glass, or other intervening obstacles can prevent expansion. Clothing fibers can wrap the nose of the bullet in a cocoon like manner and prevent expansion."[71] Consistency is the ability of the round to perform the same way every time and how much deviation occurs between shots during the same phase. Once a specific round is graded it is important to know how often it can perform to that standard. Reliability and consistency are thought to be the second most important criteria in ammunition selection but are unfortunately under appreciated. Since failures cause dangerous under-performance the reliability and consistency of duty rounds is critical.

3. Barrier Performance: Barriers are items that may cause degradation to the bullet before bullet stoppage or exit, and can exist between the weapon and target or be part of the target.

Barrier Performance can be divided into four categories:

1. Penetration through no barriers. Frangible rounds are designed for this.
2. Light domestic barrier penetration (plywood, drywall, thick clothing and bone). Light domestic barriers are incorporated in phase 3 and 5. The results in comparison to the non-barrier phases (2 and 4) yield barrier results. To see the average degradation to the round caused by the light domestic barrier see the last column marked Light Domestic Barrier Degradation Percentage (LDBD%). Frangible rounds and hollow Points are greatly degraded by light domestic barriers, while FMJ, fluted and most tumbling rounds are not.
3. Heavy barrier penetration (hardwood 2x4's, auto glass and metal car doors). Testing on heavy barriers yields data where we grade the three D's: Deflection amount, Destruction (projectile failure) and Degradation (how much less penetration and wounding capability the bullet has after passage through the heavy barrier, similar to LDBD%). The Fluted-Fluid Transfer and some tumbling rounds excel vs heavy barriers. FMJ are degraded some while hollow points and especially frangible rounds are almost completely ineffective vs heavy barriers, due to being deflected, failing to function or being significantly degraded.
4. Armor piercing. Rounds specifically designed to penetrate and retain capability after passing through armor materials as set by the National Institute of Justice (NIJ) levels

[71] US Department of Justice, "Handgun Wounding Factors and Effectiveness", FBI Firearms Training Unit, Quantico, VA, September, 1989

(listed in the armor data sheet). Only some of the Fluted-Fluid Transfer and tumbling rounds penetrated through armor.

Barriers can deflect, destroy and degrade a bullet. Penetration and Permanent Wound Cavity (PWC) size lost from non-barrier shots to barrier shots are analyzed and calculated. Real-world shots including barriers are extremely common and are generally out of the control of the shooter. Multiple shots on a barriered target does not increase the chance of penetration or incapacitation. Barriers that stop one bullet generally will stop multiple shots. Human bone is roughly equal to a light domestic barrier. The target area of a human (torso and head) is covered by bone for 70% of that area. Determining which of the four barrier performance categories you require for your ammunition is critical. Analysis of past shots in your agency or department to better understand probable future barrier encounters generally helps in this determination.

4. Permanent Wound Cavity (PWC): The volume measured in cubic inches of the destroyed part of the target created by the bullet after it goes through the target or media. PWC is a mathematical calculation comprised of penetration depth and wound diameter converted to area and is expressed in cubic inches of destroyed material. Literally it's how big a hole was made by the bullet and exactly what needs to be fixed by the emergency room.

The permanent wound cavity is measured during the gel phases 2 and 3 by measuring the actual hole size (area) at various depths and multiplying it by the penetration depth. It is listed on the data sheet for each of those two phases. During phases 4 and 5 the area of the holes through the tissue is listed. This is the average of the major and minor diameter for each of the two exit holes, converted to area. Also, a composite PWC is calculated as Volume of Wound Index (VWI) and is listed in the second to last column of the data sheet. For the tumbling rounds that create a curved trajectory in the media, Penetration Track Length (PTL) is measured and is separately used to calculate a Total Volume of Wound Index (TVWI). Unlike penetration depth, reliability of a round and barrier performance this characteristic can be increased with multiple shots and hits. With a given penetration depth, a projectile creating a larger diameter wound will destroy an equally larger amount of tissue. Small increases in diameter cause large amounts of area change ($A = \pi r^2$). Unfortunately, many reports simply measure the area of the recovered bullet after it stops or passes through the media. **The hole created by the bullet in actual tissue in most cases is not equal to the size of the projectile**. This is greatly misunderstood and is caused by several factors. In hollow points, the round does not expand fully immediately at impact. Also, if a hollow point tumbles or turns sideways then the large frontal area of the bullet is not what's producing the wound resulting in a much smaller wound then the recovered bullet size would suggest. In frangible rounds the individual channels often times cross or pieces follow other paths already destroyed in the target. With fluted rounds the fluid transfer destroys adjacent tissue which can only be measured on the actual target. Measuring the recovered bullet will render no information on the wound channel size. The wound area is extremely difficult to measure in the case of accidental turning rounds, fragmenting rounds, fluted rounds which create holes larger than their caliber and tumbling bullets that have holes that vary greatly at different depths. Fluid transfer from the fluted rounds sends a jet of high-velocity liquified tissue into adjacent tissue. It is not energy transfer! This will destroy tissue not actually contacted by the bullet. It increases the actual

hole in the tissue target (PWC). Outside of that wound channel there is still more material that is the temporary stretch cavity which just like the other bullet types is non-destroyed material and is insignificant in wounding in handgun rounds.

Hollow Points: 1.9-8.3 cubic inches of Permanent Wound Cavity.

Full Metal Jacket: FMJs create 3.6-5.45 cubic inches of Permanent Wound Cavity.

Fluted-Fluid Transfer: 6.7-22.2 cubic inches of Permanent Wound Cavity.

Frangible: Fragmenting rounds create 1.85-6.9 inches of Permanent Wound Cavity. With multiple fragments producing many tiny hard to measure wound paths in gel and in tissue most of the rounds Did Not Exit (DNE on the data sheet) so measuring wound area was problematic.

Tumbling (5.7mm / 4.6mm): 1.8-14.9 cubic inches of Permanent Wound Cavity.

While Permanent Wound Cavity is extremely important, there are four issues with concentrating solely on this number.

1. A large PWC that doesn't destroy any important body tissue because the wound is too shallow is virtually meaningless. Since the important organs are deep within the body this drives up the importance of penetration. Destroying a lot of skin and subcutaneous material does little to stop/incapacitate a human target.
2. Many rounds that create large PWC exhibit low reliability and consistency. Many of the hollow points that open extremely wide tend to do it inconsistently or accidentally fragment often, which completely limits their capability.
3. Most of the PWC calculations are done using IWBA gel. Human tissue is compressible and gel is non-compressible which creates results that don't represent reality. Using a media closer to human tissue is required to get actual realistic data.
4. About 70% of the target area of a human is covered by clothes and bones. So, 2/3^{rds} of the shots are going to encounter barriers which are not considered in most PWC calculations. Barriers greatly lowered some PWC figures. That is why Volume of Wound Index (VWI) is considered more valid because half of the data comes from light domestic barrier tests.

"The critical wounding components for handgun ammunition are penetration and permanent cavity."[72]

[72] US Department of Justice, "Handgun Wounding Factors and Effectiveness", FBI Firearms Training Unit, Quantico, VA, September, 1989

TEST RESULTS vs REAL WORLD FORENSICS

Test results and measurements in calibrated FBI International Wound Ballistics Association (IWBA) 10% ordnance gelatin (Phase 2 and 3) are vastly different from medical measurements taken during post real-world shootings on human targets. Analyzing data from five case studies of two fluted-fluid transfer rounds used in non-barrier shots (no armor, heavy clothing or intermediate barriers) to the thoracic cavity that each produce 17-20 inches of penetration in gel showed that none of the 5 shots exited through the real-world targets. Also, analyzing seven case studies of non-barrier shots (no armor, heavy clothing, intermediate barriers) to the thoracic cavity with a certain popular 9mm duty hollow point that averages 13-14 inches of penetration in gel, as tested by the FBI, DHS and us, revealed that none of the shots hit bone or penetrated >5 inches into the human targets.

Test results and measurements from animal tissue (Phase 4 and 5) showed similar results to other real-world applications. During these phases, we are only measuring wound diameter and corresponding wound hole area. Penetration depth measurements cannot be accomplished due to the requirement do measure the exit holes through the tissue during testing. Hunting shots into live animals exhibit the same wound channel diameter and area as testing on dead animal tissue with all five projectile types. During an analysis of five separate case studies of non-barrier shots to the thoracic cavity with two fluted-fluid transfer rounds mentioned above. All five real-world wound diameters matched tissue test results.

HOW TO CHOOSE A ROUND

1. Understand the four projectile characteristics listed above (Penetration, Reliability / Consistency, Barrier Performance and Permanent Wound Cavity / Volume of Wound Index conglomerate).
2. Determine your desired values for each characteristic. Be able to determine quantifiable values for each of the above four characteristics. Each agency should determine their own requirements and be able to describe their needs and desired effects. Those effects must match mission requirements. Do not use some other agencies requirements or grading system. Determine your own as desired results or mission requirements vary greatly. Remember “A bullet should do what you need it to do, not be what you want it to be.”
3. Understand the five projectile types. Know the different bullet types and major designs available to you. By first choosing which bullet type most closely matches your needs you can easily narrow down your search and find how to achieve your desired results. Knowing the strengths and weaknesses of each projectile type will help you eliminate rounds that simply cannot meet your needs. Differences in caliber are important but what is more important than caliber is projectile type. There are more differences between the wounding characteristics determined by projectile type than there is between calibers in the same projectile type, so focusing on caliber is important but is missing the bigger criterion. As an example, in hollow points only, the difference in penetration between the average 9mm hollow point and the average .45 ACP hollow point is about 20% deeper for the .45 ACP and the difference in

wound volume is about 60% larger for the .45 ACP.[73] But if you compare two 9mm (one hollow point and one fluted) you'll see a difference in penetration is about 40% and the difference in wound volume is over 100% larger for the fluted 9mm. This holds true in .40 S&W and .45 ACP as well.

4. Use the provided datasheets and ammunition summary narratives to match your desired characteristic values to actual test results. There is no best projectile, just one that most closely matches your needs. Create a list of several rounds that are acceptable and don't have any glaring deficiencies in any of the four characteristics. Then do a direct comparison of those rounds.

Typically choosing from the four Penetration Depths (Shallow, Low, Duty and Deep) and choosing which Barrier Performance (No Barrier Penetration, Light Domestic only, Heavy barriers but not armor piercing and Armor Piercing (AP)) will provide a small list of rounds. Then look at Reliability and Consistency to eliminate undesirable rounds and finally comparing Permanent Wound Cavities will deliver the best results. The DoD change to M855 reflects the Penetration and Barrier Performance selection process. Needing deeper than 17 inches in gel because of post shooting forensic medical examination in actual tissue and the need for better heavy barrier and armor capability led to their change from the M193 ammunition.

Shooters should pick the required characteristics. Drs should report on what bullets really do as far as wounding. Testers should compare test data to medical and forensic reports.

[73] The Federal Bureau of Investigation. “1989 Ammunitions Tests” and “1990 FBI Ammunitions Tests”

VOLUME OF WOUND INDEX (VWI)

Volume of Wound Index is a calculated volume of Permanent Wound Cavity (PWC). It is not a direct measurement from any single test, but rather a calculation from a combination of four tests or phases. Its scale is in cubic inches of volume and can be used as a direct comparison from round to round. Using multiple medias to more truly understand the actual effects of projectile destruction on target material is required. Volume of Wound Index uses two different medias to ascertain a better understanding of real-world shootings and provide quantitative results for comparing bullets.

To calculate VWI we use the two gel tests (phase 2 and 3) to determine the penetration part of the formula. Phase 2 is IWBA FBI gel with 4 layers of denim (exact same test the FBI and DoD use). Phase 3 is the same as phase 2 with the addition of a light domestic barrier layer consisting of a single sheet of 3/4 inch AA fur plywood (exact same barrier test the FBI and DoD use). We take at least 4 (normally 6-8) shots per round in each phase and average the phase 2 and 3 penetration depths together. This effectively increases the sample size and is a combination of non-barrier and barrier data. That average is where the penetration depth for VWI comes from.

Next, we shoot at least 4 shots (normally 6-8) into tissue in each phase 4 and phase 5. Phase 4 is 7-9 inches total thickness of hanging tissue (2 pieces back-to-back) with a denim barrier. Phase 5 is phase 4 with an added 3/4-inch AA fur plywood barrier. Each shot into tissue yields 4 measurements, major and minor diameter from the exit of both pieces of tissue. Those 4 diameters are averaged and is converted to area. We average the phase 4 and 5 results together to get the average hole area which includes both the non-barrier and barrier tests.

That wound area average (from phases 4 and 5) is multiplied by the penetration depth average (from phases 2 and 3) discussed above to create a 3-dimensional volume. That's VWI. It combines consistent penetration measurements from IWBA gel along with consistent realistic measurements of hole size in real tissue and uses barriers and non-barriers.

Volume of Wound Index is currently the most comprehensive single value of comparative bullet effectiveness in determining Permanent Wound Cavity size. This value does not represent and is not intended to describe the actual volume created in a human target. It is only used for comparison purposes.

TOTAL VOLUME OF WOUND INDEX (TVWI):

Of the five projectile types, two of them, frangible and tumbling produce wound tracks that are not linear from entry to projectile stoppage. They both exhibit wound tracks that have curves or turns in their path. Hollow points, FMJ and Fluted bullets travel straight through the media (gel, test tissue and actual human targets) unless encountering a solid barrier.

For tumbling rounds the curved path the projectile travels is longer than what is measured as the straight-line penetration depth. While penetration depth is all important in determining if a bullet

goes deep enough to impact important body organs, the longer curved path destroys more tissue, but is not evident when measuring penetration depth. Measuring the actual length of the curved track is required for determining the amount of tissue destroyed. Post impact curved trajectory Penetration Track Length (PTL) is the measurement of the curved path, not the straight line between entrance and stoppage.

This curved path was witnessed early in the development of the non-round-ball type ammunition we see today as standard rifle bullets, that are long and thin. The US Army took note of the curved path in the 1950s and by the 1960s they understood the increased wounding that was inherent in the curved path. By the 1990s cross sectional analysis of NATO 7.62x51mm, 5.56x45mm and Warsaw Pact 7.62x39mm and 5.45x39mm led to determining measurable effects. The 5.7x28mm and 4.6x30mm projectiles display the same curved path, which is a product of tumbling created by the imbalanced bullet encountering a yaw effect when entering a denser than air media.

After all other wound measurements are complete, a 3D measurement of the actual penetration track length is accomplished in both gel and tissue during phases 2-5. The results from both media are compared to make sure that the curve is observable and similar in actual tissue. The wound area average (from phases 4 and 5) is multiplied by the penetration track average (from phases 2 and 3) to create a 3-dimensional volume called Total Volume of Wound Index.

For frangible bullets, measuring and calculating wound diameter in gel and tissue is extremely problematic due to the multiple pieces, differing depths of each piece, inconsistencies shot to shot and most of the fragments not exiting the tissue allowing for a measurement, therefore only a few frangible rounds have a VWI or TVWI that is calculatable as noted in the data tables.

Penetration Depth (PD) and Penetration Track Length (PTL) are the same for Hollow points, FMJ and Fluted bullets and therefore no calculation is required or noted on the data tables.

In summary:

Penetration Depth is a straight-line measurement of how deep the bullet went in the media, regardless of the path it took. Penetration Track Length measures any curves in the path to determine actual distance traveled.

Penetration Depth (PD) x Average Hole Area = VWI

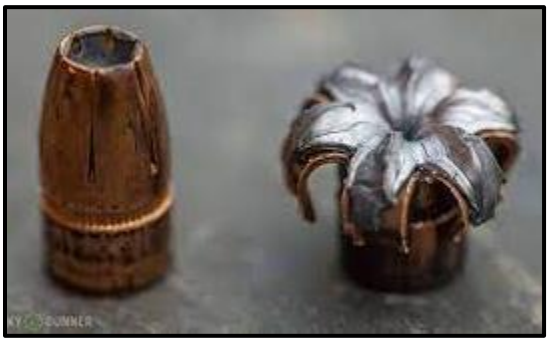
Penetration Track Length (PTL) x Av Hole Area = TVWI which is the actual amount of wounding that projectile creates.

Penetration Depth is still the single most important determinant in wounding ability as the projectile must go deep enough to contact and disrupt/destroy important body organs that reside deep inside the thoracic cavity.

FIVE TYPES OF HANDGUN PROJECTILES

Five types of handgun projectiles exist, each with their own specific design and radically different characteristics. Projectiles within each type tend to have similar characteristics in regards to function, penetration, reliability, barrier performance and overall purpose. A projectile can (1) stay linear (Full Metal Jacket) (2) reshape (Hollow Point / Tumbling) (3) create secondary effects (Fluted-Fluid Transfer / Frangible)

1. Hollow Points (HP): The most common duty and defensive ammunition used, these projectiles are designed to expand upon impact to increase the frontal area of the bullet. This is intended to increase drag which limits penetration depth as compared to an FMJ which some (non-military) consider to over-penetrate. The positive byproduct of this expansion is a larger diameter wound, if the bullet doesn't experience a failure. The FBI standardized testing and is the preeminent source for hollow point information starting in the late 1980's. The FBI has a stated requirement for their duty ammunition to expand. Since their testing also requires bullet expansion, this eliminates their testing of FMJ, tumbling and fluted rounds as they don't expand by design. This also identifies failures in hollow points that don't expand reliably. They also deem fragmentation as a negative feature for duty ammunition due to poor penetration depths and small overall PWC.



Expansion is caused by hydraulic pressure inside of the hollow point cavity. The tissue in front of the projectile is crushed under extreme pressure creating a liquid. Liquids are non-compressible, which is how hydraulics work, as a result the pressure from the round continuing into the target creates an internal cavity pressure that is exerted in all directions. The sidewalls of the hollow point are perforated either on the inside or outside allowing a failure point. When the pressure inside the hollow point cavity is high enough to tear the metal walls and overcome the frictional forces on the outside of the bullet attempting to close the hollow point, the walls of the hollow point tear, are pushed outwards and the round expands. Once the round is open past the original diameter, the pressure is relieved but friction on what was the inside of the walls takes over continuing to open the hollow point not only to full expansion but to over expansion where the petals of the hollow point wrap back onto the core of the bullet. Most of the kinetic energy of the projectile is absorbed by the bullet itself which is the actual source of the metal bending and reshaping causing the mushroom shape. Almost all of the remaining kinetic energy is what crushes the tissue in front of the bullet. The leftover kinetic energy causes the insignificant temporary stretch cavity that does not contribute to any wounding effects. The destroyed tissue trapped on the concave face of the bullet has connective and high viscosity properties increasing drag and limiting penetration depth. If a non-liquid fills the cavity, then that material inside the cavity may compress and the internal cavity pressure does not become high

enough fast enough to overcome the frictional forces on the outside of the bullet attempting to collapse the walls inward and Failure To Expand (FTE) occurs.[74] Adding a plastic tip or other device into the cavity does not guarantee opening because the material added to the cavity itself is compressible.

The destructive mechanism of the hollow point is crushing or tearing of tissue through physical contact with the bullet. The destroyed material does not flow away from the wound channel with sufficient force or focus to cause additional wounding. Most hollow point bullets are comprised of copper jacket over a lead core, but some monolithic (all copper) hollow points have no lead and are therefore lighter and faster. The monolithic hollow points tend to have much shallower penetration depths, typically below the minimum allowed for further testing by the FBI (12 inches in gel) and they tend to fragment and are designed to break apart on contact (see the information on **4. Frangible** rounds later in this chapter). In regards to overall wound size, certain bullet designs outperformed other designs, but this was the third most important hollow point characteristic, after caliber and weight, when calculating penetration and wound volumes. Expansion of the bullet, in essence is increasing the caliber. Starting with a larger caliber creates not only a larger hole but allows the metal petals of the hollow point to be larger again increasing expanded diameter. Weight is more important in a hollow point than velocity. Given the same pressure which cannot exceed the Sporting Arms and Ammunition Manufacturers' Institute (SAAMI) standards, there is a tradeoff between weight (mass) and velocity, as one goes up the other must decrease to keep the same pressure. As velocity increases drag goes up at the square of velocity and the resistance to drag, which is weight, is decreased allowing the drag to have a greater effect. These two factors decrease penetration depth in lighter faster bullets. As mass goes up velocity must go down to maintain the same pressure. With increased mass, momentum goes up (the heaviest rounds in any caliber have more momentum but less energy). So, with lower drag (lower velocity) and more resistance to drag (higher mass), heavier rounds penetrate deeper. This is also true for the FMJ. Hollow Points do not expand more when faster, since they expand to max diameter and then wrap back on themselves, increased velocity doesn't increase wound diameter. For this reason. duty hollow points are heavier and not designed to fragment, but rather have maximum weight retention to create deeper penetration. Some common hollow point failures include but are not limited to: fragmentation, jacket separation (even for bonded bullets), Failure To Expand (FTE) and turning (sideways rounds create less drag, smaller holes and deeper penetration). If the bullet turns before fully opening, then it limits opening, and if it turns after opening it doesn't present the large frontal area. All these failures are detrimental, limiting the round's ability to wound and are not supposed to occur. As stated earlier, some hollow points are designed to fragment and, in those cases, fragmenting is not considered a failure.

Penetration: The non-fragmenting duty hollow points penetrate between 9-18 inches during the FBI series gel tests (our phase 2) for determining penetration depth. Average penetration for hollow points is 12-14 inches. Unfortunately, almost all of the deeper values (15-18 inches) are caused by rounds having FTE or turning sideways and accidentally achieving deeper penetration

[74] Modern Self Protection. article "The Problem with Traditional Handgun Hollow Points" Ben Branam 2015.

depths due to the lower drag. A non-expanding hollow point, which happens a third of the time, will generally increase penetration depths approximately 6-10 inches. That skews the overall average penetration depth about 2-3 inches. There are no tested hollow points in any caliber that when functioning properly and attaining full expansion and no turning, average over 16 inches of penetration. Penetration depths are the highest in any given caliber with the heavier rounds. Larger caliber rounds penetrate deeper than smaller caliber rounds due to higher weight.

Reliability / Consistency: The average hollow point fails over one third of the time in gel. "Handgun bullets (hollow points) expand in the human target only 60-70% of the time at best. Damage to the hollow point by hitting bone, glass, or other intervening obstacles can prevent expansion. Clothing fibers can wrap the nose of the bullet in a cocoon like manner and prevent expansion."[75] Hollow points with velocities less than 800 fps resulted in larger failure to expand instances. Velocities over 1,200 fps resulted in extremely high failures due to unintentional fragmentation and to a lesser effect, jacket separation. The sweet spot for hollow point reliability is between 900-1,100 fps. Hollow points are designed to expand and function properly at specific impact velocities. Changing barrel lengths or using +P rounds may alter the desired effects in a negative manner. A faster hollow point is not always a better hollow point.

Barrier Performance:

Light Domestic Barriers: Duty hollow points in all calibers exhibited a reduced effectiveness (Light Barrier Degradation %) of approximately 5-50% (normally 20-30%) and the failure rate went up, when encountering light domestic barriers

Heavy Barriers:

- Hollow Points deflect off the 8" target >30% of the time.
- Hollow Points fail >60% of the time.
- Hollow Points are degraded 60% if they don't deflect or fail.
- Overall capability reduced >90% from heavy barriers.

Armor: No conventional lead core duty jacketed hollow point projectile penetrates HG2 (Level 3A) soft or hard armor. The monolithic light weight high-speed hollow points have shown the possibility of penetrating through HG2 (Level 3A soft (flexible)) armor, although none exhibited this capability during our testing.

Permanent Wound Cavity: The hollow point PWC range is from 1.9-8.3 cubic inches. Hollow points typically have about the same wound volume (VWI) as Full Metal Jackets. The difference is the shape of the wound, not the overall volume. The wound volume is typically higher for the hollow point then it is for a frangible round in the same caliber. The wound volume for a hollow point is generally much less than a Fluted-Fluid Transfer round.

[75] FBI Firearms Training Unit, Quantico, VA. "Handgun Wounding Factors and Effectiveness".

Summary of Hollow Points by Caliber:

CALIBER	NUMBER TESTED	AV WOUND DIAMETER	PENETRATION Min / Av / Max	AV PWC VWI
9mm	17	.58”	5.3 / **12.8** / 17.0	4.1”
.380	2	.39”	11.2 / **11.85** / 12.5	3.25”
.357 Sig	5	.525”	14.6 / **16.26** / 17.5	5.44”
.40	10	.64”	8.0 / **14.52** / 18.0	6.1”
10mm	6	.56”	14.8 / **17.15** / 22.0	7.9”
.45	9	.73”	9.0 / **14.3** / 17.5	6.85”
5.7mm	5		12.2 / **14.0** / 16.8	5.8”
4.6mm	3		14.2/ **14.7** / 15.2	4.6”

2. Full Metal Jacket (FMJ): This is the second most common defensive ammunition used and also the most widely used training or practice ammunition. FMJ are combat rounds and are favored by the military for their deep penetration, reliability and barrier performance when compared to hollow points. These rounds have been heavily tested by the various DoD services, but are not tested by the FBI due to their requirement for a bullet to expand. FMJs are normally a copper jacketed bullet that is not designed to expand, tumble or fragment. They create deeper wounds of less diameter. The destructive mechanism of the FMJ is the crushing of tissue through physical contact with the bullet. The destroyed tissue simply flows away from the face of the bullet and has no effect on the surrounding tissue due to dissipation, absorption and lack of focus. The only common failure is deformation due to barriers. Since the copper jacket is thin this is possible with strong barriers and this can cause revectoring after contact with the barrier.

Penetration: FMJs typically penetrate between 24-32 inches during the FBI series gel tests (phase 2) for determining penetration depth, with some FMJs exceeding 40 inches of penetration. This is considered to be over-penetration as the current federal standard calls for 15-21 inches of penetration.

Reliability / Consistency: FMJ have a high reliability and consistency rate.

Barrier Performance:

Light Domestic Barriers: FMJs exhibited a 5-10% reduction in effectiveness when encountering light domestic barriers (Light Barrier Degradation %).

Heavy Barriers:

- FMJ deflect off the 8" target <10% of the time
- FMJ fail <10% of the time
- FMJ are degraded approximately 50% if they don't deflect or fail
- Overall capability reduced 60-70% from heavy barriers

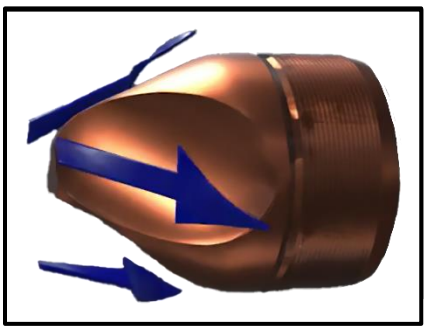
Armor: During our testing occasionally 9mm and .357 Sig FMJ penetrated HG2 (Level 3A) soft (flexible) armor, but they did not penetrate any hard (rigid) HG2 (Level 3A) panels, that may typically employ UHMWPE or a metallic strike face. The .380, .40 S&W, 10mm and .45 ACP FMJ did not penetrate either soft or hard HG2 (Level 3A) armor.

Permanent Wound Cavity: The FMJ PWC range is from 3.6-5.5 cubic inches. FMJs typically have about the same wound volume (VWI) as hollow points in the same caliber. The difference is the shape of the wound, not the overall volume. The wound volume is typically higher for the FMJ then it is for a frangible round in the same caliber. The wound volume for an FMJ is generally much less than a Fluted-Fluid Transfer round.

Summary of Full Metal Jackets (FMJ) by Caliber:

CALIBER	NUMBER TESTED	AV WOUND DIAMETER	PENETRATION	AV PWC VWI
9mm	2	.35”	30.0”	3.6”
.380	1	.35”	25.5”	3.0”
.357 Sig	1	.4”	32.1”	4.7”
.40	1	.4”	31.0”	4.5”
.45	1	.45”	27.5”	5.5”

3. Fluted-Fluid Transfer: These solid copper, brass or steel projectiles have flutes or channels and are non-expanding, non-fragmenting bullets similar to FMJ. Their designed destructive mechanism is contact tearing and fluid transfer through the Venturi effect. The flutes or channels constrict and concentrate the liquified tissue impacted by the bullet, accelerating that fluid and reducing the dissipation of the liquid by creating a focused jet of high-velocity material (cast-off) and then guiding that liquid jet directly into and tearing adjacent tissue, outside of the diameter of the bullet increasing the wound diameter and permanent wound cavity.



Several of these Fluted-Fluid Transfer rounds were tested in various calibers by US Army SOCOM in and prior to 2015 in North Carolina. In multiple days of testing, they were compared to pistol FMJ, hollow points and M4 rifle rounds. The fluted rounds showed favorable vs all of the available pistol ammunition and M855 rifle ammunition in wound ballistics testing for wounding effects. While penetration depths were more favorable with the rifle rounds, the wound diameters and areas were larger with the Fluted-Fluid Transfer pistol projectiles. Penetration and reliability were deemed to be an improvement over all tested hollow point pistol ammunition and further testing vs the issued US Army Advanced Combat Helmet (ACH) proved that the fluted armor piercing variants penetrated as designed through the helmet. Minor military use started thereafter and medium sized special operations contracts have continued[76]. In 2024 the Army Research Laboratory at Aberdeen Proving Ground conducted months of testing several newer Fluted-Fluid Transfer rounds concluding the Special Pistol Ammunition Report was valid in measurements and projectile effects and completed a trial vs FMJ and hollow point rounds in DoD service, finding the fluted rounds to be favorable in all four characteristics. The FBIs requirement for a handgun round to expand, otherwise considered a failure, has caused them to not test any fluted rounds. As such they currently have no data or experience with these rounds.

Fluted bullets lower the Terminal Ballistic Coefficient (TBC), which increases cast-off fluid velocity through constriction IAW Bernoulli's principle and the Venturi effect[77] (see equations below). It is calculated that 96% of the impacted liquified tissue is directly channeled into and down the flutes (working area). There are four main contributors to the amount of tissue that can be destroyed from the fluid transfer.

1. Fluid transfer amount is the first key ingredient to the amount of tissue damage. A larger amount of tissue contained in the liquid jet will create more damage. The area of the projectile (9mm/.357 Sig/.380 = .099", 40 S&W/10mm = .125" and the 45 ACP = .16") multiplied by the

[76] Guns.com. https://www.guns.com/news/2024/02/26/black-hills-picks-up-30-million-navy-marine-corps-ammo-contract. February 2024

[77] Cambridge University. "Bernoulli equation and Venturi effect". Published online by Cambridge University Press: 05 July 2014. Edward T. Gilbert-Kawai and Marc D. Wittenberg

working area of the projectile (96%) is the amount of material vectored into and impacting live tissue adjacent to the path of the bullet.
2. The second key ingredient to the amount of tissue damage is the focus and concentration of the tissue amount. Focusing the liquid jet (increasing Venturi effect) and directing the jet away from the projectile is caused by the design shape, size and depth of the flutes. Testing has measured that fluted bullets transfer fluid at approximately 30%-37% projectile velocity (cast-off speed). This is compared to less than 10% from hollow points or FMJ. This concentrated high-speed liquid tissue cast-off destroys adjacent tissue through direct impact. Focus is both flute shape and alignment with the tissue in relation to the combined forward and rotational velocity vector caused by the rifled barrel imparting a spin to the projectile, which increases fluid flow rates. Fluted fluid flow velocity is the combined projectile and rotational velocity vector. Changing barrel twist rate changes both the fluid flow velocity and the angle of impact which changes the focus and the drag.
3. Projectile velocity is the third key ingredient in the amount of tissue damage. Given that the cast-off speed is a percentage of projectile velocity, a higher velocity bullet will create a faster jet of tissue. Increasing velocity will always increase the diameter of the wound track, thereby increasing the permanent cavity.
4. The last key ingredient to tissue damage amount is the diameter (caliber) of the projectile. Diameter not only increases the volume of tissue in the concentrated jet to impact and tear adjacent tissue (item 1. above), but it also increases the area of the hole created by the tearing nature of the projectile itself and provides for a wider starting place for where the fluid transfer begins which is the outside edge of the bullet. Projectile diameter + (outward fluid transfer force wound radius x 2) = overall wound diameter.

The total amount of damage caused by a fluted projectile can be broken down into two components: 1. The penetration depth and 2. The 2-dimensional area of the hole. Multiplied together describes the 3-dimensional wound volume which is the permanent wound cavity. This is true for all projectile types. For the fluted projectiles, the second component, area of the hole, is caused by two elements: 1. The actual projectile diameter (caliber) calculated as an area and 2. The fluid transfer amount. To measure each amount, we calculate the area of each caliber, as listed above and measure the overall size of the hole in testing, which is annotated on the data sheets. For phase 4 and 5, the data sheets show the exact average hole area for each round. If we subtract the area caused by the diameter of the projectile, we are left with the amount of area caused solely by the fluid transfer amount. This is known as “The Percentage of Fluid Transfer”. For most of the fluid transfer rounds from all manufacturers the percent of fluid transfer is between 40-63%. That means that roughly half of the overall damage is created by the surface area of the bullet and half is created by the fluid transfer which increases the permanent wound diameter significantly.

Fluid transfer is not energy transfer temporary stretch cavity that does not destroy tissue. Temporary cavity is caused by a low-density **compressible pressure wave traveling at approximately 100 fps** (10% projectile velocity). The constricted fluid transfer cast-off is high density (over 1,000 times more dense) **non-compressible liquid traveling at up to 550 fps**. This

is particle vs wave physics[78]. This fluid transfer is direct contact high-speed fluid on live tissue. Remember that liquified tissue under high pressure causes the expansion of the hollow point by tearing the metal walls and overcoming the collapsing frictional forces.

Given a constant pressure set by the Sporting Arms and Ammunition Manufacturers' Institute (SAAMI) standards, there is a tradeoff between weight and velocity with equal pressure (as in all projectile types). A heavier, slower round will have more momentum and less drag than a lighter, faster round (drag goes up at the square of velocity) therefore, penetration depth will be increased with the heavier slower bullet. Correspondingly, given an equal pressure, making a round lighter and faster increases drag, decreases momentum (even though the projectiles energy has increased) and therefore decreases penetration depth, but will have a larger wound diameter with a fluted bullet. Penetration depth is a function of the momentum and drag of the projectile. As the fluid transfer jet removes surrounding tissue, it limits actual contact on the sidewall of the projectile which lowers drag and increases penetration depth. The overall volume of the wound for fluted rounds may be larger or smaller depending on the above trade-offs of velocity and weight, where weight controls penetration depth and velocity controls wound diameter.

Since velocity is one of the primary factors for wound diameter, the one feature that a shooter can control is barrel length. Please contact us for data on velocity results from non-standard (longer and shorter) barrel lengths. If weight stays the same and velocity is increased (longer barrel or +P ammo), a small increase in projectile velocity will result in a much larger increase in drag limiting increased penetration. Therefore, the penetration depth does not increase linear with velocity or momentum because the drag is also increased by more than its equal proportion. Typically, with non-deforming and non-tumbling rounds (FMJ and fluted projectiles) an increase in velocity of 10% will result in about a 4-8% increase in penetration depth with the same weight bullet. An increase in only velocity will create a linear increase in 1 dimensional diameter, an exponential increase in 2-dimensional area and a less than linear increase in penetration depth, resulting in a 3-dimensional increase in volume of wound that is greater than linear, with respect to the increase in velocity, as seen in testing.

Example from testing:

A 9mm FMJ (non-deforming projectile) 124 grain with a velocity of 1140 penetrates 28.1 inches.

A 357 Sig FMJ 125 grain with a velocity of 1370 penetrates 32.1 inches. That's a 20% increase in velocity, a 45% increase in energy, but only a 21% increase in momentum and a resulting 14% increase in penetration depth (less than the increase in momentum or velocity as the math shows above.)

- The Maximum Fluid Transfer Force (MFTF) (bullet face area x working area % x muzzle velocity) is the most force that can be applied by that exact projectile to adjacent tissue.

[78] Geophysical Research Abstracts. "Energy dissipation during wave propagation in bimodular media." Kuznetsova, Maria; Pasternak, Elena; Dyskin, Arcady. 2019, Vol. 21

- Power Over Drag ratio (POD) (weight x muzzle velocity / area / 7000) is penetration potential. This is only good as a ratio to other projectiles of the exact same type, where design and material are the same and sidewall drag is similar. This is essentially: Sectional Density x Velocity, expressed in foot pounds.

For exact MFTF and POD comparisons between rounds of the exact same design (same bullet, different pressure or caliber), please contact us. These numbers often explain the testing results.

The coefficient of drag (C_d) stays the same if the shape of the object and media it's traveling through stay the same.[79] FMJ and fluted projectiles are linear, non-profile changing bullets and their C_d is constant. These rounds exhibit a linear decrease in velocity over distance. Hollow points, frangible and tumbling rounds change their profile through expansion, fragmentation and turning, significantly changing their C_d. The cast-off speed, of a fluted round, is approximately 37% of the projectile velocity. Cast-off velocity decreases linearly with projectile deceleration from drag.

Cast-off velocity must be high enough to impact adjacent tissue and destroy it. So, at what point is the velocity of the cast-off too low to create wounding? How deep does the wounding from the fluid transfer occur? The velocity required for a water jet impacting skin to cause tissue destruction is approximately 60 meters per second (200 feet per second or 120 mph). This velocity is determined to predict a safe distance so that a water cannon's water velocity will not cause severe tissue damage (tearing). [80] [81] A change of fluid from water to a higher density or viscosity fluid will have a corresponding increase in damaging effects.[82] Blood is 3% denser than water (1025 kg/m^3 vs 997 kg/m^3). Viscosity is measured in the unit of centipoise (cP). The viscosity of water is 1 cP. Normal human blood serum viscosity relative to water is 1.8 cP.[83] For a liquid of 1.8 cP and 103% density to have the same force as water traveling at 200 fps, it must travel at 140 fps (non-linear due to exponential velocity formulas). At that cast-off velocity, human skin will be torn and destroyed. Since cast-off velocity is approximately 37% of the bullet's velocity, then to achieve 140 fps cast-off velocity, the projectile must travel 380 fps or greater.

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[79] National Aeronautics and Space Administration (NASA). article "The Drag Coefficient". Tom Benson. 2021 https://www.grc.nasa.gov/www/k-12/rocket/dragco.html

[80] https://phr.org/our-work/resources/health-impacts-of-crowd-control-weapons-water-cannons/

[81] Department of Justice, report. "Water Cannon-Police Weapons Center Report Series 4-70" LC Miller 1970

[82] Open Democracy, article. "White-washing the water cannon: salesmen, scientific experts and human rights abuses". Anna Feifenbaum. 2014. Retrieved 15 July 2015

[83] Cardiology Physiology Concept. article "Viscosity of Blood". Dr Richard E. Klabunde. 2022 https://www.cvphysiology.com/Hemodynamics/H011

Fluid flows without force at a wave propagation speed. "Fast-moving flow is called supercritical. In this case, the flow velocity is faster than the wave propagation speed".[84] "Wave propagation speed of water is approximately 16.2 m/s" (53 fps).[85] "As the density and viscosity rise, as in the case of liquified human tissue, the wave propagation speed decreases due to the higher flow resistance." [86] "The velocity by which the disturbance travels through the medium is the wave velocity. Pulse wave velocity is one of the main parameters in hemodynamics (the study of blood flow)." [87] Per Poiseuille's law, which describes the smooth flow of a fluid, the flow rate F is proportional to the pressure drop $\Delta p = p_1 - p_2$ divided by R, the resistance to flow. The resistance to flow, in turn, is directly proportional to the viscosity η. Therefore, the wave propagation speed of blood and roughly that of liquified tissue is approximately 30 fps.

The average muzzle velocity of a fluted round is approximately 1,500 fps. Therefore, 75% of the penetration depth is caused by a projectile with sufficient velocity (140 fps) that the liquid cast-off causes tissue tearing. After that percent of penetration, the wound size will equal the diameter of the projectile. Another effect that adds to fluid transfer causing damage and destroying internal tissue even more than the above figures show, is that the above calculations are for the velocity of fluid required to tear skin. Internal muscle tissue and organs have a lower tensile strength than skin. "Results: The full-thickness skin strips had a median tensile strength of 604 N/cm. The tensile strength of the muscle fiber was between 110 N/cm and 43 N/cm, depending on the muscle.[88] This directly correlates with the FBIs finding: "The skin is tough and flexible. Experiments have shown that it has the same resistance to bullet passage as approximately four inches of muscle tissue."[89] Therefore, the cast-off velocity required to destroy internal tissue is far less than what is required to tear through all the layers of skin. Unfortunately, no actual water velocity required for internal tissue destruction is available. It is more probable that the actual percentage of penetration depth where the fluid transfer causes internal tearing is 90% or more.

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[84] Practical Engineering. article. "Hydraulic Jump". 2019
https://practical.engineering/blog/2019/3/9/what-is-a-hydraulic-jump

[85] The Physics Classroom. article. "The Speed of a Wave".
https://www.physicsclassroom.com/class/waves/Lesson-2/The-Speed-of-a-Wave

[86] ResearchGate. article. "Effects of Liquid Viscosity on the Wave Velocity". 2015
https://www.researchgate.net/publication/275953721

[87] ScienceDirect. Journal of Biomechanics. "Effect of viscosity on the wave propagation". 2015
https://www.sciencedirect.com/science/article/abs/pii/S0021929015005102

[88] National Library of Medicine. Article. "Experimental evaluation of fiber orientation-based material properties of skeletal muscle in tension". Chetan D Kuthe, R V Uddanwadiker, Alankar Ramteke. 2016. https://pubmed.ncbi.nlm.nih.gov/25831858/

[89] Fackler, M.L., M.D., Director, Wound Ballistics Laboratory, letter: "Bullet Performance Misconceptions", International Defense Review 3, 1987.

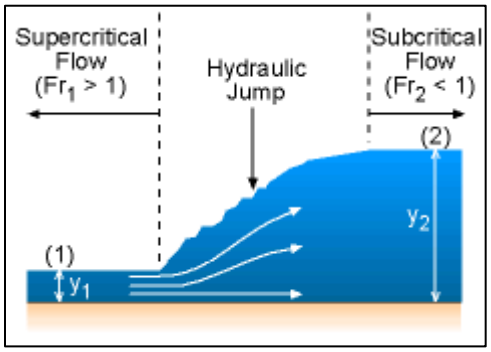
This is also shown in testing with animal tissue, during live animal shooting (hunting) post-mortem dissections and forensics reports of humans after a gunshot wound with a Fluted-Fluid Transfer round, where the diameter of the wound exceeds the diameter of the projectile through a deeper penetration depth.

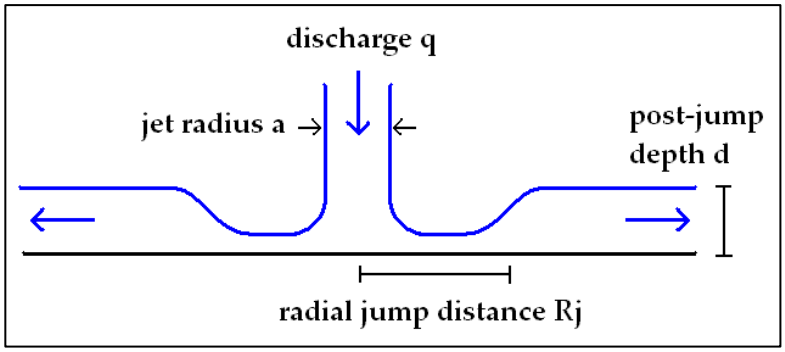
Tissue testing, hunting and human forensics reports have also provided data exhibiting a **non-linear 3-dimensional volume of wound increase with an increase in projectile velocity,** as noted in the eight data point APC velocity case study (contact us for that report) and the four data point Lehigh Defense XD 9mm case study (see last page of chapter "Ammunition Tested"). Also, the wound pattern during tissue testing was extremely well defined with a larger than projectile diameter hole and almost perfectly symmetrical smooth wound channel. Given that tissue isn't symmetrical, a smooth wound channel was unexpected. During post-shooting dissection of the tissue, the area around the hole (much larger than the diameter of the bullet) seemed to be completely unaffected and with equal resilience and composition to tissue further away from the wound track. It was assumed that the cast-off would tear tissue immediately outside the projectile track for some distance depending on velocity (which we saw) and that as the distance away from the wound track increased, the amount of tissue damage would decrease linearly (this we didn't witness). Linear tissue disruption isn't present.

Hydraulic jump explains the non-linear increase in wound volume with increased velocity, the well-defined symmetrical wound channel, and why non-linear tissue disruption is present.
"A hydraulic jump is a fluid shockwave created at the transition between laminar and turbulent flow." [90] It is caused by a fluid flowing faster (critical speed) than the wave propagation speed of that fluid in regards to its flow characteristics derived from the density and viscosity. If the initial speed of the fluid is below the critical speed, then no hydraulic jump is possible. A fluid speed greater than wave propagation speed is termed supercritical. The Fluted-Fluid Transfer rounds create a supercritical cast-off velocity. With a blood fluid wave propagation speed of approximately 30 fps (as calculated and noted above) and the focused, concentrated cast-off velocity starting at over 550 fps, with the linear deceleration, these projectiles have a supercritical cast-off for almost 95% of its penetration depth.

[90] "Hydraulic Jump", Keith Bechtol, October 31, 2007. (Submitted as coursework for Physics 210, Stanford University)

Radial Hydraulic Jump

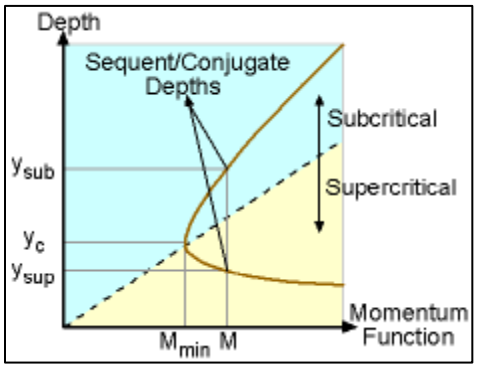


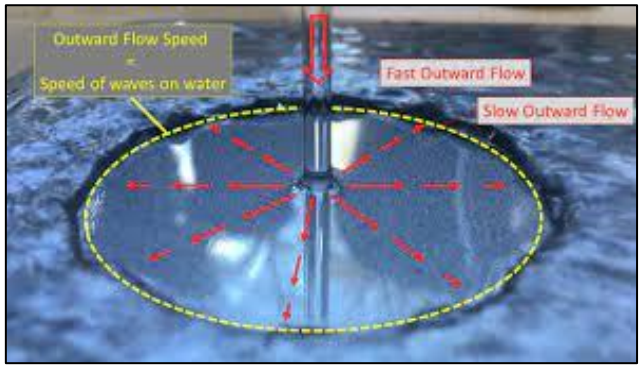


As the velocity of cast-off remains greater than liquid tissue and blood propagation speed (30 fps), the outward flow of the cast-off contacts adjacent tissue not impacted by the bullet at a Supercritical Flow speed which does not allow for a rebound or absorption of the force. The focused cast-off tears and destroys the adjacent tissue instead of simply stretching it, which would happen at subcritical flow speeds. At Supercritical Flow, the Specific Force stays high until dissipation causes the hydraulic jump and Subcritical Flow speeds where the velocity decreases non-linearly. This creates the discreet wound channel, and describes why the tissue outside the wound channel is not affected. Specific Force (Momentum Function)[91] (M) can be defined as:

$$M = \frac{Q^2}{gA} + zA$$

The Specific Force diagram plots the specific force as a function of the channel depth (y versus M), which is the focus and amount of cast-off. These diagrams show a non-linear increase in the area affected outside the radial jump distance (R_j) and a non-linear velocity decrease.





[91] eCourses. website "Fluid Mechanics Theory" https://ecourses.ou.edu/cgi-bin/ebook.cgi?topic=fl&chap_sec=10.3&page=theory

In the hydraulic jump region caused by the constriction in the flute causing high speed fluid transfer, we have a flow greater than supercritical speed which follows the Continuity of Fluid Flow Equation.

$$Q = A_1V_1 = A_2V_2$$

Q = the volumetric flow rate, A = the cross-sectional area of flow, V = the mean velocity

As the area of the flow decreases (constriction) we must see a corresponding and equal increase in the velocity of that flow.

The constricted flow caused by the flutes can be described in Bernoulli's Equation[92], which states that an increase in the speed of a fluid occurs simultaneously with a decrease in static pressure or the fluid's potential energy. Bernoulli's equation is a derivative of the Work Energy Theorem which states that the net work done by the forces on an object equals the change in its kinetic energy. Each particle in the flow has pressure exerted on it from every direction, but not equally. The flow direction and acceleration is a derivative of the Work Energy Theorem from Newtons 2nd law of motion[93], which states that (F = ma), or net force is equal to mass times acceleration. The Momentum Function is a linear increase in fluid force with an increase in velocity. Therefore, the outward force of the fluid jet in the flute is increased linearly with increased velocity corresponding to a linear increase in diameter which then increases the area of the wound exponentially (Area = $\pi \times r^2$). The force applied to the surrounding tissue is only increased linearly, but the two-dimensional area is increased exponentially. Also, as the weight of the projectile remains the same and the velocity is increased (so the pressure must have been increased by either a +P cartridge or increasing barrel length) the overall penetration depth is also increased. All three dimensions are increased, two by the increase in wound diameter and area and the third with the deeper penetration. The non-linear wound volume increase could be falsely assumed to be caused by the energy of the fluid ($E = \frac{1}{2} mv^2$). But in calculating the energy increase from velocity increase of the fluid, the resulting wound channel should be much larger than seen in testing, proving the above fluid momentum function.

-Supercritical Flow is smooth and focused, in-line directly away from the source, causing an ever-increasing wound diameter.

-Subcritical Flow is chaotic and turbulent, moving in multiple directions, not directly away from the source.

-The hydraulic jump between the two flows is a discreet area where the flow abruptly

[92] Princeton University Physics Department "Bernoulli's Equation": https://www.princeton.edu/~asmits/Bicycle_web/Bernoulli.html

[93] Integral Physics: https://www.youtube.com/watch?v=fq8zqRRBEEY

changes in focus, direction and velocity non-linearly.[94] The hydraulic jump distance defines the wound diameter.

Penetration: The penetration depth for the Fluted-Fluid Transfer rounds is between 15-23 inches during the FBI series of gel tests for determining penetration depth. Some non-duty hunting variants penetrate as deep as 41 inches. Penetration depths are very consistent for all projectile weights and calibers. Post-shooting medical and forensic report analysis shows that so far there have been no incidents of fluted-fluid transfer rounds exiting a human target after hitting the thoracic cavity.

Reliability / Consistency: Fluted rounds have a high reliability ($\geq$90%) and consistency rate. Tumbling or turning was witnessed in less than 10% of the rounds tested in gel and tissue, with and without barriers. When witnessed, almost all of the turning incidents happened in gel and were witnessed as a result of gel rebound at the end of penetration and did not occur during projectile travel. The few incidents of turning during penetration were always at the end of the penetration depth, where the negative effects of tumbling are less pronounced. Analysis of a large number of real-world post-shooting medical reports indicates that as of the time of this report not a single incident of failure to function has occurred with this projectile type.

Barrier Performance:

Light Domestic Barriers: Fluid Transfer rounds exhibited a reduced effectiveness of 5-15% when encountering light domestic barriers (Light Barrier Degradation %).

Heavy Barriers:

- Fluted rounds deflect off the 8" target <10% of the time

- Fluted rounds fail <10% of the time

- Fluted rounds are degraded approximately 30% if they don't deflect or fail

- Overall capability reduced <50% from heavy barriers

Armor: The armor penetration ability of the Fluted-Fluid Transfer rounds was varied. Please see attached armor data sheet for complete results. "Since these bullets are typically monolithic solids, they perform better against barriers, specifically armor (NIJ levels HG1 & HG2). Depending on

[94] Radial Hydraulic Jump:
https://www.youtube.com/watch?v=OoA1ASjMfag
Another video showing the relationship of wave propagation inside and outside of the hydraulic jump region. (go to time 5:37-10:15)
https://www.youtube.com/watch?v=p3P4iKb24Ng

the flute and nose design, they tend to maintain their overall shape and perform as designed through barriers (light domestic and heavy).[95]

Permanent Wound Cavity: The Fluted-Fluid Transfer rounds PWC range is from 6.7-22.2 cubic inches. Liquefaction from impact, and then constriction through the venturi effect sends a jet of high-speed liquid tissue into surrounding tissue outside of the projectile's diameter with sufficient force to cause tearing and add to the permanent wound cavity caused by the surface areas direct impact of the bullet. The wound diameter for these rounds in every single tissue test (phases 4 & 5) exceeded the projectile's diameter, proving that the fluid transfer effectively destroys adjacent media. This was shown in gel and animal tissue with and without barriers. It has also been witnessed in hunting encounters and real-world forensic data on live human targets. All the examples tested create holes of a larger diameter than any hollow point, or FMJ in the same caliber, and with the deep penetration, overall wound volumes (VWI) are greatly more significant than any other projectile type. Testing and analysis by the US military from 2015-2024 measured projectile effects for ammunition in 5.56x54mm 7.62x51mm NATO, 300BLK, 7.62x39mm (AK-47), 5.45x39mm (AK-74) and several pistol calibers. FMJ, hollow points and several Fluted-Fluid Transfer pistol rounds were tested in pistols. Measurement calculations of penetration depth, barrier performance to include amor and permanent wound cavity size were determined. In a handful of cases the Fluted-Fluid Transfer rounds not only created larger wound diameters and areas, but also created larger overall permanent wound cavity volumes when compared to the above-mentioned rifle calibers. In non-compressible gel, the cavities created by the hydraulic effect are artificially large, 3-4 times the size of those created by hollow points in the same caliber. However, in actual tissue, the wound volumes are roughly 2.0-2.5 times larger than that of hollow points in the same caliber, as shown during our phase 4 and 5 testing and medical examinations.

[95] Matt Hoffman. Buffman Range-Independent 3rd party testing. Review of chapter. May 2024 https://www.youtube.com/channel/UCE0hyXJkKD_JyEeoA0OrROw

Summary of Fluted-Fluid Transfer rounds by Caliber:

CALIBER	NUMBER TESTED	AV WOUND DIAMETER	PENETRATION Min / Av / Max	AV PWC VWI
9mm	15	.83”	15.1 / **17.1** / 19.5	9.83”
.380	2	.69”	12.5 / **13.9** / 15.2	6.1”
.357 Sig	3	1.13”	17.5 / **18.7** / 20.2	14.2”
.40	11	1.12”	18.0 / **18.9** / 21.4	14.8”
10mm	4	1.15”	19.2 / **20.4** / 22.3	17.5”
.45	9	1.05”	17.9 / **19.2** / 19.7	13.6”

4. Frangible: These rounds are designed to break apart and fragment upon striking a target or a barrier either immediately at the surface or after minimal penetration. They are expected to create large diameter wounds that do not penetrate deeply. There are two main designs of frangible rounds. First are projectiles designed with fragments that penetrate very shallow to create multiple wound paths and some fragments, namely the core, that provide deeper penetration, and do go through light domestic barriers such as dry wall. Second are bullets designed not to pass through light domestic barriers and offering shallow penetration depth with all fragments, the so called “apartment safer” rounds. The latter are intended to not create a collateral damage hazard to persons or items in other rooms as the bullets break apart on a wall if the target is missed. Additionally, there are fragmenting training rounds designed to break apart when shooting steel targets to minimize ricochet, which we will not cover here.

With either design, since penetration being judged as the most crucial characteristic, these shallow penetrating rounds may not go deep enough to encounter important body parts and typically do not penetrate bone that protects many of the critical human organs. “Frangible rounds eliminate any reasonable penetration. Such a bullet will break up to fast to penetrate to the vital organs.”[96] Note that as an object fragments it exposes some of the inside material, which after fragmenting

[96] US Department of Justice, “Handgun Wounding Factors and Effectiveness”, FBI Firearms Training Unit, Quantico, VA, September, 1989

becomes surface area. Therefore, since the surface area increases, the drag increases and the penetration depth decreases. Also, fragmentation does not reliably occur in soft tissue handgun wounds due to the low velocities of handgun bullets. "When fragmentation does occur, fragments are usually found within one-centimeter (.39 inch) of the permanent cavity."[97] This was witnessed during testing as the fragmented pieces travel farther way from the wound track in the low density IWBA gel ($\leq$45 angle from the ballistic path and $\leq$ 2 inches away from the center track) than in the tissue tests where dissection of the media did not show an outward spread of the fragments ($\leq$30 angle from the ballistic path and $\leq$ .5 inches away from the center track). Also, many of the pieces were in the wound track of another piece and did not contribute to increased wounding. There is no aerodynamic, hydrodynamic or explosive force pushing the fragments away from the wound track. As the projectile breaks into separate pieces, they will follow the same original path of the bullet. Accomplishing the equations for surface area increase of a sphere when splitting into 2, 4 and 8 pieces and taking into account multiple tracks, the average reduction in displaced volume (wound channel size) averages over 35%. These combined issues are why the overall wound volume is less. See chapter "Mechanics of Projectile Wounding: 4. Fragmentation" for a more detailed explanation of the physics of fragmentation. If minimal penetration or absolute barrier stoppage is desired, then Frangible rounds are designed for that task.

Penetration: None of these rounds penetrated the minimum required 12 inches of ballistics gel, except when they failed to open. The average penetration for frangible rounds is 10 inches. The projectile core continues forward after fragmentation and travels to the measured penetration depth, while the fragments only averaged about half that depth. Overall penetration measurements are based on the deepest fragment (typically the core), not the average of the fragments which is much shallower.

Reliability / Consistency: Frangible rounds have a high reliability ($\geq$85%) and consistency rate. The only common failure of frangible rounds is failure to fragment, which is rare. Remember fragmenting is not a failure with this projectile type, because that is their designed mechanism.

Barrier Performance:

Light Domestic Barriers: These fragmenting rounds are specifically designed to break apart on contact with almost all substances, whether a light domestic barrier like dry-wall or a tissue target. As such, they exhibited a reduced effectiveness of up to 95% when encountering light domestic barriers. Unfortunately, some rounds tested had the core continue through barriers. Although the wounding was minimal, the effects may not be desired.

Heavy Barriers / Armor: None of the rounds tested passed through, exhibiting a 100% reduction in capability as designed.

Permanent Wound Cavity: The Frangible rounds PWC range is from 1.8-6.9 cubic inches. The average permanent wound cavity of frangible rounds tends to be less than the fluid transfer, hollow point or FMJ (Please see chapter "Mechanics Of Projectile Wounding", D Fragmentation.) and is

[97] DiMaio, V.J.M.: "Gunshot Wounds", Elsevier Science Publishing Company, NY, NY

extremely difficult to measure because in gel the multiple fragments / projectiles produce many tiny hard to measure wound paths and in tissue most of the rounds Did Not Exit (DNE on the data sheet) so measuring wound exit diameters was problematic. In many cases the datasheets do not have a permanent wound cavity (phases 2 and 3), average hole area (phases 4 and 5) or a Volume of Wound Index (VWI) displayed due to the inability to measure each wound channel to a satisfactorily accurate degree.

Summary of Frangible rounds by Caliber:

CALIBER	NUMBER TESTED	AV WOUND DIAMETER	PENETRATION Min / Av / Max	AV PWC VWI
9mm	7	.61"	4.0 / **9.6** / 15.2	3.6"
.40	4	.45"	5.0 / **9.1** / 11.5	
.45	4	.55"	4.5 / **10.8** / 16.0	
5.7mm	6		13.2 / **15.3** / 20.5	5.1"

5. Tumbling: This projectile is very similar to a Full Metal Jacket (FMJ). It doesn't expand like a hollow point or fragment into pieces like a frangible round. It remains together and doesn't change its shape, but unlike an FMJ that stays straight and in-line, the tumbling bullets, upon impact, violently and chaotically turn end over end. These projectiles are designed to have a displaced center of gravity creating an unstable bullet. The bullets are perfectly stable in flight as the rifling of the barrel imparts a stabilizing spin. Any slight deviation from an external source (air) isn't enough to yaw the bullet because of the stabilizing spin. Upon impact with the target the bullet immediately starts to slow and any non-symmetrical force applied to it from something denser than air (water is more than 1,000 times denser than air and if you take density / viscosity of human liquefied tissue into account, it is 2,100 times denser than air) starts a yawing motion and the imbalanced center of gravity causes the projectile to tumble. Since it is considerably longer than it is wide, the wound channel is substantially larger than an FMJ. The longer and thinner the bullet is, the easier it is to create the center of gravity imbalance that the tumbling occurs reliably. Also, the higher the speed at impact the more the tumbling reliably occurs as it cannot simply weather vane and self-correct. At high speed as the yaw develops the large surface area forward of the center of gravity has a large amount of drag increasing the yaw and the momentum of the heavyweight base tumbling forward cause the flip. This tumbling is one of the primary kill mechanisms of high-speed anti-personnel rifle rounds (NATO 5.56x45mm, NATO 7.62x51mm,

7.62x39mm (AK-47) and 5.45x39mm (AK-74), the 5.7x28mm and the 4.6x30mm rounds and is extremely effective. There is a direct trade-off between stability and potential range. A round that is designed for long range applications, like some rifle rounds, need to be so stable as to fly perfectly straight with no or minor imbalance for extreme accuracy over the relatively long time of flight. This is the case of the US military's M-16 chambering the 5.56x45mm round that is designed for 600-900 yards operational use.[98] Increasing that stability for better ballistic qualities may impair the projectiles' ability to become disturbed enough on target to create a yaw large enough for the bullet to tumble. Creating a more imbalanced bullet will increase its potential for tumbling when disturbed at impact but may make it unstable enough for long time of flight, thereby reducing its long-range accuracy. This is the case of the 7.62x39mm military round used in the AK-47 that is designed for approximately 350 yards operational use.[99] NATOs requirement for the 9mm replacement, which spawned the 5.7x28mm and 4.6x30mm and the competition between the three calibers from 2002-2003 set an effective range requirement of 200 meters (219 yd). That short range requirement allowed both the 5.7mm and 4.6mm to be designed highly unstable allowing for earlier and more violent tumbling creating larger wound cavities. Obviously, the weapon and the round together account for the overall accuracy potential, but creating a more accurate weapon for a relatively unstable short-range round doesn't make sense, so the two must complement each other. Unfortunately, in normal handgun calibers like the 9mm, .40 S&W, 10mm, .45 ACP and the like the bullet is not long and thin enough to create a large center of gravity imbalance and the velocities at impact are extremely lower than required to cause a destabilizing force producing a yaw that results in tumbling. During testing in those normal handgun calibers with projectiles that are designed to tumble, with a sample size or over 60 shots, none of the normal pistol calibers produced tumbling even half the time and some calibers never tumbled at all essentially becoming FMJ. This was true in both gel and tissue with and without barriers. For that reason, traditional pistol caliber rounds designed to tumble are simply a gimmick and are completely unreliable.

When projectiles tumble there are many substantial benefits. This applies to rifle rounds as well as 5.7x28mm and 4.6x30mm.

1. Many tumbling projectiles have penetration tracks that are curved. The overall penetration depth is simply a measurement of the distance between the bullet entry and where it stopped. Penetration Depth (PD) is used by every agency to determine the overall depth the projectile should achieve to make sure it goes deep enough to impact or penetrate the vital organs of the target and is considered the most important component in terminal wound ballistics and the round being able to accomplish its desired results. A tumbling bullet that has a curved penetration path is passing

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[98] US Marine Corps. "Introduction To The Service Rifle" presentation. (also) US Marine Corps "Instructor Guide". (also) "Military Small Arms of the 20th Century" Hogg, Ian V.; Weeks, John S. (2000)

[99] "AK-47 Kalashnikov modernized rifle, caliber 7.62mm". Izhmash. Archived from the original on 6 October 2014. (also) "Kalashnikov". Alpharubicon.com. March 1998. Archived from the original on 13 May 2012.

through and destroying more material. If two bullets penetrate the same depth (PD), the one whose wound trajectory curves has an overall longer path and therefore more damage. Post impact curved trajectory Penetration Track Length (PTL) is the measurement of the entire track the projectile took and must be used to determine the overall Permanent Wound Cavity. PTL is used in the Total Volume of Wound Index (TVWI) for projectiles that exhibit curved wound trajectories and is measured and calculated separately for each round. Both Penetration Depth (PD) and Penetration Track Length (PTL) are important in determining what the round is capable of doing inside a target. Hollow points, FMJ and fluted bullets do not have a curved path and therefore their PD=PTL. During testing PTL is measured in IWBA gel and animal tissue. Most tumbling defensive 5.7x28mm pistol rounds show a PTL that is approximately 5-15% longer than the PD.

In gel testing (phase 2 and 3)

5.7x28mm defensive tumbling projectiles exhibited a PTL 5-15% longer than PD.

5.56x45mm M193 exhibited a PTL 10% longer than PD and the M855 9%.[100]

7.61x39mm (AK-47) 57N231 exhibited a PTL 5% longer than PD.[101]

5.45x39mm (AK-74) 7N6M exhibited a PTL 12% longer than PD. [102]

In tissue the tumbling 5.7mm projectiles showed a more divergent trajectory angle when compared to gel. It is surmised that the increase in density of tissue vs gel and the variance of that media causes a pronounced increase in asymmetric counter-force leading to earlier and increased yaw. A total PTL cannot be measured in tissue because the bullet completely passes through to allow measurement of the exit wound dimension without disturbing the media. Also, in gel a 3-dimensional post shot cross section can be observed and measured. Therefore, the angle and amount of curvature can only be precisely calculated with gel. This suggests that the percentage increase of PTL over PD increases in tissue vs gel for all tumbling rounds, rifle and pistol and this is confirmed in the referenced US Army forensic research. In military forensic exams medical reports from the review of 1,400 rifle wounds (M-16 5.56x45mm and AK-47 7.62x39mm) describe bullets traveling much more chaotic and non-linear paths than what is seen in the US Army gel test reports describing projectile functions and internal trajectories.[103] This compares

[100] US Army Institute of Research. “Effects of Small Arms on the Human Body” Wound Ballistics Laboratory.

[101] International Wound Ballistics Association. “Wound Ballistics Review”, volume 5.

[102] Ibid

[103] US Army. Wound Data and Munitions Effectiveness Team (WDMET) “Gunshot Wounds: 1.Bullets, Ballistics and Mechanism of Injury” Jeremy J Hollerman, Douglas Coldwell

favorably to what is witnessed in the tissue testing described above. So even though a PTL can only be measured and calculated for each round independently in phase 2 and 3 gel, the tissue testing and forensic reports conclusions support those figures and show the gel testing to under estimate its overall additional benefits. Therefore, a quoted minimum increase of 5-15% is easy to support with test and real-world data.

Some interesting observances have occurred during these PTL measurements and rifle wound analysis. 1. The longer the projectile, the more the center of gravity imbalance may occur and the more the tumbling occurs early in the media and more violently, which then exhibited more of a curved trajectory. 2. The heavier bullets have a higher momentum which decreases the chance of re-vectoring and lessens the amount of curvature in the wound path. 3. The higher velocity projectiles produce a faster, more erratic tumble when yaw is encountered and tend to have a more pronounced curved trajectory. These observations show a trade-off, that if the round is shortened to decrease weight and increase velocity, at some point there is not enough cg imbalance to create a violent tumble, the wound will be smaller because the bullet is smaller and the lack of momentum greatly decreases the penetration depth.

2. Tumbling bullets with a curved wound path also exhibit a better chance of staying in the target, providing a larger longer wound and reducing the chance of over-penetration. Unfortunately, this may mean the projectile veers off path and misses the target within the target.

3. The cross-sectional wound pattern of a traditional pistol round is vastly different than a tumbling projectile, which has an initial wound channel that is narrow. This takes place in a part of the target that does not include important vital body parts. Tumbling occurs deeper in the target and is the largest portion of the wound channel and happens where the vital organs are located. On the negative side this may reduce external bleeding and depressurization. Therefore, an important aspect to this wound profile is the depth at which the tumbling starts. This is critical in ensuring that the tumbling effect happens inside of the target causing a large wound at a depth of normal important organs and limiting overpenetration.

> 5.7x28mm projectiles tumble reliably starting at the 4-5 inch depth and penetrate 9-21 inches in gel.
>
> 5.56x45mm (M16/M4) M855 round (16", 1 in 8 twist barrel) (2,900-3,000 fps) tends to start to tumble by the 6-inch point and penetrates 16-24 inches in gel. (US Army acceptable penetration depth).[104]
>
> 7.62x51mm M80 projectile tends to start tumbling by the 9-inch point and penetrates 25-28 inches total in gel.[105]

[104] Wound Ballistic Review, US Army data on M193 and M855 5.56 projectiles.

[105] Wound Ballistic Review, US Army data on M80 7.62 projectile.

4. The extremely high speed (>2,000 fps) may cause a pressure-wave velocity exceeding what a body part can stretch, meaning the temporary cavity may create torn and damaged tissue as is witnessed in some high velocity rifle rounds. Remember that the bullet is slowing down in the air, so muzzle velocity and target impact velocity will be different. Also, the projectile is slowing down rapidly in the target so impacting just above the 2,000-2,200 fps threshold will yield very minimal temporary stretch cavity wounding. "Temporary cavity from a low-velocity handgun has no reliable wounding effects in elastic body tissue and is nothing more than a stretch of the tissues."[106] "The reason is that most tissue in the human target is 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 tissue in which the temporary cavity forms is no more than one tenth of the velocity of the projectile. This well within the elastic limits of tissue."[107] A projectile velocity greater than roughly 2,000-2,200 fps may cause an outward force velocity exceeding the maximum rate of expansion for most human tissue which in turn causes a tearing wound. To quote the FBI Firearms Training Unit: "Unlike high-velocity rounds, there is no temporary wound cavity created by pistol bullets." "Temporary cavity is frequently and grossly overrated as a wounding factor when analyzing pistol wounds."[108] There are five tested 5.7mm rounds that are ≥2,200 fps when fired from a pistol. Please see the section two chapter "Mechanics Of Wounding" and reference "C. Temporary Cavity" for detailed information pertaining to this effect. Also, please see the section two chapter "The Human Target" for detailed information pertaining to this effect on tissue.

5. The low drag nature of a pointed small caliber round allows the projectile to pass through a barrier with less effect on the bullet. This increases heavy barrier and armor penetration capabilities difficult to achieve with a larger caliber pistol round.

Penetration: For the 5.7mm and 4.6mm projectiles, the penetration depth varied from 9-21 inches with an average of just over 16 inches during the FBI series of gel tests for determining penetration (our phase 2).

Reliability / Consistency: The tumbling duty rounds in 5.7mm and 4.6mm have a high reliability rate (≥90%), when tested in gel and tissue, with and without barriers. Tumbling was even noted on the slow speed subsonic rounds, which is a testament to their unstable design. The consistency rate was altogether another issue. Penetration depths are very inconsistent for all projectile weights and designs. The chaotic and unpredictable nature of yaw and tumbling produced vastly different results from shot to shot. The data tables note the average but do not convey the overall spread

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[106] Wound Ballistic Workshop: "9mm vs. .45 Auto", FBI Academy, Quantico, VA, September, 1987. Conclusion of the Workshop.

[107] Fackler, M.L.M.D., Director, Wound Ballistics Laboratory, "Ballistic Injury", Annals of Emergency Medicine 15: 12 December 1986.

[108] Lindsay, Douglas, MD: "The Idolatry of Velocity, or Lies, Damn Lies, and Ballistics", Journal of Trauma 20, 1980.

that was witnessed. The rounds do consistently tumble, pass through barriers and create large overall permanent wound cavities, but the standard deviation between shots rivaled that of the hollow points, where each shot could have largely different measurements.

Barrier Performance:

Light Domestic Barriers: The duty rounds of this projectile type had the highest success rate at defeating barriers over any bullet type, however, the training and civilian rounds did not. The overall results from all rounds combined together is so varied that an average is not well defined. Light domestic barriers only degraded the tumbling rounds by 5-10%, except for rounds designed to fragment. This is the lowest amount of degradation from light domestic barriers of the five projectile types.

Heavy Barriers:

- Tumbling duty rounds deflect off the 8" target <10% of the time.

- Tumbling duty rounds fail <10% of the time.

- Tumbling duty rounds are degraded <25% if they don't deflect or fail.

- Overall capability reduced <40% from heavy barriers. Lowest of the five projectile types.

Armor: The armor penetration ability of the 5.7mm rounds was varied. Please see attached armor data sheet in section three for complete results. Also, reference section four "5.7mm LE/Mil Armor Test Presentation" for results.

Permanent Wound Cavity: The 5.7mm and 4.6mm tumbling rounds Total Volume of Wound Index (TVWI) permanent wound cavity range is from 1.8-14.9 cubic inches. There were no more varied results per projectile type when comparing permanent wound cavity measurements. Some of the training rounds produced very small wound volumes, while some of the duty tumbling rounds produced very large volumes. An average does not represent the information properly. In phase 2/3 gel the diameter of the wound track changes dramatically with respect to penetration depth, both increasing and decreasing and calculating an average diameter throughout the entire depth is impossible. Therefore, the 5.7mm and 4.6mm rounds do not have a gel permanent wound cavity calculated or displayed in the data sheets.

Please reference sections three and four for complete description of these two calibers and the data sheets for exact results, or reference our:

1. 2021 LE/Mil 5.7mm Terminal Wound Ballistics and Armor Test (November 2021). The largest 5.7mm test ever completed including 21 different 5.7x28mm rounds in 5 Terminal Wound Ballistics phases and armor testing in 13 different armor products from 5 different manufacturers.

2. 4.6x30mm Ammunition Review (January 2022)

Summary of Tumbling rounds by Caliber:

CALIBER	NUMBER TESTED	AV WOUND DIAMETER	PENETRATION Min / Av / Max	AV PWC VWI
5.7mm	15		10.2 / **15.9** / 19.9	7.9”
4.6mm	3		14.9/ **15.8** / 16.9	6.5”

In summary all projectiles, regardless of type must:

1. Hit the intended point of aim
2. Go through whatever barrier is in the way and not be deflected / defeated
3. Not fail
4. Go deep enough to destroy something important
5. Make a large diameter (area) wound to destroy a larger about of tissue and increase the chance of destroying an important body part. If the round doesn't hit the CNS, a major required organ or create enough blood loss / blood pressure decrease then its effectiveness is minimal.

Summary of characteristics by projectile type:

BULLET TYPE	PENETRATION GEL INCHES	RELIABILITY	BARRIERS PENETRATED	PWC VWI
HOLLOW POINT	9-18 12-14 average	65%	LIGHT DOMESTIC	1.9-8.3
FMJ	24-32	95%	HEAVY	3.6-5.45
FLUTED	15-23	90%	HEAVY-ARMOR	6.7-22.2
FRANGIBLE	4-16	85%	NONE-LIGHT	1.85-6.9
TUMBLING	9-21	85%	NONE-ARMOR	1.8-14.9

HANDGUN PROJECTILE WOUND PROFILES

This information represents the wound dimensions of all five different handgun projectile types. It does not highlight any differences between calibers as only averages are provided.

1. Hollow Point (HP)
2. Full Metal Jacket (FMJ)
3. Fluted-Fluid Transfer
4. Frangible
5. Tumbling (5.7mm and 4.6mm)

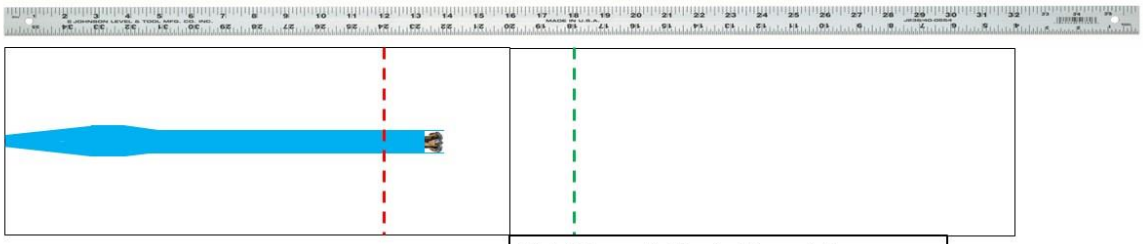
Yardstick and profile picture is to scale and is 36 inches. Rectangle is two 16x6x6 IWBA gel blocks (FBI/DoD standard). The wound profile and rectangle are to scale. Denim Barrier not shown. Federal Standard penetration minimum 12 inch (red) and optimum 18 inch (green) lines included

Wound Profile picture derived from the following:

- Wound shape comes from gel testing, forensic reports and testing in animal tissue.
- Wound diameter comes from forensic reports and testing in animal tissue. It is an average of the three listed calibers.
- Wound penetration depth comes from IWBA gelatin tests by multiple agencies. It is an average of the three listed calibers.

Average Wound Dimension table shows the average of all the rounds tested in that caliber and bullet type. For a list of all the rounds tested and included here, please see the data tables, which includes the individual dimensions used for the averages. CAO August 2025

HOLLOW POINT (HP) WOUND PROFILE

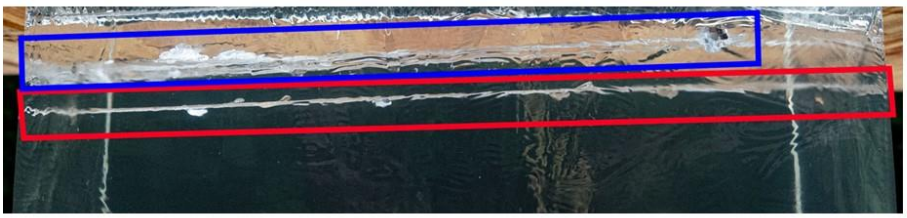


AVERAGE HP WOUND DIMENSIONS

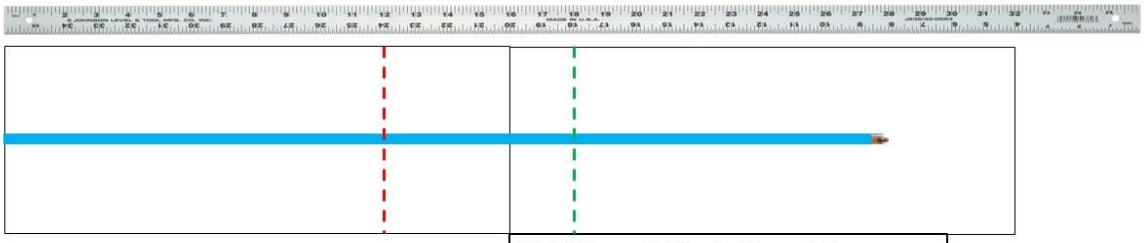
Caliber	Diameter x Penetration Depth
9mm	.58" x 12.8"
40 S&W	.64" x 14.5"
45 ACP	.73" x 14.3"

Light Domestic Barrier Degradation Percentage. Skin, light clothing, plywood, drywall and bones. 15-48% loss

Top blue = HP
Bottom red = FMJ



FULL METAL JACKET (FMJ) WOUND PROFILE

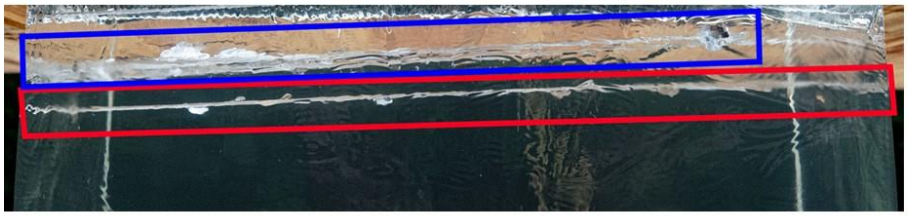


AVERAGE FMJ WOUND DIMENSIONS

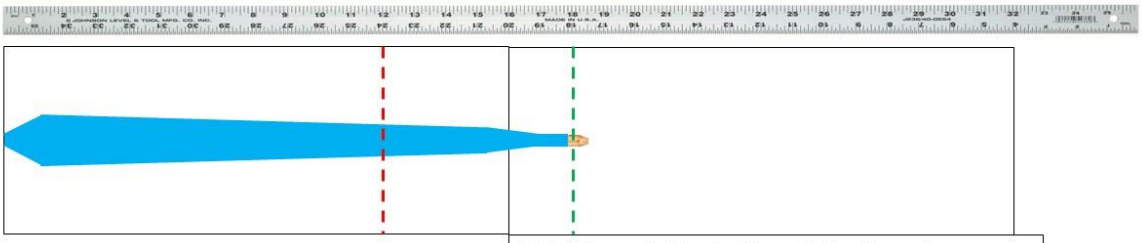
Caliber	Diameter x Penetration Depth
9mm	.35" x 30"
40 S&W	.4" x 31"
45 ACP	.45" x 27.5"

Light Domestic Barrier Degradation Percentage. Skin, light clothing, plywood, drywall and bones. 2-10% loss

Top blue = HP
Bottom red = FMJ



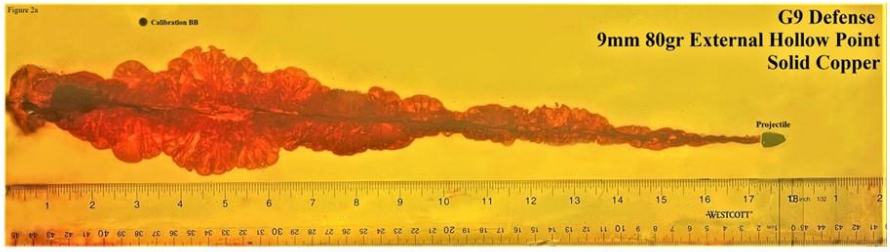
FLUTED - FLUID TRANSFER WOUND PROFILE



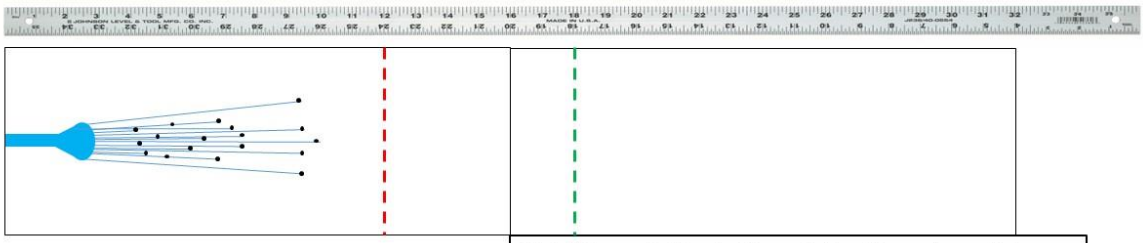
AVERAGE FLUTED WOUND DIMENSIONS

Caliber	Diameter x Penetration Depth
9mm	.83" x 17.1"
40 S&W	1.12" x 18.9"
45 ACP	1.05" x 19.2"

Light Domestic Barrier Degradation Percentage
Skin, light clothing, plywood and bones: 0-28% loss



FRANGIBLE WOUND PROFILE

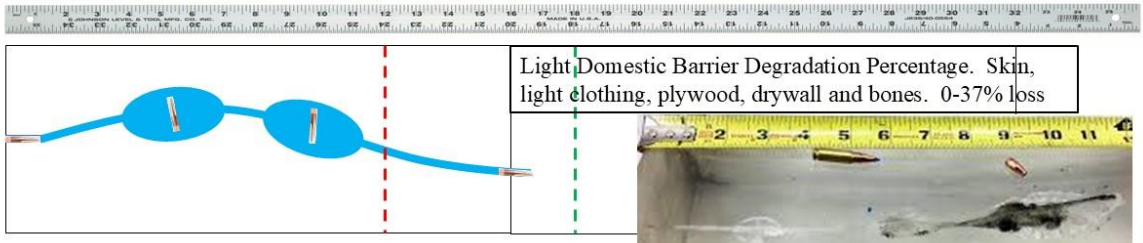


AVERAGE FRANGIBLE WOUND DIMENSIONS

Caliber	Penetration Depth
9mm	9.6”
40 S&W	9.7”
45 ACP	10.8”

Light Domestic Barrier Degradation Percentage. Skin, light clothing, plywood, drywall and bones. 15-100% loss

TUMBLING WOUND PROFILE



Light Domestic Barrier Degradation Percentage. Skin, light clothing, plywood, drywall and bones. 0-37% loss

AVERAGE TUMBLING WOUND DIMENSIONS

Caliber	Penetration Depth
4.6mm	15.8”
5.7mm	15.9”

For a composite view of all five wound profiles, see section one presentation.

Contact us for more information on the wound profiles to include tissue test and forensic results.

AMMUNITION TESTED

One hundred and fifty-eight rounds have been fully tested to date, with a sample size exceeding twenty measured shots for each. We currently have data on 9mm, .380, .357 Sig, .40 S&W, 10mm, .45 ACP, 5.7x28mm and 4.6x30mm. Data on all rounds is included in the spread sheets at the end of this chapter and section three. It is current as of August 2025. All five projectile types have been represented. Below are narrative description summaries of some of the 9mm, .40 S&W and .45 ACP rounds tested. It contains more detailed information regarding reliability, consistency and barrier performance than could be added to the datasheets. Please see sections three and four which includes information and data on the 5.7x28mm and the 4.6x30mm rounds tested. For information on rounds other than those selected here, please contact us.

9MM ROUND SUMMARIES

Included here is a sample list of narrative results from a select group of 9mm rounds that are typically used as duty ammunition. Included are FMJ, frangible, hollow points and fluted-fluid transfer rounds. For the narrative description for other 9mm rounds, please contact us. All shots were fired using stock Glock 17 or Sig Sauer P226 pistols. All rounds were tested at least four times in each of the five standard phases detailed above. All of those results are included in the data sheets. Additional rounds of each type were fired through heavy barriers to include solid wood, auto glass and metal car doors. Armor testing as detailed in the next section was performed with many rounds.

Winchester 124 grain Full Metal Jacket

Penetration: This FMJ penetrated 28 inches during phase 2 testing and 27 inches during phase 3. This is outside of the desired 15-21 inches.

Reliability and Consistency: All phases showed this round to be very reliable and consistent with deviations of less than 5% and no instances of fragmentation.

Barrier Performance: When shot through light domestic barriers this round is nearly barrier blind. There is less than 10% degradation from light barriers. In limited testing versus heavy barriers like auto glass, solid wood and metal this round had course deviations and was misshaped. Wounding effects after passing through heavy barriers was degraded 60-70%, mostly by limiting penetration depths not limiting wound diameter. This round penetrated through HG2 (Level 3A) soft armor. This round did not penetrate through HG2 (Level 3A) hard armor or RF1 (Level 3) hard armor.

Permanent Wound Cavity: The Winchester FMJ has the smallest wound diameter and the second deepest penetration of all the 9mm rounds tested in both gel and tissue. This combination makes for a PWC that is only 10% smaller than the average wound area of a 9mm hollow point (4.0 cubic inches). Its Volume of Wound Index is 3.6 cubic inches.

Overall: This consistent round has fantastic reliability but deeper than desired penetration with above average barrier performance.

Federal HST 147 grain

Penetration: This hollow point penetrated between 15-15.5 inches during phase 2 and 3 testing. Its deeper penetration during phase 3 (plywood barrier) was due to an increased clogging of the cavity causing Failure To Expand (FTE).

Reliability and Consistency: The failure rate of this round (FTE, fragmentation or tumbling) was approximately 30%. During phases 2-5 the round did not consistently open as designed. The recovered bullet showed clogging of the cavity and the petals to be deformed non-symmetrically causing the round to turn sideways limiting the overall wound hole area and limiting expansion.

Barrier Performance: When shot through light domestic barriers this round was misshaped and its results were mixed from excellent performance to minimal. There was 30% degradation from light barriers. In limited testing versus heavy barriers like auto glass, solid wood and metal this round was unreliable. It was deflected, misshaped and fragmented. Overall heavy barrier degradation was over 80%. This round did not penetrate through any HG2 (Level 3A) soft or hard armor.

Permanent Wound Cavity: This hollow point had the largest PWC of the seventeen 9mm hollow points in both gel and tissue. In fact, it was the largest PWC in the FBI test as well. Its Volume of Wound Index is 5.9 cubic inches.

Overall: Introduced in 2002, the Federal HST has always done extremely well in hollow point testing when it comes to penetration and permanent wound cavity size. It is the 9mm hollow point we have tested the most with an overall sample size of over 50 measured shots. Unfortunately, it is not as consistent as some and its reliability goes down when encountering barriers. This round is still one of the top choices in 9mm hollow point.

Hornady Critical Duty +P 135 grain

Penetration: This hollow point penetrated 13.8 inches during phase 2 and 13.1 inches during phase 3 testing. This is lower than the desired 15-21 inches.

Reliability and Consistency: The failure rate of this round (Failure To Expand (FTE), fragmentation or tumbling) was just over 20%. During non-barrier phases this round was the most consistent of all seventeen 9mm hollow points. Its failure rate was lower than others but there were still FTE and turning which greatly reduces the wound hole area. In a couple instances fragmentation occurred with only denim and plywood barriers.

Barrier Performance: When shot through light domestic barriers (plywood) this round was misshaped the least of the 9mm hollow points reviewed here. There was more than 15% degradation from light barriers. In high volume testing versus heavy barriers like auto glass, solid wood and metal this round exhibited a high deflection off-target rate. It was degraded an average amount when compared to other 9mm hollow points with fragmentation being higher than average. Through heavy barriers this round, when not deflected, typically shed its petals and penetrated just over half the distance and with the limited diameter the overall wound was approximately 30% of original (70% heavy barrier degradation). This round did not penetrate through any HG2 (Level 3A) soft or hard armor.

Permanent Wound Cavity: This hollow point has a PWC in the middle of the 9mm hollow points tested in both gel and tissue. Its Volume of Wound Index is 4.4 cubic inches.

Overall: The Hornady Critical Duty +P has reduced the failure rate of 9mm hollow points, but not significantly. By limiting its expansion, it is more reliable but creates a smaller wound. However, it did not produce the deeper penetration that is advertised. This round, introduced in 2011 is still one of the top choices in 9mm hollow point that trades off some terminal effects for better reliability. Forensic data for this round in sufficient amounts has been used for comparison to test data, revealing large differences especially in penetration depths.

Remington Golden Saber 147 grain and 124 grain

Penetration: The 147 grain variant of this hollow point penetrated 17.0 inches during phase 2 and 16.0 inches during phase 3 testing. This is within the desired 15-21 inches and was the deepest penetrating 9mm hollow point tested and vastly exceeded the 13.0 and 12.0 inches of penetration for the 124 grain +P variant of this projectile.

Reliability and Consistency: The failure rate of this round (Failure To Expand (FTE), fragmentation or tumbling) was just over 20%. During all phases (including barriers) this round was the most consistent of all 9mm hollow points. Its failure rate was lower than average, with by far the most common failure being FTE which greatly reduces the wound hole area and increases penetration depth by about 8 inches when compared to fully expanded bullets. This limited or zero expansion is what accounted for the deeper average penetration measurements by over 2 inches.

Fragmentation was rare. The 124 grain variant had a higher failure rate, with more fragmentation and less consistency.

Barrier Performance: When shot through light domestic barriers (plywood) this round was misshaped and typically collapsed and displayed minimal expansion. There was more than 25% degradation from light barriers, but the lack of expansion was fairly consistent. In extensive testing versus heavy barriers like auto glass, solid wood and metal this round exhibited a low deflection rate. It was degraded less than average when compared to other 9mm hollow points with FTE being higher than average. Through the heavy barriers this round typically collapsed and penetrated deeply, but with the limited diameter the overall wound was approximately 35% of original (65% heavy barrier degradation). This round did not penetrate through any HG2 (Level 3A) soft or hard armor.

Permanent Wound Cavity: This hollow point has a PWC in the middle of the 9mm hollow points tested in both gel and tissue. Its Volume of Wound Index is 4.5 cubic inches. The 124 grain +P variant had a reduced Volume of Wound Index of 2.6 cubic inches, mostly due to its higher failure rate and less deep penetration.

Overall: The Remington Golden Saber 147 grain, produced since 1991, is a consistent round with deeper penetration and better barrier performance than most 9mm hollow points. With its limited expansion, it creates a deeper yet smaller diameter wound. This round is still one of the top choices in 9mm hollow point. The Golden Saber 124 +P variant has less penetration, more failures, worse barrier performance and a smaller wound volume.

Speer Gold Dot +P 124 grain

Penetration: This hollow point penetrated 14.8 inches during phase 2 and 13.8 inches during phase 3 testing.

Reliability and Consistency: The failure rate of this round (failure to expand, fragmentation or tumbling) was just over 35%. This round exhibited a lower-than-average reliability and was inconsistent during all 5 terminal wound ballistics phases. Its failure rate with no or light barriers was higher due mostly to fragmentation and then Failure To Expand (FTE) which greatly reduced the wound hole area.

Barrier Performance: When shot through light domestic barriers (plywood) this round was misshaped noticeably more than average. There was just under 40% degradation from light domestic barriers. In limited testing versus heavy barriers like auto glass, solid wood and metal this round was unreliable. It was deflected, misshaped and fragmented. This round did not penetrate through any HG2 (Level 3A) soft or hard armor.

Permanent Wound Cavity: This hollow point has a smaller than average PWC of the 9mm hollow points tested due to its high failure rate limiting both its penetration and wound area size. Its Volume of Wound Index is 2.8 cubic inches.

Overall: Produced since 1991, with only cosmetic changes since, the Speer Gold Dot +P 124 grain round is a high velocity hollow point. As stated earlier, when hollow point velocities near or exceed around 1,200 fps and when smaller diameter (9mm) projectiles with their thinner walls contact a surface, they tend to fail at an incredible rate. This higher failure rate was realized with this round. In concurrent testing with the Speer 147 grain hollow point the heavier Speer hollow point showed only slightly deeper penetration but a lower failure rate resulting in a larger diameter wound and an overall larger PWC.

Winchester 127 grain Ranger T series (RA9TA) +P+

Penetration: This hollow point penetrated between 14-28 inches in IWBA FBI series calibrated ballistics gelatin. Phase 2 average was 14.5 inches and 19.0 inches for phase 3. With a sample size of 6 shots per phase for a total of 12 shots in gel, the results were so inconsistent that further testing is required to get a better standard deviation and average penetration data.

Reliability and Consistency: All phases showed this round to have poor reliability and terrible consistency with deviations of over 50%. We had multiple instances of Failure to Expand (FTE) causing extremely deep penetrations in gel. We also encountered fragmentation and tumbling with light domestic barriers in phase 3 and 5.

Barrier Performance: When shot through light domestic barriers this round exhibited both FTE and fragmentation with just under 40% degradation. In substantial testing versus heavy barriers like auto glass, solid wood and metal this round had minimal course deviations but was misshaped. Fragmentation occurred on almost all shots, but the core tended to have minimal course deflection. Wounding effects after passing through heavy barriers was degraded by limiting both wound diameter and penetration depths. Overall heavy barrier degradation was almost 90%. This round did not penetrate through any armor.

Permanent Wound Cavity: This Winchester hollow point has the third largest permanent wound cavity of the 9mm hollow points tested. Its Volume of Wound Index is 5.5 cubic inches.

Overall: A modified (1994 and again in 2010) version of the 1991 Black Talon loaded at much higher pressure and reserved for law enforcement; this inconsistent round had varied penetration. Its PWC makes it effective. Note: The Sporting Arms and Ammunition Manufacturing Institute (SAAMI) has set a pressure ceiling for standard pressure 9mm Parabellum. at 35,000 pounds per square inch (psi) and 9mm +P at 38,500 psi. There's no SAAMI specification for 9mm +P+; meaning the pressures exceeds +P standards by an unknown amount. Only for use in firearms approved for +P+ ammo, this ammo is about 20-25% higher than standard pressure, which can damage some guns and can be a danger to the operator. Please consult with the firearm manufacturer if in doubt about using +P+ ammo. The pressure of this round may reach 42,000 psi max. average.

G9 APC 77 grain and G9 FR 77 grain

Penetration: The APC is a solid brass, fluted-fluid transfer round which penetrated 19.5 inches during phase 2 and 19 inches in phase 3. The copper First Response (FR) did the same.

Reliability and Consistency: All phases showed these rounds to be very reliable and consistent with penetration and wound dimension deviations of less than 5% and no instances of fragmentation or tumbling.

Barrier Performance: When shot through light domestic barriers these rounds are almost barrier blind. There was < 10% degradation from light barriers. In limited testing versus heavy barriers like auto glass, solid wood and metal these rounds had no course deviations and were barely misshaped. In auto glass there was no measured deflection angle and penetration was degraded by less than 15%. In solid hardwood penetration through six 1-inch boards was recorded. In automobile metal the APC round went through two car doors and hit a target with no deflection on the other side of the barrier. It also penetrated through all 7 HG2 (Level 3A) soft and hard armor products. This round did not penetrate through RF1 (Level 3) hard armor.

Permanent Wound Cavity: The fluid transfer APC and FR have the largest PWC of all 42 9mm rounds tested in both gel and tissue. The Volume of Wound Index therefore is the largest at 14.0 cubic inches.

Overall: Both rounds are reliable and consistent exhibiting optimum penetration. The brass APC is a Law Enforcement and Military only ammunition, rated as armor piercing and has been in production since 2015 with one update. The APC has been extensively tested by USSOCOM and other federal government agencies with favorable results and operational use. The PWC in tissue is realistic and is very large with a diameter wider than any hollow point in any caliber. The barrier performance is unapparelled. During concurrent testing of the G9 First Response (copper version of the APC), the two rounds were almost duplicates until testing in armor and heavy barriers. During armor testing the First Response did not penetrate as well through HG2 (Level 3A) armor products and is not considered ‘armor piercing’ under BATFE guidelines.

G9 EHP +P 80 grain

Penetration: The EHP is a solid copper, fluted-fluid transfer round similar to the companies First Response (FR) and APC listed above, except with a different flute design, weight and velocity. It penetrated 16.8 inches during phase 2 and 16.4 inches in phase 3.

Reliability and Consistency: During all phases these rounds proved to exhibit high reliability and consistency with minimal deviations of penetration and wound dimensions and no instances of fragmentation or tumbling.

Barrier Performance: When shot through light domestic barriers these rounds are almost barrier blind, with almost no degradation from light barriers. In limited testing versus heavy barriers like

auto glass, solid wood and metal these rounds had minimal course deviations and were barely misshaped. This round was tested vs armor and it did not penetrate any level armor.

Permanent Wound Cavity: The fluid transfer EHP created a large PWC as tested in both gel and tissue. The Volume of Wound Index is 11.2 cubic inches.

Overall: There is a standard pressure variant of this round. Both rounds are reliable and consistent exhibiting deeper than average penetration. The PWC in tissue is realistic and is very large with a diameter wider than any hollow point. The barrier performance is excellent vs heavy barriers without the ability to go through armor.

Underwood XD +P 90 grain

Penetration: This solid copper, fluted-fluid transfer round penetrated 16.7 inches during phase 2 and 16.0 inches during phase 3.

Reliability and Consistency: All phases showed this round to be very reliable and consistent with penetration and wound dimension deviations of less than 10% and no instances of fragmentation and one instance of tumbling.

Barrier Performance: When shot through light domestic barriers this round is nearly barrier blind. There was 12% degradation from light barriers. In limited testing versus heavy barriers like auto glass, solid wood and metal this round had no course deviations and was barely misshaped with a degradation of about 25%. In solid hardwood penetration through almost five 1-inch boards was recorded. This round did not penetrate through any HG2 (Level 3A) soft or hard armor or RF 1 (Level 3) hard armor.

Permanent Wound Cavity: The fluted Xtreme Defender (XD) has a larger PWC than any hollow point in any caliber tested in both gel and tissue. Its Volume of Wound Index is 9.8 cubic inches.

Overall: Tested since its introduction in 2015, this fluted-fluid transfer 90 grain XD +P is a reliable and consistent round exhibiting excellent penetration. The PWC is very large with a diameter wider than any hollow point. The barrier performance is excellent vs all but armor. Underwood gets their projectiles from Lehigh Defense owned by Wilson Combat. These particular rounds are called Xtreme Defender and Xtreme Defense by the different companies, but are in fact the same projectile and is not to be confused with the Xtreme Penetrator (XP). Load variations and pressures may be different between ammunition companies, which could vary the velocity and therefore performance. There is a +P+ version of this round. The Sporting Arms and Ammunition Manufacturing Institute (SAAMI) has set a pressure ceiling for standard pressure 9mm Parabellum. at 35,000 pounds per square inch (psi) and 9mm +P at 38,500 psi. There is no SAAMI specification for 9mm +P+; meaning the pressures exceeds +P standards by an unknown amount. Only for use in firearms approved for +P+ ammo, as it is about 20-25% higher than standard pressure, which can damage some guns and can be a danger to the operator. Please consult with the firearm manufacturer if in doubt about using +P+ ammo.

Lehigh Defense CF +P 115 grain

Penetration: This frangible, Controlled Fracturing (CF) solid copper round penetrated 15.2 inches during phase 2 and 14.2 inches during phase 3. These figures describe the overall penetration depth of the core after the three petals break away and radiate outward, away from the original path. The petals themselves broke off around 2 inches deep and penetrated between 3.0-5.5 inches during both phases in gel. All of the petals penetrated less than 3 inches during the phase 4 and 5 tissue testing, with an average of 2 inches penetration depth.

Reliability and Consistency: All phases showed this round to be very reliable and consistent with minor penetration and wound dimension deviations. The designed fragmentation of the nose breaking into the three petals and the remaining core occurred on every shot, regardless of media and light domestic barriers.

Barrier Performance: Light domestic barriers had minimal effects. The core went through the barriers and the penetration depths and dimensions of the core were minimally affected by the barriers. This round was minimally tested vs heavy barriers and as purposefully designed did not penetrate those barriers. No armor testing was accomplished with this round.

Permanent Wound Cavity: The frangible CF, like other fragmenting rounds, has a difficult to measure overall PWC due to the four different parts (core and three petals). Calculating a separate wound volume for each path is problematic and leads to non-precise data. The fragments (three petals) never exited the tissue during phase 4 and 5 leading to only precisely measuring the exit hole made by the core, which penetrated through the media. Therefore, the listed PWC does not include the wound from the petals and is incomplete. Each petal created a small (much smaller than the core) wound diameter and with an average of 2 inches of penetration, combined together account for less PWC than the core itself. The CF's Volume of Wound Index is 2.0 cubic inches, not counting the fragments. One important note is that for most frangible rounds the fragments follow the path of the core or follow other fragment pieces which minimizes additional wounding. The wound channels from the petals of the CF have a less acute angle when compared to other frangible rounds and the max angular spread was close to 45 degrees and all paths of the three petals were distinct. The beneficial shape and mass of each petal adds to this effect.

Overall: A new round from 2023, this frangible solid copper 115 grain Controlled Fracturing bullet is a reliable and consistent round exhibiting excellent penetration. As noted in the chapter “Five Types of Handgun Projectiles” there are two different types of frangible rounds. Rounds designed not to pass through light domestic barriers and offering shallow penetration depth and those whose bullets are designed to provide deeper penetration and still have multiple wound paths that do go through light domestic barriers such as dry wall. The Controlled Fracturing (CF) projectile provides the latter with a fracturing forward portion and a deeper penetrating solid copper core.

.40 S&W ROUND SUMMARIES

Included here is a sample list of narrative results from a select group of .40 S&W rounds that are typically used as duty ammunition. Included are FMJ, hollow points and fluted-fluid transfer rounds. For the narrative description for other rounds, please contact us. All shots were fired using stock Glock 22 pistols. All rounds were tested at least four times in each of the five standard phases detailed above. All of those results are included in the data sheets. Additional rounds of each type were fired through heavy barriers to include solid wood, auto glass and metal car doors. Armor testing as detailed in the next chapter was performed with many rounds.

Winchester 180 grain Full Metal Jacket

Penetration: This FMJ penetrated 31 inches during phase 2 testing and 29.5 inches during phase 3. This is outside of the federal standard desired 15-21 inches.

Reliability and Consistency: All phases showed this round to be very reliable and consistent with deviations of less than 5% and no instances of fragmentation.

Barrier Performance: When shot through light domestic barriers this round is nearly barrier blind. There was less than 5% degradation from light barriers. In limited testing versus heavy barriers like auto glass, solid wood and metal this round had course deviations and was misshaped. Wounding effects after passing through heavy barriers was degraded about 60%, mostly by limiting penetration depths not limiting wound diameter, which is standard for this projectile type. This round did not penetrate through any of the armor products.

Permanent Wound Cavity: The Winchester FMJ has the smallest wound diameter of all the .40 S&W rounds tested in both gel and tissue. It also has the second deepest penetration of all .40 S&W rounds. This combination makes for a PWC that is below average when compared to the .40 hollow points, although it is larger than two of them. Its Volume of Wound Index is 4.5 cubic inches. As a comparison that wound volume is equal to or larger than the wound volume of most 9mm hollow points tested from 2016 to present and is over 10% larger than the average 9mm hollow point.

Overall: This consistent .40 caliber round had deeper than desired penetration and fantastic reliability and above average barrier performance. Its small PWC makes it less effective.

Federal HST 180 grain

Penetration: This hollow point penetrated 18 inches during phase 2 and 17.6 inches in phase 3 testing. This penetration through gel with and without a light domestic barrier is the deepest penetration of any of the ten .40 S&W hollow points we have tested.

Reliability and Consistency: The failure rate of this round (failure to expand, fragmentation or tumbling) was approximately 20%. Shot to shot analysis showed deviations in penetration and expansion higher than normal, although the averages were very high. During phases 2-5 the round did not consistently open as designed. The recovered bullet showed clogging of the cavity and the petals to be deformed non-symmetrically which caused the bullet to undesirably turn sideways. The limited expansion and turning greatly increase the penetration depths of the failed rounds which in-turn increase the average penetration depth.

Barrier Performance: There is approximately a 7% degradation from light barriers. In limited testing versus heavy barriers like auto glass, solid wood and metal this round had mixed results. It was deflected, misshaped and fragmented more than half the shots, but was generally better than all other .40 S&W hollow points vs heavy barriers with about a 60-70% degradation. The projectile did not penetrate through any armor.

Permanent Wound Cavity: This hollow point had the largest PWC of all the .40 S&W hollow points we have tested in both gel and tissue. It has a wound volume exceeding that of any other hollow point in 9mm, .40 S&W and .45 ACP. Its Volume of Wound Index is 8.2 cubic inches.

Overall: The Federal HST has always, since its introduction in 2002, done extremely well in hollow point testing when it comes to penetration, barrier performance and permanent wound cavity size. It is the .40 S&W hollow point we have tested the most with a sample size of over 40 measured shots. Unfortunately, it is not as consistent or reliable as some. This round is still one of the top choices in .40 S&W hollow points.

Hornady Critical Duty 175 grain

Penetration: This hollow point penetrated 17.9 inches during phase 2 and 17.2 inches during phase 3 testing.

Reliability and Consistency: The failure rate of this round (Failure To Expand (FTE), fragmentation or tumbling) was just over 15%. During all phases this round was also the most consistent of all ten .40 caliber hollow points we have tested to date. Its failure rate was lower than other hollow points but there was still some fragmentation and more turning and FTE which reduces effectiveness. These failures limited the wound area size, but increased the average penetration depth.

Barrier Performance: When shot through light domestic barriers this round was misshaped the least of the .40 hollow points, showing almost no degradation from light barriers. In limited testing versus heavy barriers like auto glass, solid wood and metal this round was unreliable. It was deflected, misshaped and fragmented with a large degree of degradation of over 80%. This round did not penetrate through any armor.

Permanent Wound Cavity: This hollow point averaged the second largest PWC of the .40 S&W hollow points, in both gel and tissue. Its Volume of Wound Index is 7.0 cubic inches.

Overall: The Hornady Critical Duty has reduced the failure rate of .40 S&W hollow points, but not significantly, since its 2011 introduction. It is more reliable and consistent but creates a smaller wound. This round is still one of the top choices in .40 S&W that trades off some terminal effects for better reliability.

Speer Gold Dot 165 grain

Penetration: This hollow point penetrated 14.3 inches during phase 2 testing. This is below the desired 15-21 inches. It penetrated 16.0 inches during phase 3. The increased penetration depth after adding a light domestic (plywood) barrier in phase 3 was caused by clogging of the cavity which decreased expansion and drag and therefore increased penetration depth.

Reliability and Consistency: The failure rate of this round (failure to expand, fragmentation or tumbling) was just over 25%. During all phases this round exhibited less than average reliability and the recovered round from the gel tests was very inconsistent. Its failure rate during the 5 phases with no or light barriers was higher due mostly to Failure To Expand (FTE) and turning which greatly reduced the wound hole area.

Barrier Performance: When shot through light domestic barriers this round was misshaped much higher than average. There was just over 30% degradation from light barriers. In limited testing versus heavy barriers like auto glass, solid wood and metal this round was unreliable being degraded by over 80%. It was deflected, misshaped and fragmented. This round did not penetrate through any armor.

Permanent Wound Cavity: This hollow point has a small PWC due to its high failure rate limiting both its penetration and wound area size. Its Volume of Wound Index is 4.1 cubic inches vs 6.1 for the average .40 S&W hollow point.

Overall: The Speer Gold Dot 165 grain has below desired penetration and less than average reliability and consistency. Originating in 1991, it did poorly vs barriers when compared to other .40 caliber hollow points.

Speer Gold Dot 180 grain

Penetration: This hollow point penetrated 16.0 inches during phase 2 and 15.1 inches during phase 3 testing.

Reliability and Consistency: The failure rate of this round (failure to expand, fragmentation or tumbling) was approximately 20%. During all phases this round was more reliable and consistent than its 165 grain version and about in the middle of the .40 caliber hollow points. Its failure rate during the 5 phases with no or light barriers was due mostly to Failure To Expand (FTE) and turning which greatly reduced the wound hole area, but less so than the 165 grain variant.

Barrier Performance: There was under 10% degradation from light barriers. In limited testing versus heavy barriers like auto glass and solid wood/metal this round was unreliable, but slightly better than the 165 grain with a degradation of almost 70%. It was deflected, misshaped and fragmented. This round was not tested versus armor.

Permanent Wound Cavity: This hollow point has an above average PWC when comparing all .40 S&W hollow points. Its Volume of Wound Index is 6.7 cubic inches.

Overall: The Speer Gold Dot 180 grain has sufficient penetration, reliability, consistency and barrier performance. Coming out in 1991 the heavier 180 grain variant has more reliable functioning. It was not superior in any category but deserves consideration for a duty round if selecting a .40 S&W hollow point.

G9 EHP 95 grain

Penetration: This solid copper fluted-fluid transfer round penetrated 19.0 inches during phase 2 and 18.7 inches in phase 3.

Reliability and Consistency: All phases showed this round to be very reliable and consistent with penetration and wound dimension deviations of less than 5% and no instances of fragmentation but tumbling was noted after most of the penetration.

Barrier Performance: When shot through light domestic barriers this round is almost barrier blind. There is approximately 8% degradation from light barriers. In limited testing versus heavy barriers like auto glass, solid wood and metal this round had no course deviations, was slightly misshaped and was degraded by about 30%. This round was not tested versus armor.

Permanent Wound Cavity: The fluid transfer G9 EHP has a very large PWC, greater than any hollow point in any caliber tested in both gel and tissue. Its Volume of Wound Index is 12.8 cubic inches.

Overall: This fluted-fluid transfer ammunition is reliable and consistent exhibiting optimum penetration. Although the hydraulic effect creates an artificially large PWC in non-compressible gel, the PWC in tissue is realistic and very large with a diameter wider than any hollow point in any caliber by a large margin. The barrier performance is exceptionally high. The overall capability of this projectile is exceeded only by the solid brass G9 APC and its copper variant the G9 FR.

G9 APC 77 grain and G9 FR 77 grain

Penetration: These solid brass (APC) and copper First-Response (FR) fluted-fluid transfer rounds penetrated 19.5 inches during both phase 2 and phase 3.

Reliability and Consistency: All phases showed these rounds to be very reliable and consistent with penetration and wound dimension deviations of less than 5% and no instances of fragmentation or tumbling.

Barrier Performance: When shot through light domestic barriers these rounds are barrier blind. There was almost 0% degradation from light barriers. In limited testing versus heavy barriers like auto glass, solid wood and metal there was no course deviations and rounds were barely misshaped. Both rounds went through almost 5 inches of solid wood and car doors with only about 25% penetration degradation. Both rounds were tested vs armor. The APC went through all HG2 (Level 3A) soft and hard armor materials, but did not penetrate through RF1 (Level 3) armor. The First Response (FR) did not penetrate as well through the armor products and is not considered 'armor piercing' under BATFE guidelines.

Permanent Wound Cavity: These two fluid transfer rounds have the largest PWC of all .40 S&W rounds tested in both gel and tissue. The Volume of Wound Index therefore is the largest at 17.0 and 16.8 cubic inches. This is the second largest PWC and Volume of Wound we have ever tested in any pistol rounds in eight calibers.

Overall: The APC is a Law Enforcement and Military only Armor Piercing (AP) round, whereas the FR is not restricted. Both .40 caliber rounds are reliable and consistent, exhibiting optimum penetration. The PWC in tissue and gel is the second largest ever tested. The barrier performance is unapparelled. This is a 2020 modified version of the original from 2015. During concurrent testing of these two rounds (APC and FR), they were almost duplicates until testing in armor.

Underwood XD 100 grain and 115 grain

Penetration: This solid copper fluted-fluid transfer round penetrated 18.0 inches during phase 2 and 17.6 inches during phase 3.

Reliability and Consistency: All phases showed this round to be very reliable and consistent with penetration and wound dimension deviations of less than 10% and no instances of fragmentation. Tumbling was rarely witnessed which caused all of the deviations.

Barrier Performance: When shot through light domestic barriers this round is nearly barrier blind. There was 14% degradation from light barriers. In limited testing versus heavy barriers like auto glass, solid wood and metal this round had no course deviations and was barely misshaped. It penetrated through almost 5 inches of solid wood and went through car doors with less than 35% penetration degradation. This round penetrated through HG2 (Level 3A) soft armor, but did not penetrate through HG2 (Level 3A) or RF1 (Level 3) hard armor.

Permanent Wound Cavity: The fluid transfer XD has a larger PWC than any hollow point in any caliber tested in both gel and tissue. Its Volume of Wound Index is 11.8 cubic inches vs 11.1 for the 115 grain variant.

Overall: This fluted-fluid transfer Xtreme Defender (XD), from 2015, is a reliable and consistent round exhibiting optimum penetration. The hydraulic effect creates an artificially large PWC in non-compressible gel. The PWC in tissue is realistic and is still very large with a diameter wider than any hollow point. There is a 115 grain version, but the lighter weight version created a slightly larger PWC with the other numbers being very similar. The barrier performance is excellent vs all but hard armor.

.45 ACP ROUND SUMMARIES

Included here is a sample list of narrative results from a select group of .45 ACP rounds that are typically used as duty ammunition. Included are FMJ, hollow points and fluted-fluid transfer rounds. The top four most used duty hollow points are included and all have very similar performance, more so than the other calibers. For the narrative description for other rounds, please contact us. All shots were fired using stock Glock 21 and Sig P227 pistols. All rounds were tested at least four times in each of the five standard phases detailed above. All of those results are included in the data sheets. Additional rounds of each type were fired through heavy barriers to include solid wood, auto glass and metal car doors. Armor testing as detailed in the next chapter was performed with many rounds.

Winchester 230 grain Full Metal Jacket

Penetration: This FMJ penetrated 27 inches during phase 2 and 3 testing. This is outside of the federal standard desired 15-21 inches.

Reliability and Consistency: All phases showed this round to be very reliable and consistent with deviations of less than 5% and no instances of fragmentation and tumbling only rarely occurring after contact with heavy barriers.

Barrier Performance: Through light domestic barriers this round is nearly barrier blind, with about 2% degradation from light barriers similar to other FMJs. In limited testing versus heavy barriers like auto glass, solid wood and metal this round had minor course deviations and was misshaped, but less than other caliber FMJs. Wounding effects after passing through heavy barriers was degraded almost 60%, mostly by limiting penetration depths not limiting wound diameter, which is standard for this projectile type. This round did not penetrate through any of the armor products.

Permanent Wound Cavity: The Winchester FMJ has the smallest wound diameter of all the .45 ACP rounds tested in both gel and tissue. It also has the second deepest penetration of all .45 caliber rounds. This combination makes for a PWC that is only 25% less than the average .45 hollow point. Its Volume of Wound Index is 5.5 cubic inches. As a comparison only 2 out of the 17 9mm hollow points have a larger wound volume. Also 5.5 cubic inches is larger than 3 of 10 .40 S&W hollow points tested from 2016 to present.

Overall: This consistent .45 caliber round had deeper than desired penetration and fantastic reliability and above average barrier performance.

Federal HST +P 230 grain

Penetration: This hollow point penetrated 15.5 and 16 inches during phase 2 and 3 testing.

Reliability and Consistency: The failure rate of this round (failure to expand, fragmentation or tumbling) was approximately 20%. Shot to shot analysis showed average deviations in penetration and expansion. During phases 2-5 the bullet performed consistently as designed. The recovered bullet showed clogging of the cavity and the petals to be deformed non-symmetrically in some cases which caused the bullet to undesirably turn sideways which limits the wound hole area.

Barrier Performance: There is approximately a 10% degradation from light barriers. In limited testing versus heavy barriers like auto glass, solid wood and metal this round had better than average (for a hollow point) results. It was deflected less than average, misshaped and fragmented often, but was generally better than all other .45 ACP hollow points vs heavy barriers. The large core penetrated through 4 inches of solid wood and passed through metal car doors with less degradation than any other hollow point regardless of caliber. Overall wound size was reduced by more than half (>50%) after passing through heavy barriers. The projectile did not penetrate through any armor.

Permanent Wound Cavity: This hollow point had a PWC almost equal to the other three top performing .45 ACP hollow points we have tested in both gel and tissue. Its Volume of Wound Index is 7.9 cubic inches vs 8.0 for two others.

Overall: The Federal HST has always done extremely well in hollow point testing, since its 2002 inception. It is the .45 ACP hollow point we have tested the most with a sample size of over 40 measured shots. This round is still one of the top choices in .45 ACP hollow points.

Hornady Critical Duty 220 grain

Penetration: This hollow point penetrated 16 inches during phase 2 and 17.2 inches during phase 3 testing.

Reliability and Consistency: The failure rate of this round (Failure To Expand (FTE), fragmentation or tumbling) was just over 15%. During all phases this round was also the most consistent of the .45 caliber hollow points we have tested to date. Its failure rate was lower than other hollow points but there was still fragmentation and turning which reduces effectiveness. FTE was minimal. Limited expansion, which is not a failure was noted on several rounds and was common. The minor inconsistencies and failures noted limited the wound diameter, but increased the penetration depth.

Barrier Performance: When shot through light domestic barriers this bullet was misshaped more than the other .45 hollow points. This reduced the expansion and therefore the drag and caused a deeper penetration than without the barriers which is always indicative of a failure. There was 20% degradation from light domestic barriers. In limited testing versus heavy barriers like auto glass, solid wood and metal this round was unreliable. It was deflected, misshaped and fragmented. Most rounds missed the media after passing through heavy barriers and the ones that could be measured had a wound size reduction of over 60%. This round did not penetrate through any armor.

Permanent Wound Cavity: The top four hollow points in .45 ACP all have large permanent wound cavities. Its Volume of Wound Index is 8.0 cubic inches.

Overall: The Hornady Critical Duty has reduced the failure rate of hollow points, but not significantly and this is equally true in the .45 ACP as with the other calibers it has been offered in since 2011. This round is still one of the top choices in .45 ACP hollow points.

Speer Gold Dot 230 grain

Penetration: This hollow point penetrated 17.5 inches during phase 2 testing and 16.5 inches in phase 3

Reliability and Consistency: The failure rate of this round (failure to expand, fragmentation or tumbling) was approximately 20%. Its failure rate during the 5 phases with no or light barriers was due mostly to Failure To Expand (FTE) and turning which greatly reduced the wound hole area and increased penetration depth.

Barrier Performance: There is approximately a 20% degradation from light barriers. In limited testing versus heavy barriers like auto glass, solid wood and metal this round was unreliable. It was deflected and or fragmented on almost every shot. This round was not tested vs armor.

Permanent Wound Cavity: This hollow point has a large PWC in gel and tissue. Its Volume of Wound Index is 8.0 cubic inches, equaling the other three top performing hollow points in .45 ACP

Overall: Since production in 1991, the Speer Gold Dot 230 grain has had excellent wound ballistic effects equal to the other three top performers in this caliber. This round is still one of the top choices in .45 ACP hollow points.

Winchester 230 grain Ranger T series

Penetration: This hollow point penetrated IWBA FBI series calibrated ballistics gelatin an average of 16.5 inches in phase 2 and 15.4 inches for phase 3.

Reliability and Consistency: This round had above average reliability and consistency with deviations of about 15%, with minimal instances of Failure to Expand (FTE), fragmentation and tumbling.

Barrier Performance: When shot through light domestic barriers this round exhibited both FTE and fragmentation but only about 15% degradation. In limited testing versus heavy barriers like auto glass, solid wood and metal this round had minimal course deviations but was misshaped. Fragmentation occurred frequently, but the core tended to have minimal course deflection. Wounding effects after passing through heavy barriers was degraded by limiting both wound diameter and penetration depths. Overall heavy barrier degradation was almost 70%. This round was not tested vs armor.

Permanent Wound Cavity: Although this Winchester hollow point has the fourth largest permanent wound cavity of the nine .45 ACP hollow points tested, it is within <5% of the leaders which is within our margin of error. Its Volume of Wound Index is 7.7 cubic inches.

Overall: A modified (1994 and again in 2010) version of the 1991 Black Talon loaded at much higher pressure and reserved for law enforcement, this round had good consistent reliable penetration. Barriers had some effect on the round's performance depending on the hardness. Its PWC makes it effective and it's near the top of the list of duty.45 ACP hollow points.

G9 APC 117 grain and G9 FR 117 grain

Penetration: The APC is a solid brass fluted-fluid transfer round which penetrated 19.7 and 19.6 inches during phase 2 and phase 3.

Reliability and Consistency: All phases showed this round to be very reliable and consistent with penetration and wound dimension deviations of less than 5% and no instances of fragmentation or tumbling vs no or light domestic barriers in both gel and tissue.

Barrier Performance: When shot through light domestic barriers these rounds are almost barrier blind. There was 2% degradation from light barriers. In limited testing versus heavy barriers like auto glass, solid wood and metal there was no course deviations and rounds were barely misshaped. It penetrated through 4.5 inches of solid wood, went through car doors and had approximately a 15-20% degradation in wound size after passing through heavy barriers. Both the brass APC and the copper First Response (FR) projectiles were tested vs armor. The APC went through all HG2 (Level 3A) soft and hard armor materials, but did not penetrate through RF1 (Level 3) armor. The copper FR did not penetrate as well through the armor products and is not considered 'armor piercing' under BATFE guidelines.

Permanent Wound Cavity: This fluid transfer bullet has the largest PWC of all .45 ACP rounds tested in both gel and tissue. The Volume of Wound Index therefore is the largest at 16.3 cubic inches.

Overall: This Law Enforcement and Military only .45 caliber ammunition (APC) is reliable and consistent, exhibiting optimum penetration. First produced in this caliber in 2015 and modified twice, this version was introduced in 2023. The PWC in tissue is very large with a diameter wider than any other .45 round ever tested. The barrier performance is unapparelled in this caliber. The copper version of this round, the 117 grain First Response (FR) was nearly identical to the APC except when tested vs armor.

Underwood XD +P 120 grain

Penetration: This solid copper fluted-fluid transfer round penetrated 19.0 inches during phase 2 and 18.4 inches during phase 3.

Reliability and Consistency: All phases showed this round to be very reliable and consistent with penetration and wound dimension deviations of less than 10% and no instances of fragmentation or tumbling.

Barrier Performance: When shot through light domestic barriers this round is nearly barrier blind. There was 5% degradation from light barriers. In limited testing versus heavy barriers like auto glass, solid wood and metal this round had no course deviations and was barely misshaped. Overall degradation from heavy barriers was 25%. This round did not penetrate through any armor.

Permanent Wound Cavity: The 45 XD has a larger PWC than any hollow point in any caliber tested in both gel and tissue. Its Volume of Wound Index is 11.8 cubic inches.

Overall: This fluted-fluid transfer Xtreme Defender (XD), released in 2015, is a reliable and consistent round exhibiting optimum penetration. The hydraulic effect creates an artificially large PWC in non-compressible gel. The PWC in tissue is realistic and is still very large with a diameter wider than any hollow point. The barrier performance is excellent vs all but armor.

TERMINAL WOUND BALLISTICS TEST DATA SHEETS

VWI - Volume of Wound Index

A computed volume in cubic inches that represents the most precise Permanent Wound Cavity (PWC) using IWBA gel for accurate penetration depth comparisons and realistic tissue media to measure the wound area and incorporating both non-barrier and barrier tests.

Averaging the two penetration depths from Phase 2 and 3 (IWBA gel tests) and multiplying by the average hole area from both tissue Phases 4 and 5.

LDBD% - Light Domestic Barrier Degradation Percentage

Phases 3 and 5 add a light domestic barrier IAW FBI / DoD protocol. The amount of degradation to each round caused by the addition of this barrier is reflected by analyzing the differences between phase 2 and phase 3 for gel and phase 4 and phase 5 with tissue and the overall average percentage of degradation is calculated and displayed in this last column.

A low number indicates that particular round was less affected by passing through a light domestic barrier prior to the target media of gel or tissue. A larger number indicates the barrier degraded the round more and the ability of the round to function after the barrier was more diminished.

9mm 42 Rounds

VIPER WEAPONS TRAINING LLC

TERMINAL WOUND BALLISTICS DATA, CAO AUGUST 2025

	Caliber / Type	Round (160)	Box Velocity	Weapon	PHASE 1 Average Velocity	PHASE 2 Gelatin / Denim Penetra.	Diam	PWC	PHASE 3 Gelatin / Plywood / Denim Penetra.	Diam	PWC	PHASE 4 Tissue / Denim Av Hole Area	PHASE 5 ue / Plywood / Denim Av Hole Area	VWI Av Pen x Av Area	LDBD%
	9mm	42 rounds													
1	FMJ	Winchester NATO 124 gr	1140	Sig P 226 / Glock 17	1140	28.1	0.35	2.7 ci	27.0	0.35	2.6 ci	0.14	0.12	3.6	10%
2	FMJ	Win. M1152 Active Duty 115 gr	1320	Glock 17	1305	>32	0.35	N/A	>32	0.35	N/A	0.14	0.13	N/A	5%
3	Frangible	G2 RIP 92 gr	1265	Glock 17	1295	4/14	0.4	1.8 ci	3.5/12.5	0.35	1.7 ci	0.15	0.13	1.85	10%
4	Frangible	Glaser Blue +P 80 gr	1500	Glock 17	1465	6.0	Frag	N/A	5.5	Frag	N/A	Did Not Exit (DNE)	Did Not Exit (DNE)	undet Area	>95%
5	Frangible	Interceptor ARX +P 65 gr	1695	Glock 17	1680	12.5	0.9	7.9 ci	12.5	0.8	6.3 ci	0.60	0.50	6.9	17%
6	Frangible	Lehigh Dfense CF +P 115 gr	1100	Glock 17	1126	15.2	Frag	N/A	14.2	Frag	N/A	0.13	0.15	2.0	6%
7	Frangible	Liberty Civil Defense 50 gr	2040	Glock 17	1980	10.5	Frag	N/A	9.8	Frag	N/A	Did Not Exit (DNE)	Did Not Exit (DNE)	undet Area	10%
8	Frangible	Sim-X Defensecore 45 gr	2250	Glock 17	2228	7.0	Frag	N/A	4.8	Frag	N/A	Did Not Exit (DNE)	Did Not Exit (DNE)	undet Area	33%
9	Frangible	Sinterfire RHA 100 gr	1300	Glock 17	1265	9.5	Frag	N/A	9.0	Frag	N/A	Did Not Exit (DNE)	Did Not Exit (DNE)	undet Area	>95%
10	Hollow Pt	American Mun. Sierra 115 gr	1250	Glock 17	1230	9.0	0.5	1.8 ci	10.0	0.4	1.3 ci	0.30	0.25	2.6	21%
11	Hollow Pt	CorBon DPX +P 115 gr	1250	Glock 17	1262	15.3	0.64	4.9 ci	14.2	0.57	3.6 ci	0.38	0.32	5.16	22%
12	Hollow Pt	CorBon Self Defense +P 115 gr	1350	Glock 17	1300	9.5	0.6	2.7 ci	7.0	0.5	1.4 ci	0.30	0.16	1.9	48%
13	Hollow Pt	Federal HST 147 gr	1000	Sig P 226 / Glock 17	1005	15.2	0.65	5.2 ci	15.5	0.5	3.0 ci	0.42	0.35	5.9	30%
14	Hollow Pt	G9 Hardened HP 101 gr	1370	Glock 17	1340	11.5	0.65	3.8 ci	13.7	0.5	2.7 ci	0.23	0.20	2.7	21%
15	Hollow Pt	Hornandy C Duty +P 135 gr	1115	Glock 17	1120	13.8	0.5	2.7 ci	13.1	0.48	2.4	0.35	0.31	4.4	15%
16	Hollow Pt	Lehigh Defense ME +P 115 gr	1100	Glock 17	1135	8.4	0.9	5.3 ci	7.1	0.88	4.3 ci	0.62	0.53	4.5	16%
17	Hollow Pt	OATH Tango 110 gr	1200	Glock 17	1150	5.3	0.8	2.7 ci	4.6	0.75	2.0 ci	Did Not Exit (DNE)	Did Not Exit (DNE)	undet Area	20%
18	Hollow Pt	Remington GS +P 124 gr	1180	Glock 17	1170	13.0	0.6	3.7 ci	12.0	0.5	2.4 ci	0.25	0.17	2.6	33%
19	Hollow Pt	Remington GS 147 gr	990	Glock 17	980	17.0	0.6	4.8 ci	16.0	0.5	3.1 ci	0.30	0.25	4.5	26%
20	Hollow Pt	Sig Sauer V 124 gr	1165	Sig P 226 / Glock 17	1150	13.8	0.6	3.9 ci	16.5	0.45	2.6 ci	0.40	0.35	5.7	24%
21	Hollow Pt	Speer GD +P 124 gr	1150	Glock 17	1112	14.8	0.5	2.9 ci	13.8	0.4	1.7 ci	0.23	0.16	2.8	37%
22	Hollow Pt	Speer GD 147 gr	985	Glock 17	970	15.5	0.6	4.4 ci	14.6	0.5	2.9 ci	0.36	0.32	5.1	23%
23	Hollow Pt	Underwood Max Exp 105 gr	1175	Glock 17	1160	10.3	0.8	5.2 ci	11.0	0.7	4.2 ci	0.50	0.41	4.8	19%
24	Hollow Pt	Winchester RASTA +P+ 127 gr	1250	Glock 17	1225	14.5	0.65	4.8 ci	13.0	0.4	2.4 ci	0.38	0.28	5.5	38%
25	Hollow Pt	Winchester Ranger T 147 gr	990	Glock 17	1000	14.5	0.6	4.1 ci	16.0	0.4	2.0 ci	0.30	0.25	4.2	35%
26	Hollow Pt	Win. M1153 Active Duty 147 gr		Glock 17	982	15.2	0.55	3.6 ci	13.8	0.5	2.7 ci	0.22	0.20	3.0	15%
27	Tumbling	Fort Scott 80 gr	1350	Sig P 226 / Glock 17	1405	19.5	0.4	2.5 ci	18.8	0.4	2.4 ci	0.27	0.25	5.0	6%
28	Fluted FT	Black Hills HB +P 100 gr	1300	Glock 17	1310	16.5	0.7	6.3 ci	14.8	0.7	5.7 ci	0.47	0.41	6.9	11%
29	Fluted FT	Black Hills Subsonic 125 gr	1050	Glock 17	1040	17.5	0.6	4.9 ci	17.0	0.6	4.8 ci	0.41	0.37	6.7	6%
30	Fluted FT	G9 EHP 80 gr	1480	Glock 17	1512	16.2	1.1	15.4 ci	16.0	1.0	12.6 ci	0.65	0.65	10.5	1%
31	Fluted FT	G9 EHP +P 80 gr	1520	Glock 17	1602	16.8	1.1	15.9 ci	16.4	1.1	15.6 ci	0.67	0.68	11.2	1%
32	Fluted FT	G9 First Response 77 gr	1550	Glock 17	1540	13.5	1.2	22.0 ci	13.0	1.1	18.1 ci	0.73	0.71	13.9	9%
33	Fluted FT	G9 APC 77 gr	1550	Glock 17	1555	13.5	1.2	22.0 ci	13.2	1.2	21.7 ci	0.73	0.72	14.0	1%
34	Fluted FT	G9 APC Subsonic 123 gr	1040	Glock 17	1034	18.8	0.55	4.7 ci	18.4	0.55	4.4 ci	0.42	0.40	7.6	2%
35	Fluted FT	G9 EHP Subsonic 126 gr	1020	Glock 17	1028	17.1	0.6	4.8 ci	16.7	0.6	4.7 ci	0.45	0.42	7.4	5%
36	Fluted FT	G9 Woodsman +P 124 gr	1250	Glock 17	1260	34.0	0.7	13.1 ci	33.0	0.7	12.7 ci	0.42	0.46	14.7	1%
37	Fluted FT	Lehigh Defense XD 90 gr	1300	Glock 17	1328	15.1	0.75	6.7 ci	14.2	0.7	5.5 ci	0.55	0.48	7.5	6%
38	Fluted FT	Lehigh Defense XP 115 gr	1100	Glock 17	1153	38.0	0.45	6.1 ci	38.0	0.45	6.1 ci	0.21	0.19	7.6	0%
39	Fluted FT	Underwood XD +P 65 gr	1800	Glock 17	1760	16.5	1.1	15.7 ci	15.5	1.0	12.2 ci	0.65	0.63	10.2	8%
40	Fluted FT	Underwood XD 90 gr	1400	Sig P 226 / Glock 17	1480	16.0	0.8	8.0 ci	15.2	0.7	5.8 ci	0.60	0.47	8.3	25%
41	Fluted FT	Underwood XD +P 90 gr	1475	Sig P 226 / Glock 17	1505	16.7	0.9	10.6 ci	16.0	0.8	8.0 ci	0.60	0.60	9.8	12%
42	Fluted FT	Underwood XD +P+ 90 gr	1550	Glock 17	1585	17.5	1.0	13.7 ci	17.0	0.9	10.8 ci	0.65	0.65	11.2	11%

.40 S&W 27 Rounds

VIPER WEAPONS TRAINING LLC

TERMINAL WOUND BALLISTICS DATA, CAO AUGUST 2025

	Caliber / Type	Round (160)	Box Velocity	Weapon	PHASE 1 Average Velocity	PHASE 2 Gelatin / Denim Penetra.	Diam	PWC	PHASE 3 Gelatin / Plywood / Denim Penetra.	Diam	PWC	PHASE 4 Tissue / Denim Av Hole Area	PHASE 5 Tissue / Plywood / Denim Av Hole Area	VWI Av Pen x Av Area	LDBD%
	40 S&W	27 rounds													
1	FMJ	Winchester FMJ 180 gr	1020	Glock 22	1005	31.0	0.4	3.9 ci	29.5	0.4	3.7 ci	0.14	0.16	4.5	3%
2	Frangible	G2 RIP 115 gr	1080	Glock 22	1100	5/11.5	0.5	2.6 ci	5/11.2	0.4	1.4 ci	0.20	Did Not Exit (DNE)	undet Area	
3	Frangible	Glaser Blue 115 gr	1400	Glock 22	1355	7.0	Frag	N/A	6.5	Frag	N/A	Did Not Exit (DNE)	Did Not Exit (DNE)	undet Area	>95%
4	Frangible	Liberty Civil Defense 60 gr	2000	Glock 22	1965	11.2	Frag	N/A	10.5	Frag	N/A	Did Not Exit (DNE)	Did Not Exit (DNE)	undet Area	
5	Frangible	Sinterfire RHFP 125 gr	1350	Glock 22	1330	10.75	Frag	N/A	10.0	Frag	N/A	Did Not Exit (DNE)	Did Not Exit (DNE)	undet Area	>95%
6	Hollow Pt	Federal HST 180 gr	1000	Glock 22	988	18.0	0.6	5.1 ci	17.6	0.6	5.0 ci	0.49	0.43	8.2	7%
7	Hollow Pt	Hornady C Duty 175 gr	1010	Glock 22	1020	17.9	0.6	5.0 ci	17.2	0.6	4.9 ci	0.40	0.40	7.0	2%
8	Hollow Pt	OATH Tango 125 gr	1250	Glock 22	1225	8.0	0.8	4.0 ci	6.7	0.8	3.4 ci	Did Not Exit (DNE)	Did Not Exit (DNE)	undet Area	
9	Hollow Pt	Remington GS 165 gr	1150	Glock 22	1145	15.3	0.5	3.0 ci	17.2	0.4	2.2 ci	0.30	0.20	4.1	25%
10	Hollow Pt	Remington GS 180 gr	1015	Glock 22	1020	17.2	0.6	4.9 ci	16.4	0.5	3.9 ci	0.44	0.36	6.7	19%
11	Hollow Pt	Sig Sauer V 165 gr	1090	Glock 22	1100	16.5	0.6	4.7 ci	16.1	0.6	4.6 ci	0.45	0.41	7.0	7%
12	Hollow Pt	Speer Gold Dot 165 gr	1050	Glock 22	1060	14.3	0.7	5.5 ci	16.0	0.5	3.1 ci	0.30	0.24	4.1	32%
13	Hollow Pt	Speer Gold Dot 180 gr	1025	Glock 22	1040	16.0	0.6	4.5 ci	15.1	0.6	4.3 ci	0.45	0.41	6.7	7%
14	Hollow Pt	Underwood Max Exp 140 gr	1050	Glock 22	1060	8.5	1.0	6.7 ci	9.5	0.9	6.0 ci	0.69	0.58	5.7	13%
15	Hollow Pt	Winchester Ranger T 180 gr	990	Glock 22	1000	13.5	0.7	5.2 ci	12.7	0.6	3.6 ci	0.42	0.36	5.1	23%
16	Tumbling	Fort Scott 125 g	1320	Glock 22	1290	22.0	0.5	4.3 ci	20.8	0.4	2.6 ci	0.20	0.28	5.1	15%
17	Fluted FT	G9 EHP Range Limiter 80 gr	1625	Glock 22	1640	19.0	1.3	25.2 ci	18.5	1.2	20.9 ci	0.78	0.76	14.4	10%
18	Fluted FT	G9 EHP 95 gr	1460	Glock 22	1445	19.0	1.0	14.9 ci	18.7	0.9	11.9 ci	0.70	0.66	12.8	8%
19	Fluted FT	G9 First Response 77 gr	1680	Glock 22 Sig 320	1670	19.3	1.5	34.1 ci	19.2	1.5	33.9 ci	0.90	0.85	16.8	4%
20	Fluted FT	G9 First Response 90 gr	1450	Glock 22	1450	19.2	1.1	18.2 ci	19.0	1.0	14.9 ci	0.75	0.74	14.2	9%
21	Fluted FT	G9 First Response 100 gr	1500	Glock 22	1536	20.5	1.2	23.2 ci	20.7	1.2	23.4 ci	0.82	0.81	16.8	0%
22	Fluted FT	G9 First Response 115 gr	1420	Glock 22	1454	21.4	1.1	20.3 ci	21.1	1.1	20.0 ci	0.74	0.77	16.0	1%
23	Fluted FT	G9 APC 77 gr	1700	Glock 22	1670	19.5	1.5	34.5 ci	19.5	1.5	34.5 ci	0.88	0.86	17.0	1%
24	Fluted FT	G9 APC 90 gr	1450	Glock 22	1460	19.2	1.1	18.2 ci	19.1	1.1	18.2 ci	0.75	0.75	14.4	0%
25	Fluted FT	G9 Woodsman 130 gr	1300	Glock 22 Sig 320	1315	33.0	0.8	15.8 ci	32.0	0.8	16.1 ci	0.55	0.52	17.4	3%
26	Fluted FT	Underwood XD 100 gr	1500	Glock 22	1510	18.0	1.0	14.1 ci	17.6	0.9	11.2 ci	0.69	0.64	11.8	14%
27	Fluted FT	Underwood XD 115 gr	1400	Glock 22	1425	18.5	0.9	11.8 ci	18.1	0.9	11.5 ci	0.63	0.58	11.1	5%

.45 ACP 24 Rounds

VIPER WEAPONS TRAINING LLC

TERMINAL WOUND BALLISTICS DATA, CAO AUGUST 2025

	Caliber / Type	Round (160)	Box Velocity	Weapon	PHASE 1 Average Velocity	PHASE 2 Gelatin / Denim Penetra.	Diam	PWC	PHASE 3 Gelatin / Plywood / Denim Penetra.	Diam	PWC	PHASE 4 Tissue / Denim Av Hole Area	PHASE 5 Tissue / Plywood / Denim Av Hole Area	VWI Av Pen x Av Area	LDBD%
	45 ACP	24 rounds													
1	FMJ	Winchester FMJ 230 gr	835	Sig P227E / Glock 21	865	27.5	0.45	4.4 ci	27.0	0.45	4.3 ci	0.18	0.22	5.5	2%
2	Frangible	G2 RIP 162 gr	960	Glock 21	995	4.5/16	0.5	3.1 ci	8.8 FTE	0.6	2.5 ci	0.18	0.24	2.6	20%
3	Frangible	Glaser Blue +P 145 gr	1350	Glock 21	1330	7.2	Frag	N/A	7.0	Frag	N/A	Did Not Exit (DNE)	Did Not Exit (DNE)	undet Area	>95%
4	Frangible	Liberty Civil Defense 78 gr	1900	Glock 21	1885	11.5	Frag	N/A	10.8	Frag	N/A	Did Not Exit (DNE)	Did Not Exit (DNE)	undet Area	
5	Frangible	Sinterfire Special Duty 155 gr	1150	Glock 21	1125	13.75	Frag	N/A	12.5	Frag	N/A	0.15	Did Not Exit (DNE)	undet Area	
6	Hollow Pt	Federal HST +P 230 gr	950	Sig P227E / Glock 21	950	15.5	0.7	6.0 ci	16.0	0.7	6.2 ci	0.55	0.45	7.9	9%
7	Hollow Pt	Federal Hydra Shok 230 gr	900	Sig P227E / Glock 21	860	15.0	0.7	5.8 ci	17.2	0.6	4.9 ci	0.31	0.32	5.1	8%
8	Hollow Pt	Hornady C Duty +P 220 gr	975	Glock 21	960	16.0	0.7	6.5 ci	17.2	0.6	4.9 ci	0.52	0.44	8.0	20%
9	Hollow Pt	OATH Tango 163 gr	1100	Glock 21	1105	9.0	0.9	5.7 ci	11.3	0.7	4.3 ci	0.61	0.53	5.8	19%
10	Hollow Pt	Remington GS 185 gr	1140	Glock 21	1115	15.1	0.7	5.8 ci	13.8	0.6	3.9 ci	0.40	0.36	5.5	21%
11	Hollow Pt	Sig Sauer V 230 gr	830	Glock 21	850	15.1	0.7	5.8 ci	16.2	0.7	6.2 ci	0.50	0.42	7.2	8%
12	Hollow Pt	Speer Gold Dot 230 gr	890	Glock 21	810	17.5	0.7	6.7 ci	16.5	0.6	4.7 ci	0.50	0.44	8.0	21%
13	Hollow Pt	Underwood Max Exp 174 gr	1050	Glock 21	1035	9.0	1.2	10.2 ci	7.5	1.1	7.1 ci	0.79	0.79	6.5	15%
14	Hollow Pt	Winchester Ranger T 230 gr	880	Glock 21	910	16.5	0.7	6.3 ci	15.4	0.6	4.4 ci	0.48	0.48	7.7	15%
15	Tumbling	Fort Scott 180 gr	989	Glock 21	1000	22+ FTT	0.5	N/A	22+ FTT	0.48	N/A	0.20	0.28	undet Pen	
16	Fluted FT	G9 EHP 117 gr	1400	Glock 21	1315	17.9	0.9	11.4 ci	17.2	0.9	10.9	0.67	0.65	11.6	3%
17	Fluted FT	G9 EHP +P 117 gr	1480	Glock 21	1410	19.0	1.0	14.9 ci	18.7	0.9	11.9 ci	0.72	0.71	13.5	2%
18	Fluted FT	G9 APC 110 gr 2022	1550	Glock 21	1490	18.8	1.4	28.9 ci	18.5	1.3	24.5 ci	0.84	0.80	15.3	4%
19	Fluted FT	G9 First Response 117 gr	1500	Glock 21	1495	19.5	1.4	30.0 ci	19.5	1.4	30.0 ci	0.80	0.85	16.1	1%
20	Fluted FT	G9 APC 117 gr 2023	1500	Glock 21	1470	19.7	1.4	30.3 ci	19.6	1.4	30.2 ci	0.83	0.82	16.2	2%
21	Fluted FT	G9 Woodsman 165 gr	1230	Glock 21	1215	30.0	0.8	15.1 ci	28.5	0.7	11.0 ci	0.58	0.55	16.5	6%
22	Fluted FT	Underwood XD 120 gr	1320	Sig P227E / Glock 21	1400	18.5	0.9	11.8 ci	17.6	0.8	8.8 ci	0.60	0.42	9.2	28%
23	Fluted FT	Underwood XD +P 120 gr	1420	Sig P227E / Glock 21	1460	19.0	0.9	12.1 ci	18.4	0.9	11.7 ci	0.65	0.61	11.8	5%
24	Fluted FT	Underwood XD Super 120 gr	1600	Sig P227E / Glock 21	1550	19.5	1.0	15.3 ci	19.0	0.9	12.1 ci	0.825	0.71	14.8	17%

.380 5 Rounds

VIPER WEAPONS TRAINING LLC

	TERMINAL WOUND BALLISTICS DATA, CAO AUGUST 2025				PHASE 1	PHASE 2			PHASE 3			PHASE 4	PHASE 5	VWI	LDBD%
	Caliber / Type	Round (160)	Box Velocity	Weapon	Average Velocity	Gelatin / Denim Penetra.	Diam	PWC	Gelatin / Plywood / Denim Penetra.	Diam	PWC	Tissue / Denim Av Hole Area	Tissue / Plywood / Denim Av Hole Area	Av Pen x Av Area	
	.380	5 rounds													
1	FMJ	Winchester FMJ 95 gr	955	Glock 42	940	25.5	0.35	2.5 ci	24.2	0.35	2.3 ci	0.12	0.12	3.0	5%
2	Hollow Pt	Hornady XTP 90 gr	1000	Glock 42	1010	12.5	0.4	1.6 ci	11.2	0.38	1.3 ci	0.32	0.25	3.4	18%
3	Hollow Pt	Speer GD 90 gr	1040	Glock 42	1055	11.2	0.42	1.5 ci	12.5	0.35	1.2 ci	0.32	0.20	3.1	25%
4	Fluted FT	G9 First Response 77 gr	1140	Glock 42	1130	15.2	0.75	6.7 ci	14.8	0.7	5.7 ci	0.52	0.45	7.3	9%
5	Fluted FT	Underwood XD +P 65 gr	1400	Glock 42	1370	12.5	0.7	4.8 ci	12.0	0.6	3.4 ci	0.42	0.38	4.9	7%

.357 Sig 9 Rounds

VIPER WEAPONS TRAINING LLC

	TERMINAL WOUND BALLISTICS DATA, CAO AUGUST 2025				PHASE 1	PHASE 2			PHASE 3			PHASE 4	PHASE 5	VWI	LDBD%
	Caliber / Type	Round (160)	Box Velocity	Weapon	Average Velocity	Gelatin / Denim Penetra.	Diam	PWC	Gelatin / Plywood / Denim Penetra.	Diam	PWC	Tissue / Denim Av Hole Area	Tissue / Plywood / Denim Av Hole Area	Av Pen x Av Area	
	357 SIG	9 rounds													
1	FMJ	Winchester FMJ 125 gr	1350	Glock 22 conv barl	1370	32.1	0.4	4.0 ci	30.8	0.4	3.9 ci	0.15	0.15	4.7	10%
2	Hollow Pt	Federal HST 125 gr	1360	Glock 22 conv barl	1375	17.2	0.6	4.9 ci	19.7	0.5	3.9 ci	0.46	0.37	7.6	20%
3	Hollow Pt	Hornady C Duty 135 gr	1225	Glock 31	1277	14.6	0.55	3.5 ci	12.6	0.5	2.5 ci	0.36	0.26	4.2	28%
4	Hollow Pt	Sig Sauer V 125 gr	1356	Glock 22 conv barl	1375	17.0	0.6	4.8 ci	22.0	0.4	2.8 ci	0.44	0.32	7.4	35%
5	Hollow Pt	Speer GD 125 gr	1350	Glock 22 conv barl	1385	17.5	0.6	4.9 ci	14.5	0.5	2.8 ci	0.28	0.16	3.5	43%
6	Hollow Pt	Winchester Defender 125 gr	1350	Glock 31	1327	15.0	0.55	3.6 ci	12.4	0.45	2.0 ci	0.41	0.25	4.5	47%
7	Fluted FT	G9 APC 77 gr	1750	Glock 31	1740	20.2	1.4	31.1 ci	19.8	1.4	30.5 ci	0.86	0.83	16.9	1%
8	Fluted FT	Underwood XD 65 gr	2100	Glock 22 conv barl	2060	17.5	1.0	13.7 ci	16.5	1.0	13.0 ci	0.78	0.71	12.7	7%
9	Fluted FT	Underwood XD 90 gr	1700	Glock 22 conv barl	1690	18.3	1.0	14.4 ci	17.4	1.0	13.7 ci	0.78	0.68	13.0	9%

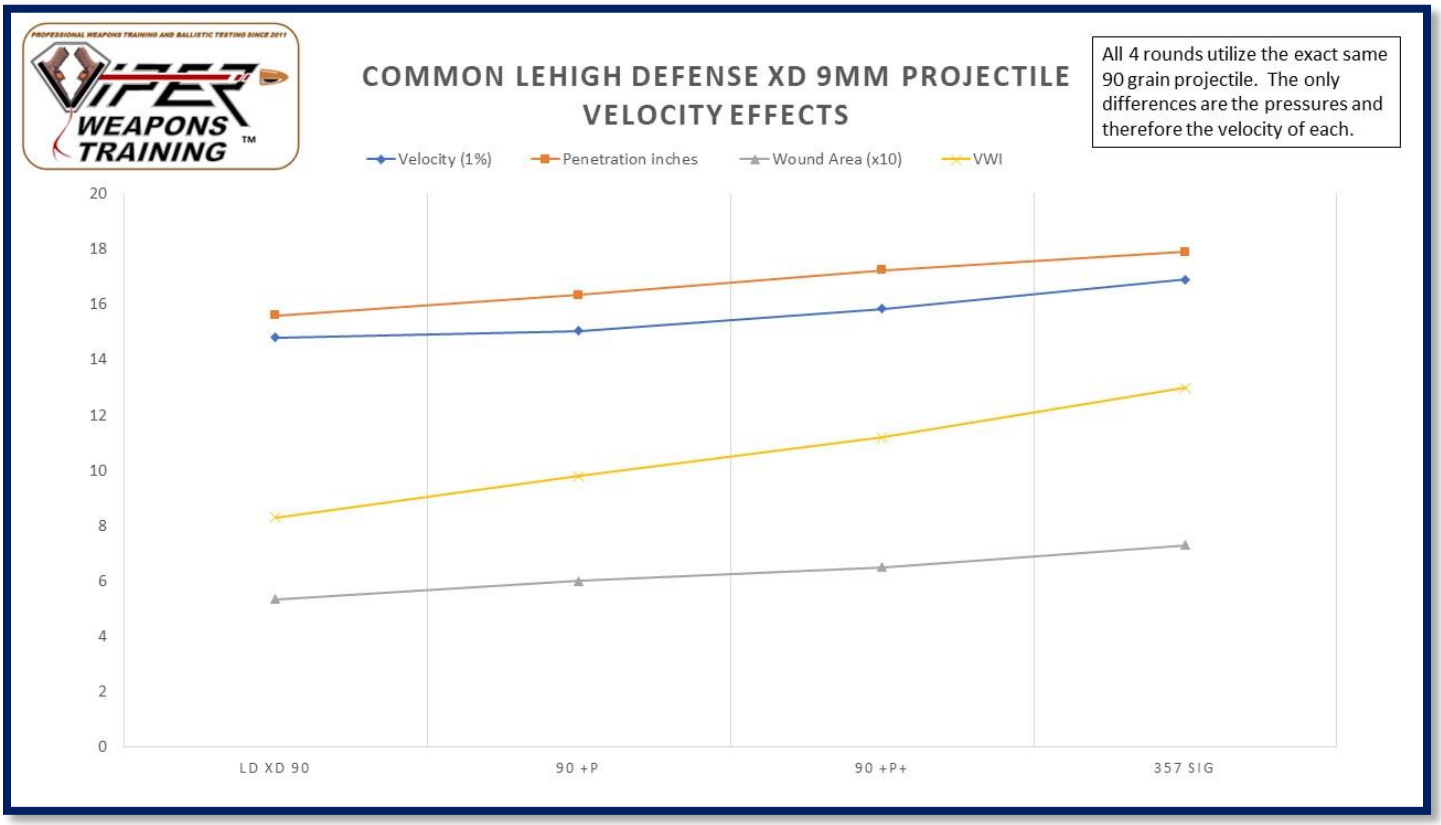
10mm 11 Rounds

VIPER WEAPONS TRAINING LLC

	TERMINAL WOUND BALLISTICS DATA, CAO AUGUST 2025				PHASE 1	PHASE 2			PHASE 3			PHASE 4	PHASE 5	VWI	LDBD%
	Caliber / Type	Round (160)	Box Velocity	Weapon	Average Velocity	Gelatin / Denim Penetra.	Diam	PWC	Gelatin / Plywood / Denim Penetra.	Diam	PWC	Tissue / Denim Av Hole Area	Tissue / Plywood / Denim Av Hole Area	Av Pen x Av Area	
	10mm	11 rounds													
1	FMJ	Winchester FMJ 200 gr	1050	Glock 20	1020	22+	0.4	N/A	22+	0.4	N/A	0.16	0.16	undet Pen	
2	Hollow Pt	Federal Hydra Shok 180 gr	1030	Glock 20	1005	16.6	0.6	4.7 ci	17.4	0.5	3.4 ci	0.54	0.44	8.3	23%
3	Hollow Pt	Federal HST 200 gr	1130	Glock 20	1106	17.8	0.65	5.9 ci	16.8	0.62	5.1 ci	0.51	0.47	8.5	11%
4	Hollow Pt	Hornady C Duty 175 gr	1160	Glock 20	1180	22.0	0.5	4.3 ci	16.0	0.6	4.5 ci	0.44	0.42	8.2	5%
5	Hollow Pt	Sig Sauer 180 gr	1250	Glock 20	1200	16.0	0.6	4.5 ci	15.0	0.6	4.2 ci	0.60	0.36	7.4	23%
6	Hollow Pt	Speer Gold Dot 200 gr	1100	Glock 20	1043	15.7	0.5	3.1 ci	14.6	0.45	2.3 ci	0.48	0.51	7.5	12%
7	Hollow Pt	Winchester SX 175 gr	1290	Glock 20	1300	14.8	0.6	4.2 ci	18.5	0.5	3.6 ci	0.50	0.40	7.5	17%
8	Fluted FT	G9 EHP 95 gr	1720	Glock 20 / FN 510	1705	19.6	1.1	18.6 ci	19.7	1.1	18.7 ci	0.84	0.79	16.0	3%
9	Fluted FT	G9 First Response 100 gr	1750	Glock 20 / FN 510	1776	22.3	1.7	50.2 ci	22.1	1.7	49.9 ci	1.03	0.97	22.2	3%
10	Fluted FT	G9 Woodsman 145 gr	1450	Glock 20	1315	41.0	0.8	20.6 ci	40.0	0.8	20.1 ci	0.66	0.66	26.7	1%
11	Fluted FT	Underwood XD 115 gr	1700	Glock 20	1750	19.2	1.0	15.1 ci	18.7	1.0	14.7 ci	0.78	0.72	14.2	5%

The chart below shows the effects of velocity on a Fluted-Fluid Transfer projectile. It compares four rounds: Lehigh Defense 9mm XD, XD +P, XD +P+ and XD .357 Sig. All four rounds utilize the same 90 grain bullet. The difference between the rounds is the pressure which with the same bullet weight changes only velocity. Note that as velocity goes up (blue line) penetration (orange line), wound area (grey line) and the corresponding Permanent Wound Cavity Volume of Wound Index (yellow line) increases. Also, the VWI goes up exponentially more than the other characteristics as discussed in the chapter Five Types Of Handgun Projectiles.

In another comparison three Lehigh Defense 9mm 65 grain XD rounds were compared (XD .380, XD 9mm and XD .357 Sig), with the same outcome. We also used non-standard barrel lengths to create a wider velocity spread and those results were identical and are available. Lastly, we conducted testing with the G9 APC and FR. With eight different velocities of the same projectile the results, while different than that of the XD showed the same effects with a non-linear increase in wound size to a corresponding increase in velocity and all rounds fell on a very straight line showing consistent and repeatable results that confirmed the physics discussed in the Fluted-Fluid Transfer portion of the Five Types Of Handgun Projectiles chapter.



For any of the velocity case study charts, which describes the same effects, please contact us.

ARMOR TEST DESCRIPTION

Ammunition testing vs armor has been conducted since 2017, using thirteen different armor products from seven manufacturers. None of the armor was out of date. Rounds were tested between 2 and 3 shots per product. Eight of the products are rated NIJ Level HG2 and five products are rated for rifle rounds. Please see sections three and four for armor information, data and pictures for the 5.7x28mm and 4.6x30mm rounds. For calibers other than what is included in this report, please contact us.

ARMOR PRODUCT DESCRIPTIONS:

VETERANS MFG:

HG2 (3A) Soft Plate

HG2 (3A) Hard Plate (1 lb)

ANGEL ARMOR:

HG2 (3A) Soft Plate

SAFECO:

HG2 (3A) Hard Plate

SHOTSTOP:

HG2 (3A) Soft Plate

HG2 (3A) Hard Plate

RF1 (3) ICW Hard Plate

RF2 (3+) Hard Plate

UNIVERSAL ARMOR:

HG2 (3A) Hard Plate

RTS:

HG2 (3A) Soft Plate

RF2 (3+) Steel Plate

RF3 (4) Hard Plate

ARMORCORE:

UL Level 7 Hard Dry Wall

ARMOR TEST DATA SHEETS

DNP- Did Not Penetrate PEN- The entire round Penetrated and went completely through the ballistic material

National Institute of Justice (NIJ) Standard 00101.07 Armor Levels. IAW NIJ Standard 0123.00

Level 1 (obsolete): .22 LR and .380 ACP

HG1 (Level 2A): 9mm, .40 S&W, .45 ACP fired from short barrel handguns

HG1 (Level 2): 9mm +P, .357 Magnum fired from short barrel handguns

HG2 (Level 3A): 9mm FMJ (1470 fps), .357 Sig, .44 Magnum fired from long barrel handguns.

RF1 (Level 3) (standard rifle): 7.62 x51mm, 7.62x39mm and 5.56x45mm M193

RF2 (Level 3+): 5.56mm M855 Light Armor Piercing (LAP) round

RF3 (Level 4) (armor piercing rifle): .30-06 Armor-Piercing (AP) steel core, tested at 15 meters

Non-NIJ rating RF1 ICW: Plate becomes RF! when used In Conjunction With an HG2 soft armor panel

Underwriter Laboratories (UL) grades certain ballistic materials in their 8-level system

Level 1 – 1/4 inch thick rated for 9mm

Level 7 – 1 1/8 inch rated for 5.56mm

Level 8 - 1 7/16 inch rated for 7.62mm

VIPER WEAPONS TRAINING LLC

ARMOR RESULTS, CAO Aug 2025		VETERANS MFG		ANGEL ARMOR	SAFECO	SHOTSTOP				UNIVERSAL	RTS			Dry Wall
Caliber		HG2	HG2	HG2	HG2	HG2	HG2	RF1	RF2	HG2	HG2	RF2	RF3	LVL 7
Type	Round	Soft	Hard 1 lb	Soft	Hard	Soft	Hard	Hard	Hard	Hard	Soft	Steel	Hard	Hard
9mm	21 rounds													
FMJ	Winchester FMJ 124 gr	PEN	DNP	PEN	DNP	PEN	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP
Frangible	Sim-X Defensecore 45 gr	DNP	DNP	-	DNP	-	-	-	-	-	DNP	-	-	-
Hollow Pt	Federal HST 147 gr	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP
Hollow Pt	Hornady C Duty +P 135 gr	DNP	DNP	DNP	DNP	DNP	DNP	DNP	-	DNP	-	-	-	-
Hollow Pt	Lehigh Defense ME +P 115 gr	DNP	DNP	-	DNP	-	-	-	-	-	DNP	-	-	-
Hollow Pt	Speer Gold Dot +P 124 gr	DNP	DNP	DNP	DNP	DNP	DNP	DNP	-	DNP	-	-	-	-
Hollow Pt	Speer GD 147 gr	DNP	DNP	DNP	DNP	DNP	DNP	DNP	-	DNP	-	-	-	-
Hollow Pt	Winchester RA9TA 127 gr +P+	DNP	DNP	-	-	DNP	DNP	DNP	DNP	-	DNP	DNP	DNP	DNP
Hollow Pt	Winchester Ranger T 147 gr	DNP	DNP	DNP	DNP	DNP	DNP	DNP	-	DNP	-	-	-	-
Fluted FT	Black Hills HB +P 100 gr	DNP	DNP	DNP	DNP	DNP	DNP	DNP	-	DNP	-	-	-	-
Fluted FT	Black Hills Subsonic 125 gr	DNP	DNP	DNP	DNP	DNP	DNP	DNP	-	DNP	-	-	-	-
Fluted FT	G9 EHP 80 gr	DNP	DNP	DNP	DNP	DNP	DNP	DNP	-	DNP	-	-	-	-
Fluted FT	G9 First Response 77 gr	PEN	DNP	PEN	DNP	PEN	DNP	DNP	DNP	DNP	PEN	DNP	DNP	DNP
Fluted FT	G9 APC 77 gr (1560 fps)	PEN	PEN	PEN	PEN	PEN	PEN	DNP	DNP	PEN	PEN	DNP	DNP	DNP
Fluted FT	G9 APC Subsonic 123 gr	-	PEN	-	PEN	-	-	DNP	-	PEN	PEN	-	-	-
Fluted FT	Lehigh Defense XD 90 gr	DNP	DNP	-	DNP	-	-	-	-	-	DNP	-	-	-
Fluted FT	Lehigh Defense XP 115 gr	DNP	DNP	-	DNP	-	-	-	-	-	DNP	-	-	-
Fluted FT	Underwood XD +P 65 gr	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP
Fluted FT	Underwood XD 90 gr	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP
Fluted FT	Underwood XD +P 90 gr	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP
Fluted FT	Underwood XD +P+ 90 gr	DNP	DNP	PEN	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP

ARMOR RESULTS, CAO Aug 2025		VETERANS MFG		ANGEL ARMOR	SAFECO	SHOTSTOP				UNIVERSAL	RTS			Dry Wall
Caliber		HG2	HG2	HG2	HG2	HG2	HG2	RF1	RF2	HG2	HG2	RF2	RF3	LVL 7
Type	Round	Soft	Hard 1 lb	Soft	Hard	Soft	Hard	Hard	Hard	Hard	Soft	Steel	Hard	Hard
40 S&W	8 rounds													
FMJ	Winchester FMJ 180 gr	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP
Hollow Pt	Federal HST 180 gr	DNP	DNP	DNP	DNP	DNP	DNP	DNP		DNP				
Hollow Pt	Hornady C Duty 175 gr	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP
Hollow Pt	Speer Gold Dot 165 gr	DNP	DNP	DNP	DNP	DNP	DNP	DNP		DNP				
Hollow Pt	Winchester Ranger T 180 gr	DNP	DNP	DNP	DNP	DNP	DNP	DNP		DNP				
Fluted FT	G9 First Response 77 gr	PEN	DNP	PEN	DNP	PEN	PEN	DNP	DNP	DNP	PEN	DNP	DNP	DNP
Fluted FT	G9 APC 77 gr	PEN	PEN	PEN	PEN	PEN	PEN	DNP	DNP	PEN	PEN	DNP	DNP	DNP
Fluted FT	Underwood XD 100 gr	PEN	DNP	PEN	DNP	PEN	PEN	DNP	DNP	DNP	PEN	DNP	DNP	DNP

ARMOR RESULTS, CAO Aug 2025		VETERANS MFG		ANGEL ARMOR	SAFECO	SHOTSTOP				UNIVERSAL	RTS			Dry Wall
Caliber		HG2	HG2	HG2	HG2	HG2	HG2	RF1	RF2	HG2	HG2	RF2	RF3	LVL 7
Type	Round	Soft	Hard 1 lb	Soft	Hard	Soft	Hard	Hard	Hard	Hard	Soft	Steel	Hard	Hard
45 ACP	5 rounds													
FMJ	Winchester FMJ 180 gr	DNP		DNP	DNP		DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP
Hollow Pt	Federal HST +P 230 gr	DNP	DNP	DNP	DNP		DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP
Hollow Pt	Hornady C Duty 220 gr	DNP		DNP	DNP		DNP	DNP	DNP		DNP	DNP	DNP	DNP
Fluted FT	G9 APC 117 gr	PEN	PEN	PEN	PEN	PEN	PEN	DNP	DNP	PEN	PEN	DNP	DNP	DNP
Fluted FT	Underwood XD +P 120 gr	DNP	DNP	DNP	DNP		DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP

PROFESSIONAL WEAPONS TRAINING AND BALLISTIC TESTING SINCE 2011

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SPAR II

SECTION 3

5.7MM & 4.6MM TERMINAL WOUND BALLISTICS & ARMOR REPORT

FOREWORD

This section of the Special Pistol Ammunition Report II (SPAR 2) contains the 5.7mm and 4.6mm Terminal Wound Ballistics and Armor Test Report. It is a composite analysis including data from numerous tests from 2016 to present, including the "5.7mm Terminal Performance Test and Report". It features thirty-three 5.7x28mm rounds from American Eagle, Fiocchi, FNH, Hornady, Speer, Elite Ammunition and Vanguard Outfitters. Starting in November 2021 until present, nine rounds chambered in 4.6x30mm were tested and reported on. Since there are less weapons chambered in the 4.6mm, some reserved only for law enforcement and military use, and there are far fewer cartridges available, there is limited information and data presented here on that caliber. Information and data on these two calibers are included in this section and section four.

All of these tests followed the protocols and phases, described in section two, used during the 2016/17 Joint Agency Ballistic Test For Defensive Handgun Ammunition. Additional small-scale testing was accomplished IAW NATO testing protocols for comparative purposes. Following the five Terminal Wound Ballistics phases, heavy barrier and armor testing was completed using armor products from five different manufacturers with thirteen different armor products. Section four contains the 5.7mm LE/MIL Armor Test Presentation.

The entire test was hosted by Viper Weapons Training LLC and included testers and experts from multiple agencies to include the FBI, DHS, CBP, DoD, US Air Force Research Laboratories (AFRL), NASA, Marshalls, and multiple state DPS's and local police, sheriff and constables' offices. This report also contains information and data from NATO's Etablissement Technique de Bourges (ETBS) 9x19mm vs 5.7x28mm vs 4.6x30mm test, the NATO Army Armaments Group (NAAG) Quick Reaction Team (QRT) final report, Switzerland's Defense Procurement Agency 5.7mm assessment and the United States Secret Service (USSS) James J. Reilly Secret Service Training Center 5.7x28mm review.

No employees or representatives from any ammunition manufacturer were present for any of the testing or influenced any measurements, results or information included in this report. The training and testing company ensured continuity, consistency and accuracy of all tests and generated this final report which is only intended to be released to law enforcement, military and the ammunition/armor manufacturers.

SPECIAL PISTOL AMMUNITION REPORT II

SECTION THREE

5.7mm & 4.6mm TERMINAL WOUND BALLISTICS & ARMOR REPORT

TABLE OF CONTENTS

OVERVIEW: FNH 5.7 x 28mm & HK 4.6 x 30mm

The FNH 5.7 x 28mm is a small-caliber, high-velocity cartridge designed for handgun and Personal Defense Weapon (PDW) applications manufactured by Fabrique Nationale Herstal (FNH). The 5.7×28mm cartridge, projectile and two weapons (FN P90 PDW and FN Five-seveN pistol) were developed concurrently in response to NATO seeking a replacement for the 9×19mm Parabellum cartridge. NATO published Doc D296 in 1990 defining the requests to find a replacement for the 9mm, which it declared obsolete and ineffective due to new threats and the emergence of new ballistic protections.

The Heckler & Koch (HK) 4.6 x 30mm is a small-caliber, high-velocity, smokeless powder, cartridge designed for personal defense weapons, namely the HK MP7. It was introduced in 1999 as a competitor to FN Herstal's 5.7 x 28mm cartridge and the 9mm.

In September of 2000 cartridge trials were held at Fort Halstead (UK). There were originally four candidates tested. In 2002 and 2003, NATO conducted ballistics and terminal wound ballistics testing of the two final contenders, the FNH 5.7 x 28mm and the Heckler & Koch (HK) 4.6 x 30mm. Three separate full-scale tests were performed by different groups: NATO's ETBS who performed 22 tests, the NAAG Quick Reaction Team (QRT) and the Swiss Defense Procurement Agency. The tests compared three calibers, the standard 9x19mm, the FN 5.7×28mm cartridge and the Heckler & Koch 4.6×30mm cartridge. The six attributes, in comparison to the 9mm, focused on during testing were:

1. Greater terminal performance
2. Greater capability of penetrating body armor (CRISAT)[109]
3. Greater range and accuracy
4. Equal or greater round capacity
5. Equal or less weight
6. Equal or less recoil

The NATO group chose the 5.7×28mm cartridge, which showed superior performance over both the 9mm and the 4.6mm during the two years of testing. ETBS concluded "Greater effectiveness of the 5.7mm against unprotected targets and against protected targets." "The 5.7x28mm level of perforation of the CRISAT targets is superior." The results from the QRT final report show that "the 5.7mm is 27% more effective against unprotected targets and 11% more effective against CRISAT protected targets at 100m than the 4.6mm." NATOs two tests were compared to the Swiss test and they were comparable and in agreement. The test results were then analyzed by ballistics experts from Canada, France, the United Kingdom, and the United States who agreed

[109] The CRISAT target is defined IAW STANAG 4512 as a 1.6 mm titanium (UK IMI Ti 318) plate supplemented by 20 layers of Kevlar (UK/SC/4468). This target replicates the Warsaw Pact 683 personal protection vest, and it is still used as the reference standard. The CRISAT target will stop the 9×19mm Parabellum full metal jacket and hollow point cartridges, but it is pierced by the 5.7×28mm and 4.6×30mm personal defense weapon cartridges.

that the 5.7×28mm was "undoubtedly the more effective cartridge." "The cartridge was proven to exhibit superior effectiveness in all six desired attributes."

The FN's 5.7×28mm firearms, the P90 PDW and Five-SeveN pistol, have been in service with military and police forces in over 40 nations throughout the world. In March 2021 NATO finalized the standardization process of the FNH 5.7x28mm caliber by approving the standardization agreement (STANAG) 4509. The 5.7x28mm caliber is now integrated into the Multi-Caliber Manual Of Proof and Inspection (AEP-97) and joins the standardized NATO small caliber ammunition along with the 9x19mm NATO, the 5.56x45mm NATO, the 7.62x51mm NATO and the 12.7x99mm NATO

In addition to being used in the FN P90 and FN Five-seveN firearms, the 5.7×28mm cartridge is used in a number of other weapons, such as the AR-57 and FN PS90 carbines. Also, Excel Arms has four firearms, MasterPiece Arms has three firearms, CMMG has AR-Style firearms, Smith & Wesson, Ruger and PSA each have a semi-automatic pistol chambered in this cartridge and Kel-Tec has the P50 handgun, which uses 50 round P90 magazines.

The FN Five-SeveN pistol and FN P90 personal defense weapon are very popular with the various cartels operating in Mexico and Central/South America. The round has been shown to be effective in penetrating body armor as well as vehicle doors and windows.

There are few weapons chambered in the 4.6mm from Heckler & Koch, CMMG and Tommy Built. Currently the MP7 has no civilian variant and is in limited use worldwide.

Although variations exist, the duty 5.7mm and 4.6mm projectiles are designed to exhibit tumbling properties (no expansion or fragmentation). Please see the section two chapter "Five Types of Handgun Projectiles" and reference type 5 Tumbling for information pertaining to these projectiles. These properties are exactly like most military rifle rounds, such as the 5.56 x 45mm NATO M855, 7.62 x 54mm NATO M80, 7.62 x 39mm AK-47 rounds and 5.45 x 39mm AK-74 7N series rounds. Some exceptions are the few hollow points. In small caliber projectiles, reliable expansion is difficult with hollow points. As the meplat shrinks the internal pressure required to tear and push out the sidewalls becomes exponentially higher. Failure To Expand (FTE) increases as caliber decreases when comparing hollow points in .45 ACP, .40 S&W, 9mm and 5.7mm. Also, the point of expansion is to increase diameter (caliber), hence starting from a smaller diameter greatly limits a gain. There are some rounds that are frangible to limit penetration and barrier performance, but these are generally not regarded as LE/Mil duty rounds, but rather civilian varieties.

AMMUNITION TESTED

Thirty-three 5.7 x 28mm rounds have been fully tested. One round from American Eagle, three from Fiocchi, seven rounds from FNH, two rounds each from Hornady and Speer, six from Elite Ammunition and twelve rounds from Vanguard Outfitters all completed a ≥20 shot, five phase set of tests. Additionally, nine rounds were minimally tested in 4.6 x 30mm as the request on these rounds centered on functionality in the weapon, velocity and penetration depth only.

All thirty-three 5.7mm rounds went through five terminal wound ballistics phases included in this test using 2 stock FN Five-seveN pistols, one a USG and the other a MK2. Following those five phases, many rounds underwent heavy barrier testing to include solid wood, auto glass and metal car doors. and armor testing (phase 6) using thirteen armor products from five manufacturers. Included at the end of this chapter is the complete data sheet with all 5.7mm rounds. The 4.6mm rounds were tested using an HK MP7. All data is current as of August 2025. For rounds of other calibers, please see sections one and two. We currently have data on 9mm, .380, .357 Sig, .40 S&W, 10mm, .45 ACP, 5.7x28mm and 4.6x30mm.

FNH 5.7 x 28mm ROUND SUMMARIES

Listed here are the narrative results from all tested 5.7mm rounds. All rounds were tested at least four times in each of the five standard phases detailed in section 2.

In 5.7 x 28mm there are four main projectile types:

1. Training Rounds. Intended for target shooting and as training rounds. These tend to be lower pressure with projectiles not designed for maximizing wounding effects. These rounds may or may not tumble, fragment or expand.
2. Frangible Rounds. These bullets are designed to fragment into pieces upon contact with the target or a barrier. They may start as an FMJ or hollow point, but their intention is fragmentation. This intentionally minimizes penetration depth and barrier performance.
3. Hollow Points. These projectiles are designed to expand AND not fragment.
4. Duty Tumbling Rounds. These bullets are intended to enter the target and then due to a designed imbalance, tumble on contact to create larger wounds. This design also aids in deeper penetration and enhanced barriers performance.

Please reference chapter “Five Types Of Handgun Projectiles” for complete information.

ROUND 1: American Eagle (Training)

This is the most readily available round in 5.7mm. It is a 40 grain projectile and is designed as a training round.

The rounds lower velocity creates a small wound size. Tumbling was rarely witnessed. This round did not penetrate through any heavy barriers or armor, as designed. It is perfectly suited in the training role it was designed for.

ROUND 2: Fiocchi Frangible Hollow Point (Frangible)

This 35 grain jacketed hollow point projectile is a self-defense load designed to fragment when contacting barriers or the target.

This round was the only one tested from Fiocchi that is designed for deformation or fragmentation. It consistently fragmented limiting penetration and created multiple small wound channels near the path of the bullet. It exhibits a small permanent wound cavity. Due to the fragmentation this round is not designed to penetrate heavy barriers or armor. It performed as intended and is a good choice in this caliber for a round with less lethal effects after contacting barriers or if you desire limited penetration and almost no barrier penetration capabilities.

ROUND 3: Fiocchi Hyperformance (Training)

This 40 grain round is the heaviest of the Fiocchi rounds and appears to be very similar to the FNH SS197SR or the American Eagle 40 grain rounds. It is primarily used as a training round.

Due to the heavier projectile, this round had the deepest penetration of the three Fiocchi rounds. This round is not designed to tumble, fragment or penetrate heavy barriers or armor. Its overall Volume of Wound was small. It is stable and accurate and makes a fine training round.

ROUND 4: Fiocchi Subsonic (Tumbling)

This is a subsonic round designed to be employed suppressed. This 62 grain round was tested with a threaded barrel longer than stock. We tested it with a suppressor (Gemtech GM-9) after completion of our normal testing.

The reduction in velocity comes with the penalty in reduced terminal performance as expected. It surprisingly tumbled most of the time, as designed and exhibited low penetration depths. This round is not intended to penetrate heavy barriers or armor. We tested it with a suppressor (Gemtech GM-9) after completion of our normal testing and found it to be extremely quiet, on par with a suppressed .22LR. This round is an excellent choice for suppressed applications.

ROUND 5: FNH SS190 (Tumbling)

The standard military SS190 ball loading features a 31 grain armor-piercing FMJ-BT projectile. It has a steel penetrator and an aluminum core. It is classified by the BATFE (Bureau of Alcohol, Tobacco, Firearms and Explosives) as armor-piercing (AP) handgun ammunition, with restricted sales to the military and law enforcement. This round is not to be confused with the original SS90 cartridge that stopped production in 1993. That round was less effective with a lighter (23 grain), but longer projectile.

The restricted SS190 performed well with very consistent results. It tumbled reliably, created the largest wound of the seven FN factory rounds and excelled in the heavy barrier and armor tests (phase 6) as designed. It should be considered barrier-blind as it went through armor better than any of the other 5.7mm rounds. Its overall penetration was right at the minimum standard of 12 inches during phase 2.

ROUND 6: FNH SS192 (Hollow Point)

This is one of the original rounds manufactured by FNH and has been discontinued since 2004, yet is still available. The 28 grain bullet is listed as a hollow point yet FNH describes its projectile effects as tumbling. The design of the opening in the tip for this round and its two replacement rounds the SS195LF (Round 8) and SS198LF (Round 10) is a small opening, not designed for a full expansion like a traditional hollow point, but rather to open just far enough to increase the drag at the very tip of the projectile to incur a yaw effect after impact, which creates the tumbling. All three rounds feature the same 28 grain projectile, but the SS192 has a pressure and therefore velocity between the other two. The two successor rounds are not described by FNH as hollow points and we do not list them as such.

The SS192 has characteristics between its two successor rounds as expected. Its penetration depth is lower than what is considered the minimum for duty ammunition. Its relatively low velocity does not promote consistent tumbling on every shot. It exhibited a below average permanent wound cavity size. This round did not penetrate through any heavy barriers. Due to limited supplies this round was not tested vs armor.

ROUND 7: FNH SB193 Subsonic (Tumbling)

This is a subsonic round designed to be employed suppressed. This round was formerly known as the SS193. This edition contains a 60 grain projectile, while previous versions of this round had a 55 grain bullet. This round is restricted by FNH to Law Enforcement and Military (LE/Mil).

Of the three subsonic 5.7mm rounds tested, this was the lightest at 60 grain vs 62 and 64 grains. The reduction in velocity comes with the penalty in reduced terminal performance as expected. It exhibited low penetration depths, but higher than the other two subsonic.rounds in this caliber. Tumbling was very minimal which shows its stability and explains its penetration depths and barrier capabilities. Shots into tissue exhibited the same minimal tumbling effect. With the excellent barrier performance, it is surmised that the projectile is designed around adequate penetration depths and armor penetration capability while being subsonic, which is quite a feat. Both the 55 grain and these 60 grain variants penetrate through heavy barriers and soft HG2 (Level 3A) armor.

ROUND 8: FNH SS195LF (Training)

A civilian version of the SS198LF (Round 10) with the same 28 grain projectile but lower pressure/velocity. It is designed as a training round. This is the civilian successor to the SS192.

The rounds lower velocity creates a smaller wound size and penetration depth. It exhibited tumbling on several instances, but not consistently. This round, as designed does not penetrate through any heavy barriers or armor. It is perfectly suited in the training role it was designed for. This round is used in comparison for velocity effects with two other rounds that use the exact same projectile. (See the graph on the last page of the next chapter.)

ROUND 9: FNH SS197SR (Training)

This 40 grain plastic tipped round is the heaviest of the factory FN rounds. This round is extremely similar to the American Eagle and Fiocchi Hyperformance 40 grain rounds. It is primarily used for training.

Due to its heavier projectile, this round had the deepest penetration of the seven factory FN rounds. This round, as designed does not penetrate through any heavy barriers or armor. Its overall Volume of Wound was small. It is stable and accurate and makes a suitable training round.

ROUND 10: FNH SS198LF (Tumbling)

This 28 grain round is marketed as a "For Law Enforcement And Military Use Only" round. It is the standard non-armor piercing duty ammunition offered by FNH. It is a higher pressure / higher velocity version of the SS195LF (Round 8) and a successor to the SS192 (Round 6).

This restricted ammunition performed very similar to the SS195 but created a slightly larger Volume of Wound and deeper penetration, but still below what is considered the minimum for duty ammunition. Tumbling was more pronounced than in the SS195LF, or SS192, but still not consistently witnessed in ordnance gelatin on all occasions. Tumbling happened at a higher rate during the tissue tests. This round is designed to penetrate heavy barriers and did very well, with minimal deflection and retained wounding potential after passing through the barriers. When shot into armor this round only penetrated older armor products with the pistol and did better with the added velocity from the PS90. In the pistol, it penetrated a few HG2 (Level 3A) products but should not be considered armor piercing during duty use. This round is used in comparison for velocity effects with two other rounds that use the exact same projectile. (See the graph on the last page of the next chapter.)

ROUND 11: FNH SS200 DFNS (Hollow Point)

This new in 2024 30 grain round from FN Herstal is intended for defensive and training use, not duty use.

The round creates a small wound size and low penetration depth. During testing with no barriers, it occasionally fragmented, limiting the penetration. The fragments did not travel away from the wound path. When shot through light domestic barriers, the projectile was degraded and the penetration depth was limited. This round, as designed does not penetrate through any heavy barriers. Armor testing was not accomplished on this round. It is perfectly suited in the training role it was designed for and has a minor application for defense use.

ROUND 12: Hornady Black V-MAX (Training)

This 40 grain projectile appears to be similar in design and function to the FNH SS 197SR, except loaded to a higher pressure. It is a plastic tipped bullet, primarily used as a training round.

As compared to the SS197, this round had slightly more inconsistent results, which is not uncommon when increasing velocity. During gel tests this round penetrated slightly less, but tumbled occasionally creating a slightly larger wound diameter. This effect was witnessed in tissue as well. It shows that increasing velocity does not always create predictable effects. Barriers created smaller changes in results than other rounds, which again is common with increasing the velocity of a 5.7mm round until it starts to fragment, which this one did not. This round, as designed does not penetrate through any heavy barriers or armor. Its overall wound volume (VWI) is larger than the SS197SR.

ROUND 13: Hornady FTX Critical Defense (Hollow Point)

This 40 grain projectile is a plastic tipped hollow point similar to their traditional pistol rounds offered in many other calibers. The plastic tip is intended to minimize "clogging and inconsistency that often plagues hollow point bullets." Clogging of the hollow point greatly increases the occurrence of Failure to Expand (FTE) which greatly inhibits a hollow points ability to wound.

This is one of five hollow point 5.7mm rounds. We recorded 12.5 inches of penetration during the FBI series (phase 2) gelatin tests and 11.8 inches when a light domestic barrier was added (phase 3). This is the second least amount of penetration from the 5.7mm hollow points during both phases. In small caliber projectiles, reliable expansion is difficult and all 5.7mm hollow points suffered from FTE. Barriers created larger changes in results than other 5.7mm hollow point rounds. It is not intended to penetrate any heavy barriers or armor and during testing it did not penetrate those barriers. Its overall wound volume (VWI) is 5.1 cubic inches.

ROUND 14: Speer Gold Dot Hollow Point (original)

This 40 grain projectile is designed as a hollow point. The bullet is built using Speer's exclusive Uni-Cor® method to minimize core-jacket separation for a projectile that is accurate, tough and consistent through all common barriers.

During gel tests this round consistently opened as designed in phase 2/3 with only a couple instances of Failure to Expand. During tissue tests the round sometimes opened up completely and sometimes turned which limits expansion. Barriers created large changes in results. As a hollow point it is not designed to penetrate any light domestic, heavy barriers or armor and during testing it did not penetrate through those barriers. Its penetration depth and overall volume of wound exceeded that of any round from FN and is a good choice as a duty hollow point round.

ROUND 15: Speer Gold Dot Hollow Point (version 2 2024)

This is a 40 grain hollow point and an update to their previous Gold Dot (Round 12). The bullet is also built using Speer's exclusive Uni-Cor® method.

During gel tests this round penetrated less than the previous version, but fairly consistently opened as designed in phase 2/3 with some instances of Failure to Expand. During tissue tests the round sometimes opened up completely and sometimes turned, minimizing expansion even more than the original design. Barriers created larger changes in results than before. As a hollow point it is not designed to penetrate any light domestic, heavy barriers or armor and during testing it did not penetrate through those barriers. Its penetration depth and overall volume of wound was diminished when comparing it to the original Speer Gold Dot.

ROUND 16: Elite S4M (Tumbling)

This is a 28 grain bullet like the factory FN SS195 / 198, but this high-pressure round has a muzzle velocity of just over 2400 fps. It is a high-performance pistol load with excellent accuracy, good terminal performance and excellent barrier properties. It is the fastest round tested in this caliber.

This ammunition performed almost exactly as it did in the 2016/17 Joint Agency Ballistic Test For Defensive Handgun Ammunition. It penetrated just below the minimum required for defensive ammunition. The increased velocity causes an extremely large increase in drag which may account for the additional tumbling as the yaw effects are more pronounced. It was an extremely consistent round with a large permanent wound cavity and excellent barrier performance. Being the fastest tested, this round penetrated heavy barriers well and some armor. This is a good consideration for those wishing less deep penetration, but still a large permanent wound cavity. This round is used in comparison for velocity effects with two other rounds that use the exact same projectile. (See the graph on the last page of the next chapter.)

ROUND 17: Elite T6B (Tumbling)

This ammunition is the primary duty 5.7mm round produced by Elite Ammunition. It utilizes a technically advanced 27 grain projectile which helps create larger wound channels while retaining deep penetration and superior barrier properties.

The design of this round and in particular the area in front of the center of rotation has cuts that in low density air have very little effect, but in high density tissue grab the viscous material and help promote a yaw. When the round yaws those cuts display a high drag profile which makes the round tumble chaotically. Also, with the high change in coefficient of drag (C_d) the projectile tends to have a more pronounced curved wound path. This longer path is shown in the comparison of Penetration Depth (PD) and the Penetration Track Length (PTL) and accounts for an overall increase in permanent wound cavity. This ammunition consistently performs extremely well with good penetration and a very large permanent wound cavity. This round has been tested vs multiple barriers and continues to be almost barrier blind, to include many HG2 (Level 3A) armor products. No soft HG2 armor stopped it. This is one of Elite Ammunitions best defensive rounds and should be considered for duty use.

ROUND 18: Elite PenetraTOR (Tumbling)

This 40 grain FMJ round is designed for deeper penetration.

This round functioned flawlessly during all phases and as designed had consistent deep penetration. This bullet is more stable than some of the other rounds produced by Elite and tumbles less. That added with the heavier weight explains the deeper penetration. This round is designed to penetrate heavy barriers and even penetrated some HG2 (Level 3A) soft armor. HG2 hard armor stopped this round consistently.

ROUND 19: Elite ProtecTOR (Frangible)

This 40 grain thin jacket projectile is a self-defense load designed to break apart and fragment when going through walls reducing lethality after passing through domestic barriers.

The only round tested from Elite Ammunition that exhibited deformation or fragmentation. It still penetrated well but created a smaller overall permanent wound cavity volume. Due to the fragmentation, regardless of what media we used, this round reliably broke apart. This round, as designed does not penetrate through any heavy barriers or armor. It performed as intended and is a good choice in this caliber for a round with less lethal effects after contacting barriers.

ROUND 20: Elite DevastaTOR 2.0 (Tumbling)

A Law Enforcement/Military only (LE/Mil) round, this 37 grain projectile was one of the top two rounds tested in 5.7mm during the 206/17 Joint Agency Ballistic Test For Defensive Handgun Ammunition. It features fantastic penetration, reliability and a very large permanent wound cavity.

This Law Enforcement/Military only (LE/Mil) projectile is almost barrier blind and has always done excellent when tested vs multiple different types of barriers from armor to wood to auto glass. This round consistently goes through most HG2 (Level 3A) armor products. This bullet violently tumbles, yet penetrates deeply. Its penetration, reliability and large permanent wound cavity are very impressive. The overall Volume of Wound was one of the largest tested. It remains one of the top rounds tested in 5.7mm. This round should certainly be on your list if your agency is selecting duty rounds.

ROUND 21: Elite DevastaTOR 3.0 (Tumbling)

This Law Enforcement/Military only (LE/Mil) round is a lighter faster redesign of the previous DevastaTOR 2.0 (Round 18). It features a 27 grain projectile which is almost barrier blind.

This redesigned round is just as barrier blind as its predecessor. Regardless of what we shot it through, this round continued to create extremely damaging effects in all media. The projectile went through almost all the HG2 (Level 3A) armor products soft and hard. It has a fantastic penetration depth which is very surprising due to its low weight. It reliably tumbles and recorded the largest Volume of Wound of any 5.7mm round. Most likely due to its lighter weight and increased velocity, this projectile displayed a curved wound path even more pronounced than its predecessor. It was very consistent with one of the smallest standard deviations between measured shots. This is another round to seriously consider for duty use.

ROUND 22: Vanguard Black Fang (Tumbling)

This ammunition is the primary duty 5.7mm round offered by Vanguard Outfitters. It utilizes an advanced 34 grain projectile which helps create larger wound channels while retaining deep penetration and good barrier performance. It was one of the top two rounds tested in 5.7mm during the 2016/17 Joint Agency Ballistic Test For Defensive Handgun Ammunition.

The description here applies to all five of the Vanguard Black Fang variants (Rounds 22-26). The cuts on these projectiles forward of the center of rotation have a dual effect. First, they grab tissue which increases yaw and tumbling and second, they also help to cut the tissue instead of pushing through it which reduces a portion of the increased drag aiding in deeper penetration. When the bullet yaws those cuts display a high drag profile which makes the projectile tumble chaotically. Also, with the large change in coefficient of drag (C_d) after yaw, the projectile tends to have a more pronounced curved wound path. When comparing the Penetration Depth (PD) and the Penetration Track Length (PTL) these bullets indicate some of the largest curves of any accounting for the overall increase in permanent wound volume. The violent unpredictable tumbling leads to variations in the wound dimensions but exhibited impressive results. They penetrate very well, have a large permanent wound cavity and excel through barriers, especially through heavy barriers and armor. They penetrated almost all HG2 (Level 3A) armor tested. These five variants with only minor differences remain one of the top choices in the 5.7mm.

ROUND 23: Vanguard BDF LE (Tumbling)

A 34 grain Law Enforcement/Military only (LE/Mil) variant, this round is an upgrade and redesign of the Vanguard Black Fang (Round 22, see description above). It utilizes a similar but modified projectile which helps create superior barrier properties while retaining the large wound channel and deep penetration.

This Law Enforcement/Military only (LE/Mil) ammunition was designed to increase barrier performance of the Vanguard Black Fang of which it is modified from. Overall results were slightly better than its civilian counterpart and the increase to consistency and barrier performance were noted. It performed extremely well with excellent penetration and a very large permanent wound cavity. This round was further tested vs multiple barriers and proves to be almost barrier blind. Like the civilian version, this projectile penetrated almost all the HG2 (Level 3A) armor. Consider this round as another great choice for duty use.

ROUND 24: Vanguard BDF HVP LE (Tumbling)

This 34 grain Law Enforcement/Military only (LE/Mil) round has a harder copper alloy than the Vanguard BDF LE (Round 23). The harder modified projectile was designed for even more superior barrier performance while retaining the large wound channel and deep penetration of the original Black Fang (Round 20, see description above).

Utilizing a harder copper alloy, this Law Enforcement/Military only (LE/Mil) ammunition was designed as a comparison with Round 23. During our initial 5 phases we did not note any changes, good or bad between the rounds. Both were very consistent and retained the great barrier performance of the Vanguard Black Fang of which it is modified from. Overall results were slightly better than its civilian counterpart and the increase to consistency and barrier performance were substantial but roughly the same as their other LE/Mil round. Like the civilian version, this projectile penetrated almost all the HG2 (Level 3A) armor. It performed extremely well with excellent penetration and a large overall Volume of Wound. We tested these two rounds LE/Mil rounds (Rounds 23 and 24) vs as many barriers as we could find to try to find a difference and failed to do so. Both rounds are equally barrier blind and are a great choice for a duty round.

ROUND 25: Vanguard Longfang SE (Tumbling)

This 34 grain monolithic copper projectile is a variation of the 34 grain Black Fang (Round 22, see description above). Its longer frontal portion creates an Overall Length (OAL) of 19mm vs 16.8mm. It utilizes a technically advanced shape to help create larger wound channels while retaining deep penetration and excellent barrier performance. The patented cutouts and added length promote tumbling.

The overall performance and capabilities of this round are similar to its predecessors. It was almost 60 fps faster for the same grain weight. This ammunition also had great penetration with and without barriers. The penetration depth was slightly less in both phase 2 and phase 3, but this was due almost entirely to the increased curvature of the wound track. Exact measurements of the Penetration Track Length of both bullets showed the Longfang exhibited an increase which indicates that the round tumbles more chaotically. The round seemed to tumble earlier, although we have insufficient data for the exact difference between the two rounds in this regard. During the tissue tests (phase 4 and 5) we measured a larger average hole. This could be caused by the longer projectile, increased velocity or increased tumbling. Most likely a combination of the above made it more effective. The Longfang produces a very large permanent wound cavity and is one of the top choices in the 5.7mm. Overall, of all the five Black Fang variants we have tested, the Longfang exhibited the largest Volume of Wound Index (VWI) and Total Volume of Wound Index (TVWI). This round was minimally tested vs heavy barriers and proves to be almost barrier blind. Due to limited supplies, this round was not tested versus armor.

ROUND 26: Vanguard Lightning Fang (Tumbling)

This 25 grain round is the lightest weight and the second fastest round tested. It's a version of the 34 grain Black Fang (Round 22, see description above) that is shorter overall with only one cutout resulting in the weight decrease. The copper is a proprietary alloy for maximizing penetration in balance with deformation for wound results. It utilizes a technically advanced projectile which helps create larger wound channels while retaining deep penetration and good barrier properties.

This ammunition had great penetration with and without barriers. It produced a very large permanent wound cavity and is one of the top choices in the 5.7mm. With the higher velocity and lighter-weight we expected to see a shallower penetration in the gel (phases 2 and 3). It was a little less but not as much as expected given the momentum numbers were low. We suspect the shorter round had less drag during the tumbling. There was a very erratic wound path after hitting the gel which highlighted its tumbling capabilities. During the tissue tests (phase 4 and 5) we were expecting a larger area of wound due to the higher velocity but suspect that the shorter overall length made a smaller hole while tumbling. One thing to note is that we measure the hole from both the front and back tissue pieces and almost always the second hole from the back tissue piece is larger, but with this round that was not the case. Dissection of the tissue showed that the tumbling happened a little earlier than the other Black Fang varities, which made a bigger hole early and the drag and light weight created a smaller hole on exit. Overall, this is a lower penetration Black Fang with a similar sized Volume of Wound Index (VWI). Due to limited supplies, this round was not tested versus armor.

ROUND 27: Vanguard Barnes Hollow Point

This 50 grain hollow point round is designed for deep penetration with expansion. This round intentionally expands reducing barrier performance. It is a self-defense load that tends to break apart or fragment going through walls reducing lethality after passing through domestic barriers.

This round was the only one tested from Vanguard that exhibited deformation or fragmentation. It penetrated well but the least of all their rounds except for the subsonic (Round 33). It created a large permanent wound cavity with no barriers and had the most reduction in capability of the Vanguard rounds when barriers were introduced. This is one of only five 5.7mm hollow points. Through no barriers it penetrated the deepest and exhibited the largest permanent wound cavity of the five 5.7mm hollow points. When barriers were introduced, the degradation was increased more than the other hollow points in this caliber. As a hollow point it is not designed to penetrate any light domestic, heavy barriers or armor and during testing it did not penetrate well through those barriers. It performed as intended and is a good choice if you are looking for a round with less lethal effects after penetrating common barriers. Its overall performance in regards to penetration depth, reliability and permanent wound cavity volume exceeded that of the other 5.7mm hollow points.

ROUND 28: Vanguard Combined Technology (Tumbling)

This 50 grain projectile is a hunting and varmint bullet designed for accuracy, and longer-range stability.

This hunting and varmint bullet demonstrated a large permanent wound cavity with above average penetration. It performed very consistently and when tested at longer ranges (70 yards) it achieved excellent accuracy. This round, as designed does not penetrate through any heavy barriers or armor. This round is a perfect choice for small animal applications as intended.

ROUND 29: Vanguard GPMI (Frangible)

This 40 grain round is designed for deep penetration. The projectile is a lead-free, high-performance Quadra-Shock. It is a non-frangible fused copper powder composition that has almost no copper fouling.

This high-performance ammunition recorded the deepest penetration with and without barriers. It trades off some permanent wound cavity size for the deeper penetration. This round, as designed does not penetrate through any heavy barriers or armor. It is a very reliable and consistent round that shoots extremely clean. This is an excellent choice when deep penetration is the primary required characteristic.

ROUND 30: Vanguard GPMI DF (Frangible)

This is a 35 grain lighter weight version of the 40 grain GPMI (Round 29). It is designed for shallower penetration for self-defense vs duty use. The solid copper projectile is lead-free and designed to fragment away at the tip with at least 4 petals with the base continuing for penetration. It is intended for close distance and indoors to limit barrier penetration.

This ammunition recorded less penetration through a domestic barrier. It is a very reliable and consistent round that shoots extremely clean and is an excellent choice for less penetration. We encountered the designed fragmentation which can be hard to measure. Penetration was inconsistent due to the fragmentation and was less than the heavier variant which is in line with its intended use. In tissue the fragmentation is even harder to calculate and find. Initial measurements found several pieces during the dissection. Overall wound size is more estimated due to adding smaller depths and separate channels. The round did very well, performed as designed and is a lower penetration home defense variant of the original. Due to limited supplies, this round was not tested versus armor.

ROUND 31: Vanguard Low Collateral (Frangible)

This is a 35 grain frangible, (low collateral) tapered boattail projectile. It is designed for close quarters engagements, providing sufficient penetration into tissue. Due to the unique construction this bullet is intended to penetrate through soft HG2 (Level 3A) armor, while disintegrating when encountering heavy barriers such as metal, solid wood and auto glass. It is produced with no metal jacket, thereby reducing dangerous spall/shrapnel and ricochet. This ammunition is not designated as Armor Piercing (AP) rounds but rather are designated as 5.7 low collateral VO-LC-LE. Please contact the manufacturer for sales and export information.

This ammunition is similar to Vanguards GPMI DF (Round 30) in regards to its fragmentation, yet this projectile has the ability to penetrate soft armor. Our testing recorded an average of 13.9 inches of penetration in phase 2 gel and with a light domestic barrier it penetrated 13.1 inches (phase 3). Of note, as with all designed fragmenting rounds, penetration is variable and the stated averages had a large standard deviation. A larger sample size may yield different values. It went through light domestic barriers with minimal degradation. Overall wound size (7.4 cubic inches) is more estimated due to adding smaller depths and separate channels from the fragmentation. In tissue the fragmentation is difficult to identify, although we found several fragments during post measurement dissection. The round performed as planned and is a lower penetration yet larger wound diameter option. As designed, the projectile did not penetrate through any heavy barriers. As advertised this round penetrated through 2 different products rated as soft HG2 (Level 3A) armor with all six shots from a FN 5.7 pistol. When encountering hard HG2 this round did not penetrate through the armor.

ROUND 32: Vanguard FRAG HP (Frangible)

This is a 32 grain high velocity hollow point, designed to fragment on contact with tissue and light domestic barriers. This monolithic copper projectile expands to create pedals that also fragment off. It is designed as a self-defense round for close quarters and optimized for 50 yards or less in pistol use, with shallower penetration. The solid copper projectile is lead-free and designed to fragment with the base continuing for penetration.

This round worked as advertised. We noticed consistent expansion and the fragmentation occurred reliably. Penetration of the base itself was consistent and shallow. We witnessed the designed fragmentation at varying depths and the total wound volume is hard to measure. In tissue the fragmentation is even harder to calculate and find. Initial measurements found several pieces during the dissection. Overall wound size is more estimated due to adding smaller depths and separate channels. The round did very well, performed as designed and is a consistent choice for lower penetration home defense scenarios. Due to limited supplies, this round was not tested versus heavy barriers or armor, but witnessing how it was degraded by light domestic barriers we can surmise that these rounds will not penetrate heavy barriers or armor.

ROUND 33: Vanguard Bonded Subsonic (Tumbling)

This is a subsonic bonded ammunition designed to be employed suppressed. This 64 grain round was tested with a threaded barrel longer than stock. We tested it with a suppressor (Gemtech GM-9) after completion of our normal testing. This is the heaviest round tested in this caliber.

This subsonic round went through the normal series of tests and was a very reliable subsonic 5.7 round. The reduction in velocity comes with the penalty in reduced terminal performance as expected. It exhibited low penetration depths, good barrier performance and good permanent wound cavity size. This round, as designed does not penetrate through any heavy barriers or armor. We tested it with a suppressor (Gemtech GM-9) after completion of our normal testing and found it to be extremely quiet, on par with a suppressed .22LR. This round is an excellent choice for suppressed applications.

5.7 x 28mm and 4.6 x 30mm TERMINALWOUND BALLISTICS TEST DATA SHEETS

VWI - Volume of Wound Index

A computed volume in cubic inches that represents the most precise Permanent Wound Cavity (PWC) using IWBA gel for accurate penetration depth comparisons and realistic tissue media to measure the wound area and incorporating both non-barrier and barrier tests. Averaging the two penetration depths from Phase 2 and 3 (IWBA gel tests) and multiplying by the average hole area from both tissue Phases 4 and 5.

LDBD% - Light Domestic Barrier Degradation Percentage

Phases 3 and 5 add a light domestic barrier IAW FBI / DoD protocol. The amount of degradation to each round caused by the addition of this barrier is reflected by analyzing the differences between phase 2 and phase 3 for gel and phase 4 and phase 5 with tissue and the overall average percentage of degradation is calculated and displayed in this last column.

A low number indicates that particular round was less affected by passing through a light domestic barrier prior to the target media of gel or tissue. A larger number indicates the barrier degraded the round more and the ability of the round to function after the barrier was more diminished.

5.7 x 28mm 33 Rounds

VIPER WEAPONS TRAINING LLC

TERMINAL WOUND BALLISTICS DATA, CAO AUGUST 2025

	Caliber	Round (160)	Box	Weapon	PHASE 1	PHASE 2			PHASE 3			PHASE 4	PHASE 5	VWI	LDBD%	TVWI
	Type		Velocity		Average Velocity	Gelatin / Denim Penetra.	Diam	PWC	Gelatin / Plywood / Denim Penetra.	Diam	PWC	Tissue / Denim Av Hole Area	Tissue / Plywood / Denim Av Hole Area	Av Pen x Av Area		Av PTL x Av Area
	5.7mm	33 rounds														
1	Training	American Eagle 40 gr	1655	FN 5.7	1575	12.5			11.5			0.30	0.20	3.0	20%	3.0
2	Frangible	Fiocchi Frangible HP 35 gr	1750	FN 5.7	1715	13.2			10.5			0.18	0.12	1.8	25%	ND
3	Training	Fiocchi Hyperformance 40 gr	1750	FN 5.7	1735	13.5			12.8			0.22	0.24	3.0	0%	ND
4	Tumbling	Fiocchi Subsonic 62 gr		FN 5.7	950	10.5			9.0			0.25	0.23	2.3	10%	ND
5	AP Tumbling	FNH SS190 31 gr	2130	FN 5.7	2130	12.0			11.2			0.39	0.39	4.5	3%	ND
6	Hollow Pt	FNH SS192 28 grain		FN 5.7	2046	9.7			9.1			0.35	0.32	3.2	7%	3.4
7	Tumbling	FNH SB193 Subsonic 60 grain	984	FN 5.7	1042	13.5			13.8			0.22	0.21	2.9	0%	3.2
8	Training	FNH SS195LF 28 gr	2000	FN 5.7	1900	9.1			8.3			0.29	0.27	2.4	9%	2.6
9	Training	FNH SS197SR 40 gr	1700	FN 5.7	1620	13.8			12.7			0.22	0.20	2.8	9%	2.9
10	Tumbling	FNH SS198LF 28gr	2150	FN 5.7	2092	10.2			9.6			0.38	0.34	3.6	10%	3.9
11	Hollow Pt	FNH SS200 DFNS 30 gr	1894	FN 5.7	1817	12.2			9.5			0.36	0.28	3.5	22%	ND
12	Training	Hornady Black V-Max 40 gr	1810	FN 5.7	1794	13.2			11.7			0.24	0.31	3.4	0%	3.5
13	Hollow Pt	Hornady Critical Defense 40 gr	1810	FN 5.7	1835	12.5			11.8			0.49	0.35	5.1	15%	5.1
14	Hollow Pt	Speer Gold Dot HP 40 gr orig.	1800	FN 5.7	1775	14.5			15.0			0.51	0.42	6.9	9%	6.9
15	Hollow Pt	Speer Gold Dot HP 40 gr v2 2024	1800	FN 5.7	1705	13.8			13.5			0.39	0.44	5.7	5%	5.8
16	Tumbling	Elite S4M 28gr	2650	FN 5.7	2410	12.5			11.9			0.44	0.50	5.7	3%	6.4
17	Tumbling	Elite T6B 27 gr	2570	FN 5.7	2230	15.1			14.7			0.54	0.51	7.8	2%	8.9
18	Tumbling	Elite PenetraTOR 40 gr	1900	FN 5.7	1905	17.2			15.9			0.35	0.10	3.7	37%	ND
19	Frangible	Elite ProtecTOR 40 gr	2100	FN 5.7	1910	16.5			15.3			0.13	0.12	2.0	8%	ND
20	Tumbling	Elite DevastaTOR 37 gr		FN 5.7	2005	18.7			18.3			0.62	0.58	11.1	4%	12.0
21	Tumbling	Elite DevastaTOR 3.0 27 gr		FN 5.7	2310	19.9			19.7			0.66	0.66	13.0	1%	14.9
22	Tumbling	Vanguard Black Fang 34 gr	2150	FN 5.7	2130	18.9			18.7			0.63	0.51	10.6	8%	12.2
23	Tumbling	Vanguard BDF LE 34 gr	2150	FN 5.7	2200	19.2			19.0			0.57	0.55	10.7	2%	ND
24	Tumbling	Vanguard BDF HVP LE 34 gr	2150	FN 5.7	2190	19.3			19.2			0.55	0.56	10.7	1%	ND
25	Tumbling	Vanguard Longfang SE 34 gr	2125	FN 5.7	2188	17.7			18.2			0.63	0.65	11.5	0%	13.4
26	Tumbling	Vanguard Lightning Fang 25 gr	2350	FN 5.7	2305	17.5			17.7			0.61	0.57	10.4	3%	ND
27	Hollow Pt	Vanguard Barnes HP 50 gr	1725	FN 5.7	1590	16.8			15.0			0.56	0.40	7.6	20%	ND
28	Tumbling	Vanguard Comb Tech 50 gr		FN 5.7	1635	17.0			16.2			0.59	0.50	9.0	10%	ND
29	Frangible	Vanguard GPMI 40 gr		FN 5.7	1970	20.5			19.5			0.48	0.43	9.1	9%	ND
30	Frangible	Vanguard GPMI DF 35 gr	2150	FN 5.7	2140	16.2			15.0			0.50	0.40	7.0	14%	ND
31	Frangible	Vanguard Low Collateral 35 gr	2025	FN 5.7	2076	13.9			13.1			0.54	0.55	7.4	4%	7.5
32	Frangible	Vanguard FRAG HP 32 gr	2225	FN 5.7	2134	11.2			10.0			0.28	0.31	3.1	10%	ND
33	Tumbling	Vanguard EXP Subsonic 64 gr		FN 5.7	1030	13.2			12.4			0.28	0.24	3.3	10%	ND

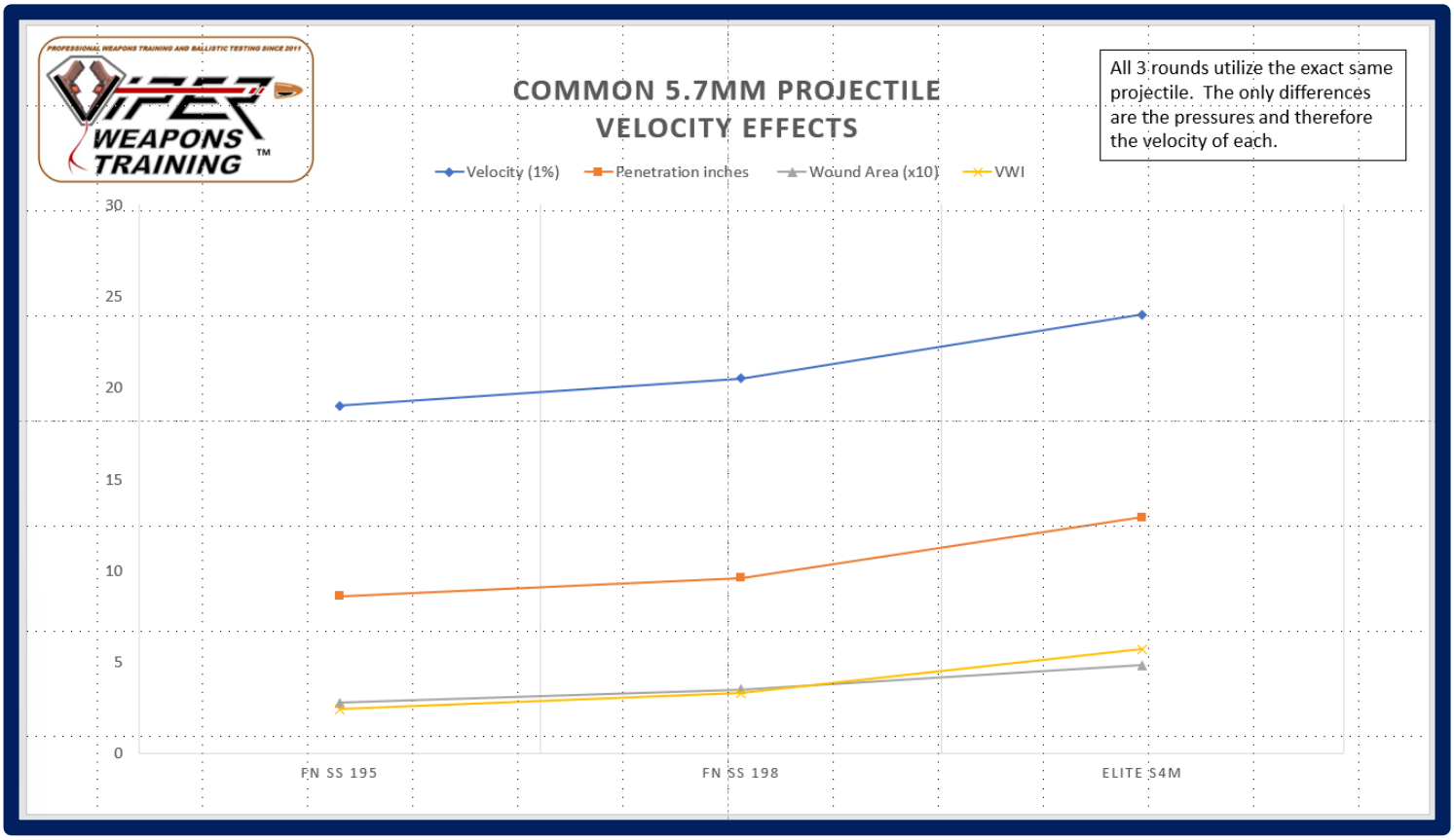
4.6 x 30mm 9 Rounds

VIPER WEAPONS TRAINING LLC

TERMINAL WOUND BALLISTICS DATA, CAO AUGUST 2025

	Caliber	Round (160)	Box	Weapon	PHASE 1	PHASE 2			PHASE 3			PHASE 4	PHASE 5	VWI	LDBD%	TVWI
	Type		Velocity		Average Velocity	Gelatin / Denim Penetra.	Diam	PWC	Gelatin / Plywood / Denim Penetra.	Diam	PWC	Tissue / Denim Av Hole Area	Tissue / Plywood / Denim Av Hole Area	Av Pen x Av Area		Av PTL x Av Area
	4.6mm	9 rounds														
1	Training	Fiocchi 40 gr	1900	HK MP7	1875	18.2			16.5			0.29	0.25	4.7	5%	
2	Soft Pt	Fiocchi 40 gr Soft Point	1900	HK MP7	1912	16.2			13.8			0.27	0.32	4.4	10%	
3	Training	Sellier & Bellot 40 gr	2067	HK MP7	2020	20.5			18.8			0.34	0.33	6.6	3%	
4	Tumbling	Hornady Black V-Max 38 grain	2100	HK MP7	2048	14.9			14.1			0.39	0.38	5.6	3%	
5	Tumbling	Vanguard Solid Penetrator 31 gr	2250	HK MP7	2125	15.75			15.2			0.41	0.38	6.1	6%	
6	Tumbling	Vanguard SP LE 31 gr	2375	HK MP7	2247	16.9			16.2			0.45	0.48	7.7	1%	
7	Hollow Pt	Barnes TSX 31 gr	2328	HK MP7	2328	15.2	0.8		13.5			0.30	0.33	4.5	3%	
8	Hollow Pt	Vanguard EXP 31 gr	2250	HK MP7	2130	14.2	0.7		13.1			0.35	0.31	4.5	9%	
9	Hollow Pt	Vanguard EXP LE 31 gr	2375	HK MP7	2240	14.8	0.7		13.3			0.28	0.40	4.8	1%	

The chart below shows the effects of velocity on a 5.7x28mm projectile. It compares three rounds (FN SS 195, FN SS 198 and Elite Ammunition S4M). All three rounds utilize the same 28 grain bullet. The difference between the rounds is the pressure which with the same bullet weight changes only velocity. Note that as velocity goes up (blue line) penetration (orange line), wound area (grey line) and the corresponding Permanent Wound Cavity, Volume of Wound Index (yellow line) increases.



Please contact us for more technical information on the above findings.

5.7 x 28mm and 4.6 x 30mm ARMOR TEST DESCRIPTION

Armor testing with 5.7mm ammunition was conducted using thirteen different armor products from five manufacturers. None of the armor was out of date. Rounds were tested between 2 and 5 shots per product. One round (SS190) was also tested on a special SWAT 3A+ vest. Armor testing was accomplished with both the Five-seveN pistol and in some cases the FN PS90. Four 4.6mm rounds underwent limited testing vs two armor products. Section four contains the 5.7mm LE/MIL Armor Test Presentation.

ARMOR PRODUCT DESCRIPTIONS:

VETERANS MFG:

Ballistic HG1 (Lvl 2+) soft panel

Ballistic HG1 (Lvl 2) hard plate

Helmet HG1 (Lvl 2+)

HG2 (3A) Soft Panel

HG2 (3A) Hard Plate (1 lb.)

Titanium HG2 (3A)

AR/AK Rifle Plate RF1 (Lvl 3)

ANGEL ARMOR:

HG2 (3A) Soft Panel

SAFECO:

HG2 (3A) Hard Plate

SHOTSTOP:

HG2 (3A) Soft Panel

HG2 (3A) Hard Clipboard

RF1 (3) ICW Hard Plate

UNIVERSAL ARMOR:

HG2 (3A) Hard Plate

5.7 x 28mm and 4.6 x 30mm ARMOR TEST DATA

DNP- Did Not Penetrate PEN- The entire round Penetrated and went completely through the ballistic material

National Institute of Justice (NIJ) Standard 00101.07 Armor Levels. IAW NIJ Standard 0123.00

Level 1 (obsolete): .22 LR and .380 ACP

HG1 (Level 2A): 9mm, .40 S&W, .45 ACP fired from short barrel handguns

HG1 (Level 2): 9mm +P, .357 Magnum fired from short barrel handguns

HG2 (Level 3A): 9mm FMJ (1470 fps), .357 Sig, .44 Magnum fired from long barrel handguns.

RF1 (Level 3) (standard rifle): 7.62 x51mm, 7.62x39mm and 5.56x45mm M193

RF2 (Level 3+): 5.56mm M855 Light Armor Piercing (LAP) round

RF3 (Level 4) (armor piercing rifle): .30-06 Armor-Piercing (AP) steel core, tested at 15 meters

Non-NIJ rating RF1 ICW: Plate becomes RF! when used In Conjunction With an HG2 soft armor panel

Viper Weapons Training	ARMOR PRODUCTS																							
2025 Armor Results	VETERANS MFG									ANGEL ARMOR		SAFECO		SHOTSTOP						UNIVERSAL ARMOR	
	HG1 Soft	HG1 Hard	HG1 Helmet	HG2 Soft		HG2 Hard 1 lb		HG2 Titanium	RF1 Rifle Plate	HG2 Soft		HG2 Hard		HG2 Soft		HG2 Clipboard		RF1 Hard		HG2 Hard	
5.7x28mm Rounds	Pistol	Pistol	Pistol	Pistol	PS90	Pistol	PS90	Pistol	Pistol	Pistol	PS90	Pistol	PS90	Pistol	PS90	Pistol	PS90	Pistol	PS90	Pistol	PS90
American Eagle 40 gr	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	-	-	DNP	DNP	DNP	DNP
SS190 31 gr	PEN	PEN	PEN	PEN	PEN	PEN	PEN	DNP	DNP	PEN	PEN	PEN	PEN	PEN	PEN	PEN	PEN	DNP	PEN	PEN	PEN
SS195LF 28 gr	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP
SS197SR 40 gr	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	-	-	DNP	DNP	DNP	DNP
SS198LF 28gr	PEN	DNP	DNP	DNP	PEN	DNP	DNP	DNP	DNP	DNP	PEN	DNP	PEN	DNP	PEN	PEN	PEN	DNP	DNP	DNP	DNP
Hornady Black V-Max 40 gr	-	-	-	DNP	-	DNP	-	-	-	-	-	DNP	-	-	-	-	-	-	-	-	-
Speer Gold Dot HP 40 gr	-	-	-	DNP	DNP	DNP	DNP	-	-	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP
Elite S4M 28gr	PEN	PEN	PEN	DNP	PEN	DNP	DNP	DNP	DNP	PEN	PEN	PEN	PEN	DNP	PEN	PEN	PEN	DNP	DNP	DNP	DNP
Elite T6B 28 gr	PEN	PEN	PEN	PEN	PEN	DNP	DNP	DNP	DNP	PEN	PEN	DNP	DNP	PEN	PEN	PEN	PEN	DNP	DNP	DNP	DNP
Elite PenetraTOR 40 gr	PEN	PEN	PEN	DNP	DNP	DNP	DNP	DNP	DNP	PEN	PEN	-	-	-	-	-	-	-	-	-	-
Elite ProtecTOR 40 gr	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	-	-	-	-	-	-	-	-	-	-
Elite DevastaTOR 37 gr	PEN	PEN	PEN	PEN	PEN	PEN	PEN	DNP	DNP	PEN	PEN	-	-	-	-	-	-	-	-	-	-
Elite DevastaTOR 3.0 27 gr	PEN	PEN	PEN	PEN	PEN	PEN	PEN	DNP	DNP	PEN	PEN	PEN	PEN	PEN	PEN	PEN	PEN	DNP	DNP	PEN	PEN
Vanguard Black Fang 34 gr	PEN	PEN	PEN	PEN	PEN	DNP	DNP	DNP	DNP	PEN	PEN	PEN	PEN	PEN	PEN	PEN	PEN	DNP	DNP	PEN	PEN
Vanguard BDF LE 34 gr	PEN	PEN	PEN	PEN	PEN	DNP	DNP	DNP	DNP	PEN	PEN	-	-	PEN	PEN	-	-	-	-	-	-
Vnguard BDF HVP LE 34 gr	PEN	PEN	PEN	PEN	PEN	DNP	DNP	DNP	DNP	PEN	PEN	-	-	PEN	PEN	-	-	-	-	-	-
Vanguard Barnes HP 50 gr	PEN	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	-	-	-	-	-	-	-	-	-	-
Vanguard Comb Tech 50 gr	PEN	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	PEN	-	-	-	-	-	-	-	-	-	-
Vanguard GPMI 64 gr	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	-	-	-	-	-	-	-	-	-	-
Vanguard Low Collateral 35 gr	-	-	-	-	-	DNP	-	-	-	PEN	-	-	-	PEN	-	-	-	-	-	DNP	-
Vanguard Subsonic 64 gr	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	-	-	-	-	-	-	-	-	-	-
4.6x30mm Rounds																					
Vanguard FMJ 31 gr	-	-	-	-	-	-	-	-	-	-	-	DNP	-	-	-	-	-	-	-	DNP	-
Vanguard FMJ LE 31 gr	-	-	-	-	-	-	-	-	-	-	-	DNP	-	-	-	-	-	-	-	DNP	-
Vanguard EXP 31 gr	-	-	-	-	-	-	-	-	-	-	-	DNP	-	-	-	-	-	-	-	DNP	-
Vanguard EXP LE 31 gr	-	-	-	-	-	-	-	-	-	-	-	DNP	-	-	-	-	-	-	-	DNP	-

We also tested the armor piercing duty round, the SS190 with 4 shots on a special SWAT 3A+ vest (old NIJ .06 rating). None of the rounds penetrated.

SPAR2 SECTION FOUR

5.7mm LE/MIL

Armor Test Presentation

PROFESSIONAL WEAPONS TRAINING AND BALLISTIC TESTING SINCE 2011

www.ViperWeapons.us

5.7x28mm Armor Test

All armor products were new, unused and none out of date. We are not grading armor, but rather using the armor products for ammunition comparison

The armor ratings are from the National Institute of Justice (NIJ) and are IAW Standard 0101.07 Armor Levels (April 2024) and NIJ Standard 0123.00

All slides will note the weapon used (FN 5.7 pistol or FN PS90)

Penetrations are defined as projectiles that pass completely through the armor product. All penetrations are in RED

Stopped By Armor are defined as projectiles that do not pass completely through and are either stopped on the surface, are embedded inside the product, or have poked through but are attached to the material. These are in BLUE

ANGEL ARMOR HG2 SOFT

(All Shots with FN 5.7 pistol)

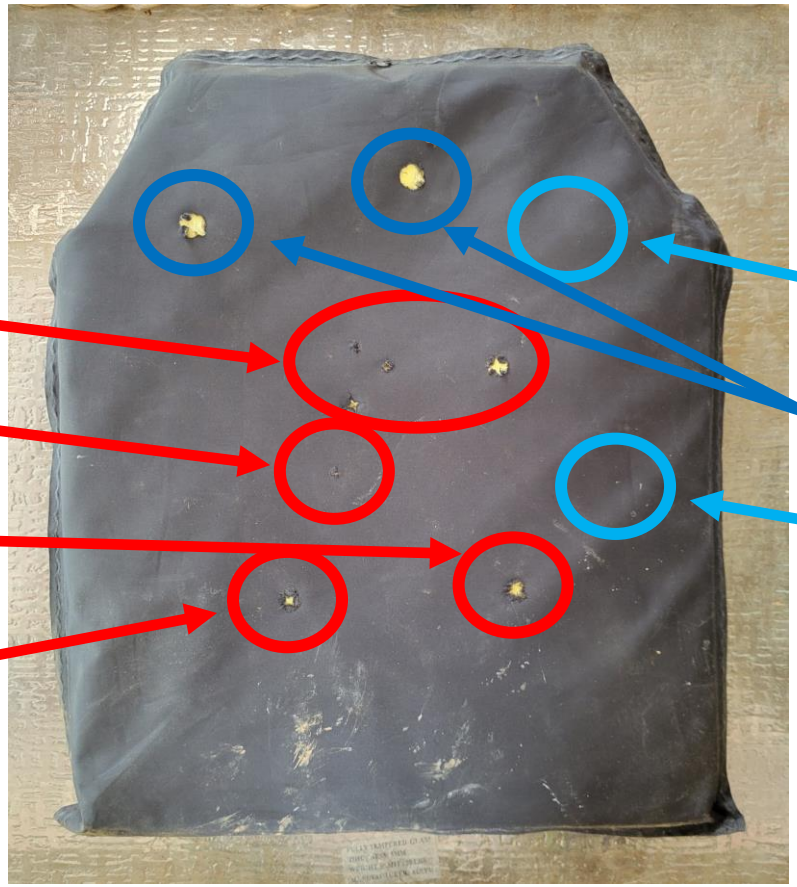
PENETRATIONS

Elite S4M (4)

Elite T6

FN SS190

Vanguard Black Fang



STOPPED BY ARMOR

FN SS195

FN SS198 (2)

Speer Gold Dot HP

SAFECO HG2 HARD

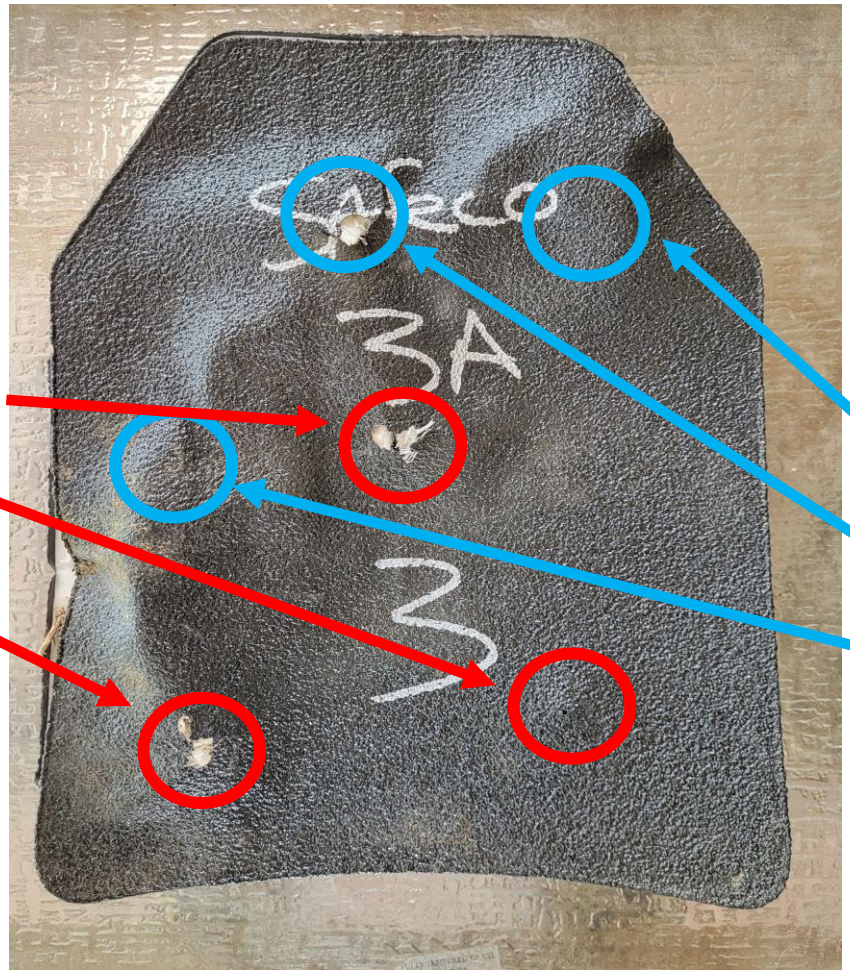
(All Shots with FN 5.7 pistol)

PENETRATIONS

Elite S4M

FN SS190

Vanguard Black Fang



STOPPED BY ARMOR

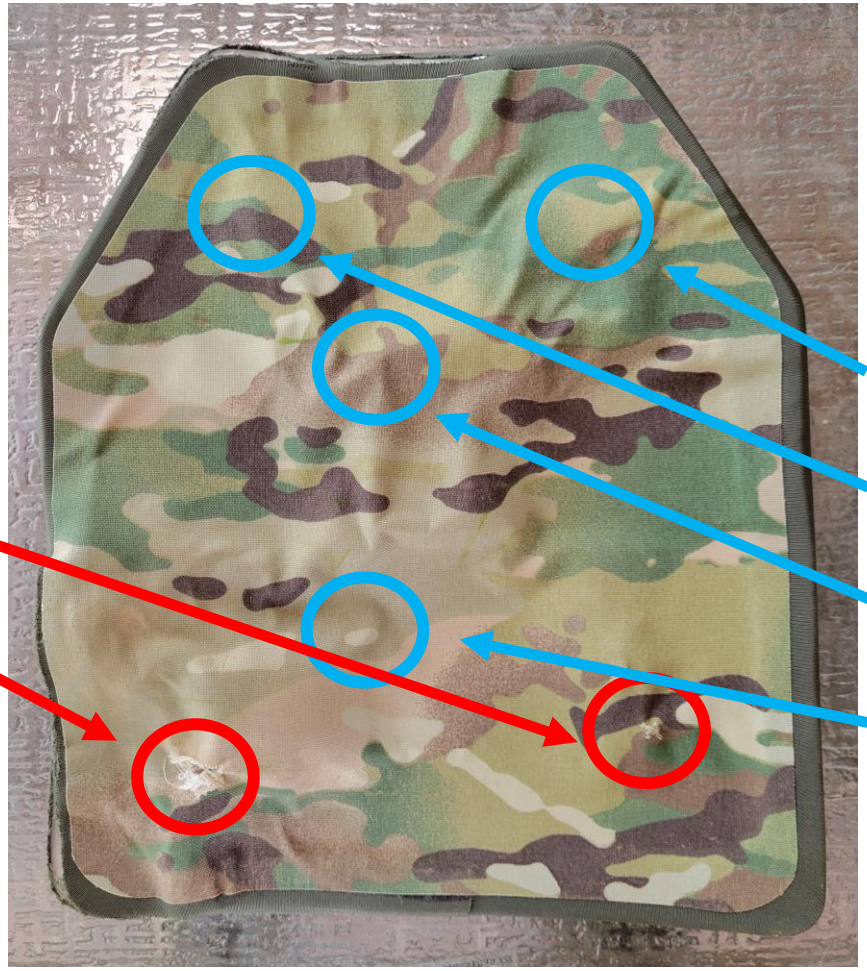
FN SS195

FN SS198

Speer Gold Dot HP

UNIVERSAL HG2 HARD

(All Shots with FN 5.7 pistol)



PENETRATIONS

FN SS190

Vanguard Black Fang

STOPPED BY ARMOR

FN SS195

FN SS198

Elite S4M

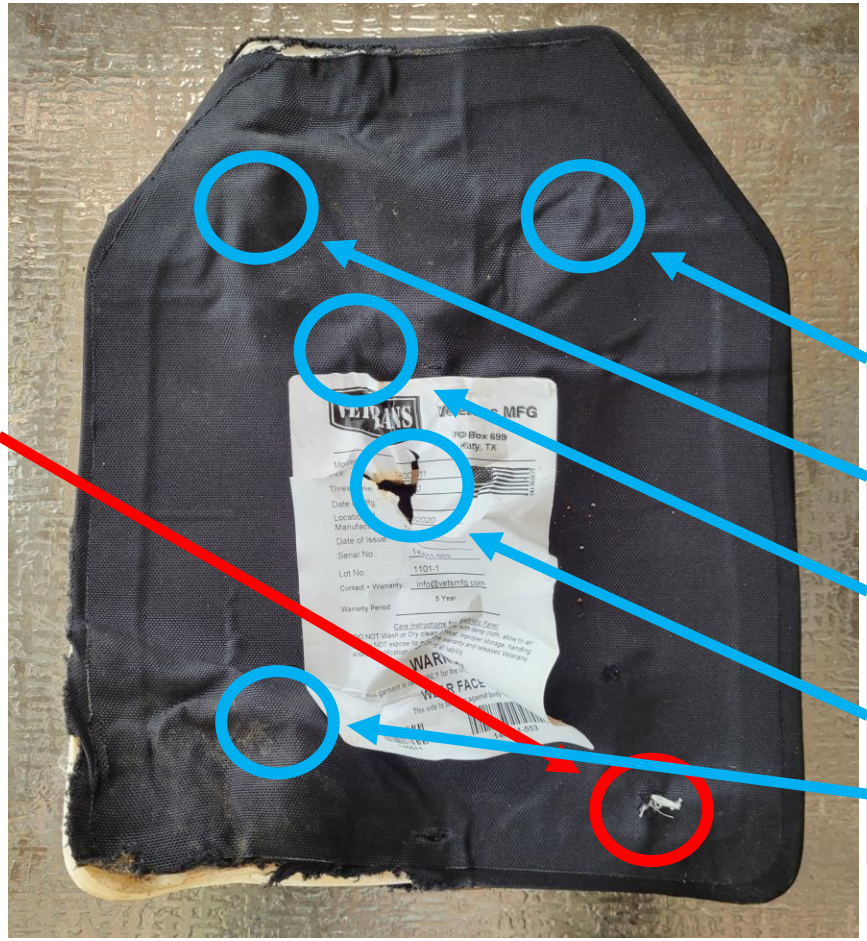
Speer Gold Dot HP

VETERANS MFG HG2 HARD

(All Shots with FN 5.7 pistol)

PENETRATIONS

FN SS190



STOPPED BY ARMOR

FN SS195

FN SS198

Elite S4M

Speer Gold Dot HP

Vanguard Black Fang

VETERANS MFG HG2 SOFT

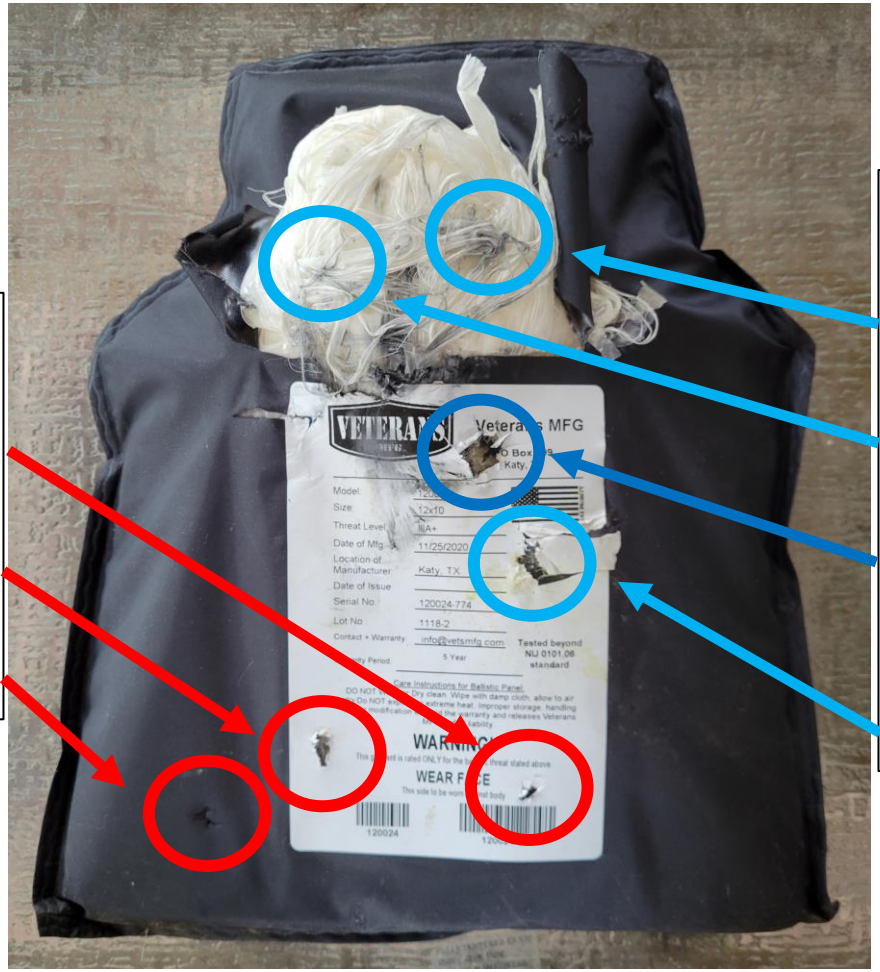
(All Shots with FN 5.7 pistol)

PENETRATIONS

FN SS190

Elite T6

Vanguard Black Fang



STOPPED BY ARMOR

FN SS195

FN SS198

Elite S4 (Full puncture, no exit)

Speer Gold Dot HP

SHOTSTOP HG2 SOFT

(All Shots with FN 5.7 pistol)

PENETRATIONS

Vanguard BDF LE

Vanguard BDF HVP LE

Elite Devastator

Elite T6

FN SS190

Vanguard Black Fang

STOPPED BY ARMOR

FN SS195

FN SS198

Elite S4

Speer Gold Dot HP

SHOTSTOP HG2 CLIPBOARD

(All Shots with FN 5.7 pistol)

PENETRATIONS

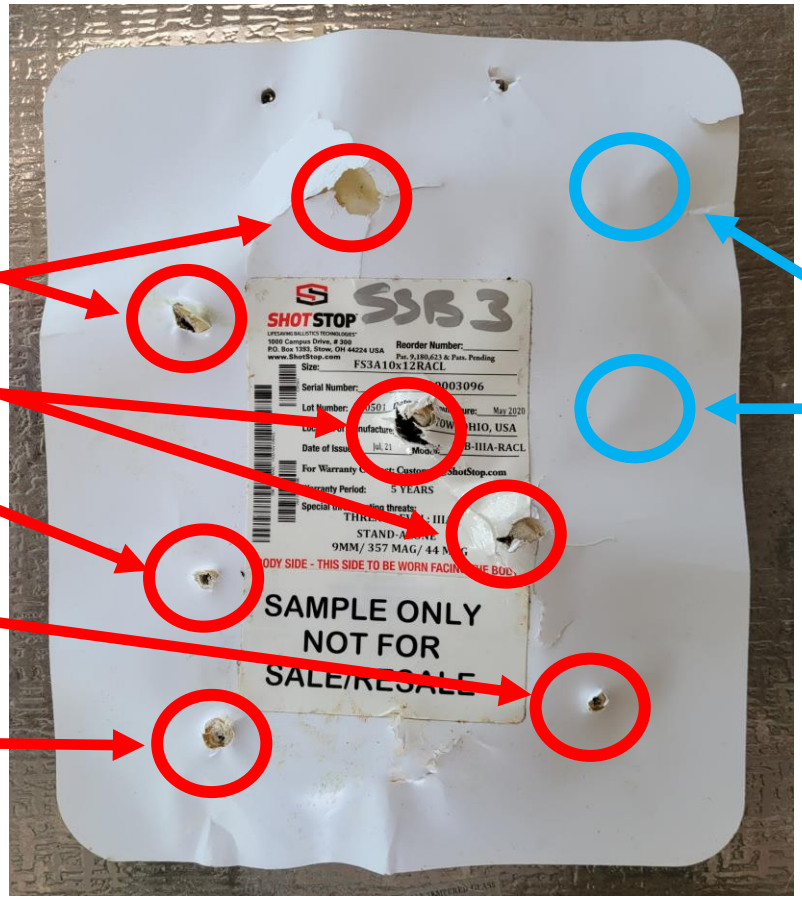
FN SS198

Elite S4

Elite T6

FN SS190

Vanguard Black Fang



STOPPED BY ARMOR

FN SS195

Speer Gold Dot HP

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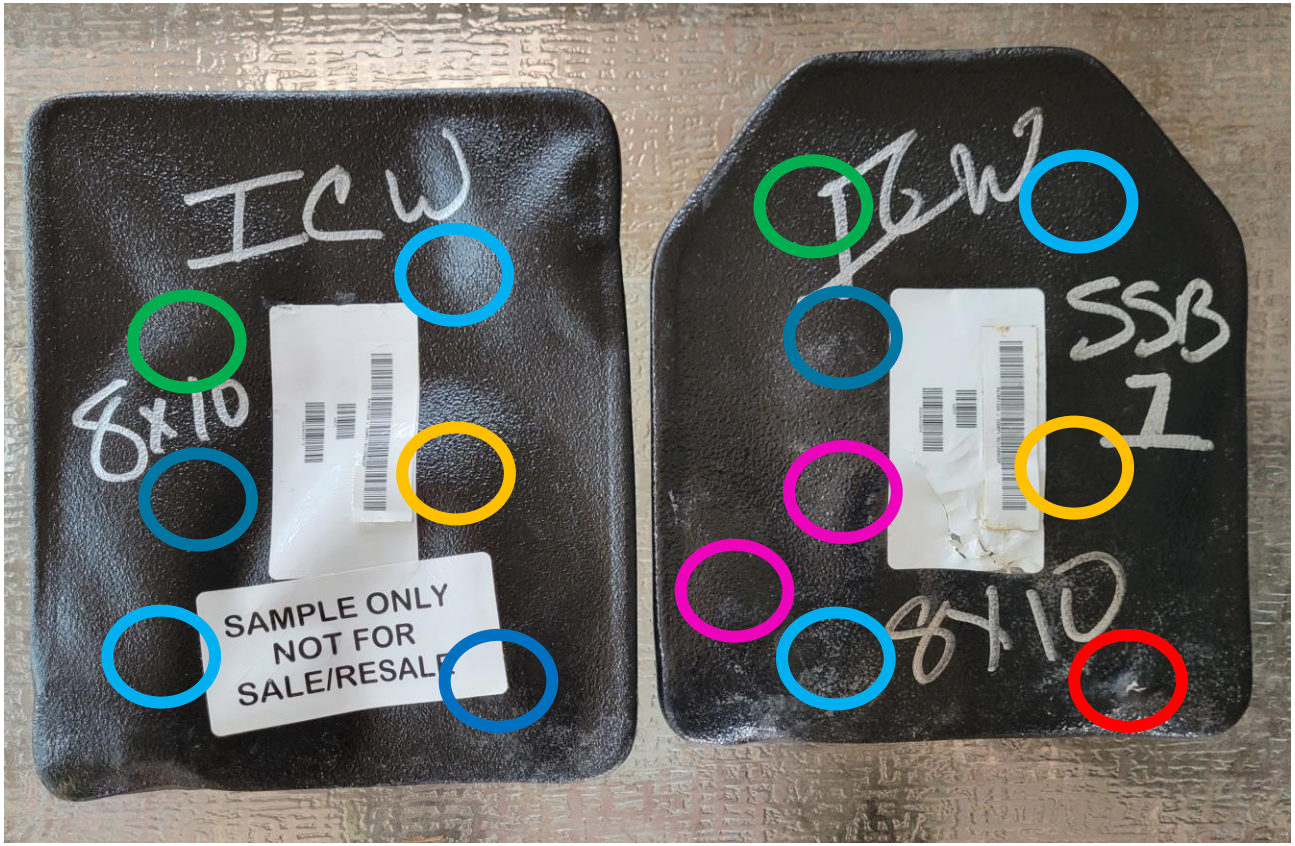
SHOTSTOP RF1 HARD ICW

PENETRATIONS
Shot by PS90
FN SS190

(Soft panel not included)



STOPPED BY ARMOR
All shot by FN 5.7 pistol

FN SS195

FN SS198

Elite S4M

Speer Gold Dot HP

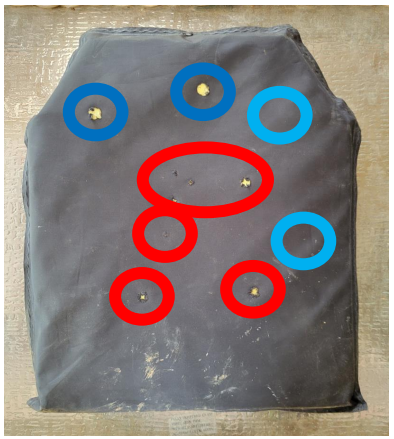
Elite T6

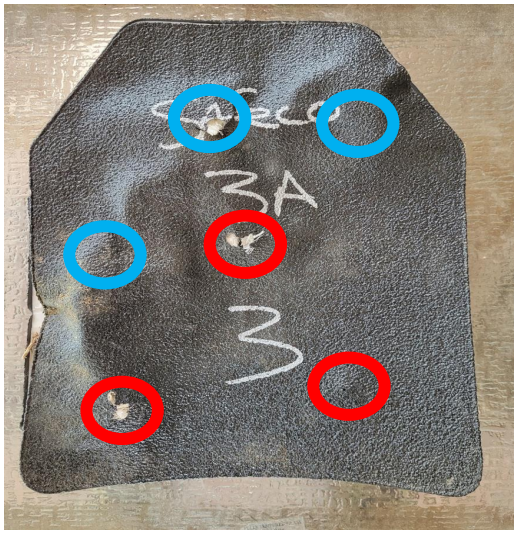
FN SS190

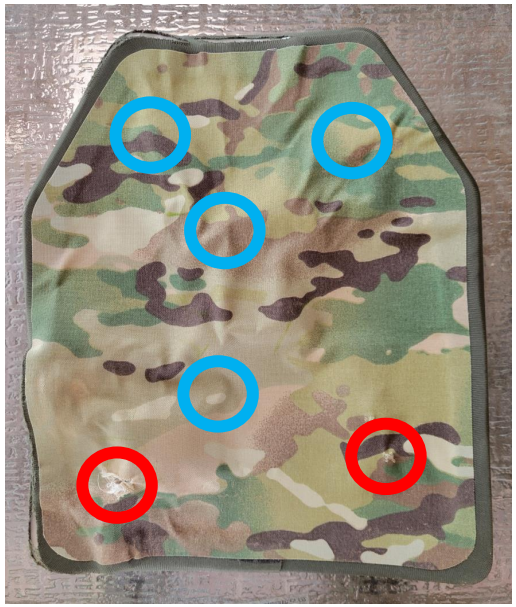
Vanguard Black Fang

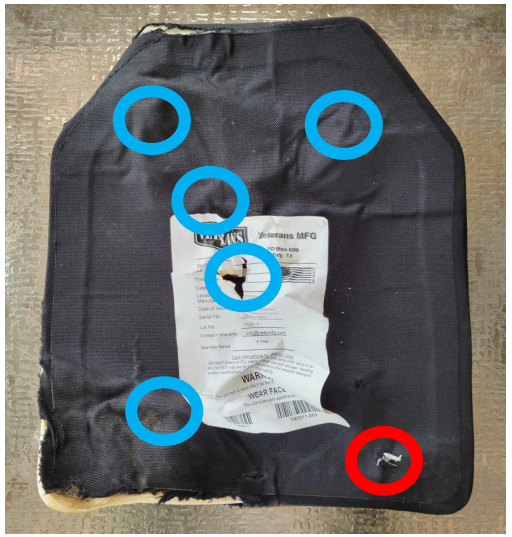
LAW ENFORCEMENT / MILITARY ONLY

5.7mm LE/Mil Armor Test









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CONTACT US

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ACKNOWLEDGEMENTS / WHO WE ARE

This report and presentation are a composite from testing accomplished from 2016 to present using the exact same protocols, phases and materials. There are so many people to credit with the amount of data that was measured and calculated during all of this testing. People involved in these tests came from multiple agencies to include the FBI, DHS, CBP, DoD, US Air Force Research Laboratories (AFRL), NASA, Marshalls, and multiple state DPS's and local police, sheriff and constables' offices, several local gun stores and two training schools. One local grocery store chain gave a great discount on the tissue used in Phases 4 and 5. No ammunition or armor manufacturers were allowed to attend any test. They were only allowed to provide supplies and nothing else. We would like to thank the armor manufacturers, gun stores and police departments that supplied the armor for our testing and for their understanding that the armor information will not be openly released.

A very special thanks to all the volunteers who helped set up, tear down, measure, re-measure, document, calculate, check all the data and create this report. Only through their diligent thorough work could this much accurate data be generated. We would also like to thank our sponsors from 3rd Coast Ordnance and Dog Will Hunt LLC that provides all our gunsmithing. Also, Slick Shot Gun Lubricants that provides us with all our training gun grease, oil and cleaning solvents and Triple T Holsters.

Lastly, a great deal of work went into the production of this document to include editing and formatting. Thank you to all who worked on this report and reviewed the multitude of drafts. A special thanks goes out to Danny Coulson, whose service to this country during over 30 years at the FBI are greatly appreciated. He created and commanded the Hostage Rescue Team (FBI HRT) and finished as Deputy Assistant Director of the FBI. After countless meetings, phone calls and emails as well as his review of this document and adding many improvements, he wrote "This is typical of ur work. Facts. No conjecture."

There are no conclusions in this test. Testing was accomplished only to provide quantifiable raw data on a large scale with an enormous sample size into multiple realistic media. We answer the What. Where is really important and our experts from the above listed agencies answer the How.

Any questions regarding this test, other tests or to inquire on a future test should be made to: viperweaponstraining@gmail.com

Other information and reports are available at: www.viperweapons.us

Viper Weapons Training LLC was created in 2011, as a handgun training company while we were in various military services. We offer 18 different courses with a complete description and syllabus for each course online. We are the handgun instructors for 10 local stores and ranges. In 2014, while still in the DoD, we were asked to accomplish a pistol ammunition analysis and comparison. That led to testing which was started in 2015. With coordination with other DoD groups and the FBIs Firearms Training Unit we developed our testing protocols that combined both standardized DoD and FBI phases. In 2017 after several of our employees retired, we incorporated wound ballistics testing into our company. Stores, departments/agencies and ammo manufacturers have paid for unbiased results.

We currently have published 52 reports on the subject of terminal wound ballistics. None of our reports contain conclusions, recommendations or rank ordering. We simply shoot projectiles into standardized media and measure results. Included are professional explanations and analysis from government sources with comparisons to real-world medical forensic reports. Our tests, results and reports are unbiased, fact based and all quantitative. All our testing protocols match those of federal agencies and we openly share how we set up the tests, the media used and the way we measure, record and calculate all listed data. We charge for testing which includes the media and results. The resulting reports are free to the client as well as LE/Mil. We participate in demos to help federal, state and local LE/Mil. We also teach three different academic courses on Terminal Wound Ballistics as described on our website and have taught these courses to federal, state and local agencies. Our company now has two halves: training and terminal wound ballistics testing. We are independent, not part of any other company and not contracted to represent any equipment or ammunition.

Please contact us for questions or follow-on testing:

www.viperweapons.us