2023 COMPOSITE TERMINAL WOUND BALLISTICS TEST, HANDGUN AMMUNITION REPORT & PRESENTATION

Version 2.0 updated August 2023

PROFESSIONAL WEAPONS TRAINING AND BALLISTIC TESTING SINCE 2011

VIPER WEAPONS TRAINING ™

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FOREWORD

The 2023 Composite Terminal Wound Ballistics Test, Handgun Ammunition Report & Presentation v 2.0 is a compilation analysis containing data from terminal wound ballistics and armor testing of one hundred and thirty rounds in eight calibers, in all five different projectile types. Material on the 9mm, .40S&W, .45ACP, .380, .357 Sig and 10mm are in sections one and two. Information included in sections three and four contains data on the 5.7mm and 4.6mm rounds. This reports information was obtained during multiple tests from 2016 to present, all following the standardized protocols and phases used during the 2016/17 Joint Agency Ballistic Test For Defensive Handgun Ammunition (available upon request). Limited testing was also accomplished using heavy barriers and that information is included in this report. In addition to the terminal wound ballistics' phases, armor testing was completed using armor products from different 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 full description in the section two report
B. Academics to present to a group with pictures and bullet statements (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 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, NASA, Marshalls, 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 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 and data on armor capability is not to be openly released. This is our 33rd published report and 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.
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 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, most of the rounds were tested vs some of the best armor available. Different levels and product designs were used to get a better picture of ammunition and armor capability.

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 August 2023. 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 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. Round failures to function on target are all included which is how reliability and consistency are 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.

This version 2.0 was updated August 2023 and incorporates revisions to several chapters and to the data tables with testing updates.

SECTION ONE

2023 Composite Terminal Wound Ballistics Test, Handgun Ammunition Presentation

PROFESSIONAL WEAPONS TRAINING AND BALLISTIC TESTING SINCE 2011

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SUMMARY

- This presentation is a concise version of the 2023 Composite Terminal Wound Ballistics Handgun Ammunition Report. Please see that report (section 2) for a more detailed explanation, math and references
- The 2023 Composite Terminal Wound Ballistics Test, Handgun Ammunition Presentation features information compiled from multiple tests performed between 2016 and 2023. The tests were conducted by Viper Weapons Training LLC, and selected ballistics experts, who ensured continuity, consistency and accuracy of all tests and generated this report and presentation
- All testing uses the same protocols, test phases and grading criteria. 130 rounds in 8 calibers have been tested to date (discontinued rounds removed). Each round was tested $\geq$20 shots with a total of over 3,000 shots. Included here are 79 rounds in 3 calibers. See sections 3 and 4 for 5.7mm and 4.6mm
- Test results, briefings and reports will only be distributed to Law Enforcement and Military (LE/Mil) and ammunition manufacturers involved
- Current As Of August 2023
- 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
- 4 Grading Criteria
- Volume of Wound Index (VWI)
- Five Types Of Handgun Bullets
- Ammunition Tested And Round Summaries
- Terminal Wound Ballistic Test Data Sheets
- Acknowledgements

TEST PURPOSE

- Each wound ballistics test was accomplished for specific agencies or departments as a comparative study of different types of defensive ammunition, conducted in 6 separate phases, using 4 grading criteria
- All 5 bullet types were tested
  - Hollow Points (HP), Full Metal Jackets (FMJ), Solid Metal Fluid Transfer-Fluted (SMFT), 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 or selections were made
  - 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
- 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
  - 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 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 and 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

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
- Extreme damage to vital organs
  - 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
- 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 only internal holes. The more the holes the greater the chance of 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. 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). Comparison results from that test are included in this briefing to increase sample size

TARGET MEDIA

1. Calibrated FBI 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 designed to be a simulation of any human tissue. Gel is a fluid and is non-compressible unlike human or animal material
- Density and resistance are not similar to human tissue (as noted by 3 inches of BB penetration depth at calibration)
- 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 happened frequently) and some rounds cut through material while others push allowing the gel to recover, which is similar to 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
  - 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 5 phases.

1. All rounds chronographed
2. Calibrated 10% ordnance gelatin IAW IWBA standards with a standard denim barrier (FBI series 2 test)
3. Calibrated 10% ordnance gelatin with a single ¾ inch thick AA fir plywood panel and a standard denim barrier (FBI series 5 test)
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. All rounds fired at least 4 times into calibrated IWBA 10% ordnance gelatin with a standard 4 layer denim barrier
2. Recovered rounds inspected for failures, retained weight and overall dimensions
3. Testing Overall Penetration Depth
   - FBI/DoD standard 12” minimum and 15-21” desired
   - Noted in data tables as **Penetration** in inches
4. 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. All rounds were fired at least 4 times into media
2. 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
3. Recovered rounds inspected for failures, retained weight and overall dimensions
4. Testing Overall Penetration Depth after a light domestic barrier
5. Testing Overall Permanent Wound Cavity
   - Measured in cubic inch volume
6. 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 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

4 GRADING CRITERIA

4 grading criteria were used in each test

1. Penetration-Phase 2 data. Desired 15-21” and a minimum of 12”
2. Consistency and Reliability
   - Standard Deviation for each shot tested within a Phase
   - Failure to function (Tumble, Failure to open, fragmentation and jacket separation)
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 / DoD Minimum 12 inches
   - Hollow Points, Tumbling
3. Duty (15-21 inches, aka: the federal standard)
   - FBI / DoD Optimum 18 inches
   - Solid Metal Fluid Transfer (Fluted), Tumbling
4. Deep (roughly >24 inches)
   - Since there are no tested rounds between 21” and 24” there is a gap
   - FMJ, Solid Metal Fluid Transfer (Fluted)

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, bullet properties after contact with the barriers and 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, rounds that cause a compression will create a permanent wound cavity that is exaggerated. To better understand and grade/compare rounds that cause compression a 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 was created by averaging the penetration results from 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

5 TYPES OF BULLETS

1. Hollow Points (HP)
   - Expand on impact to increase frontal area
2. Full Metal Jacket (FMJ)
   - Copper jacketed, solid and not designed to expand, tumble or fragment
   - They are designed to create small diameter wounds that penetrate deep
3. Solid Metal Fluid Transfer (SMFT) aka Fluted
   - Contact tearing and fluid transfer through the Venturi Effect
4. Frangible
   - Designed to break apart and fragment upon striking a target or a barrier either immediately at the surface or after minimal penetration
   - They are designed to create large diameter wounds that do not penetrate deep
4. Tumbling
   - Only works on long, high speed rounds like rifle, 4.6mm and 5.7mm
   - Not included in this presentation (see report for description and sections 3 and 4)

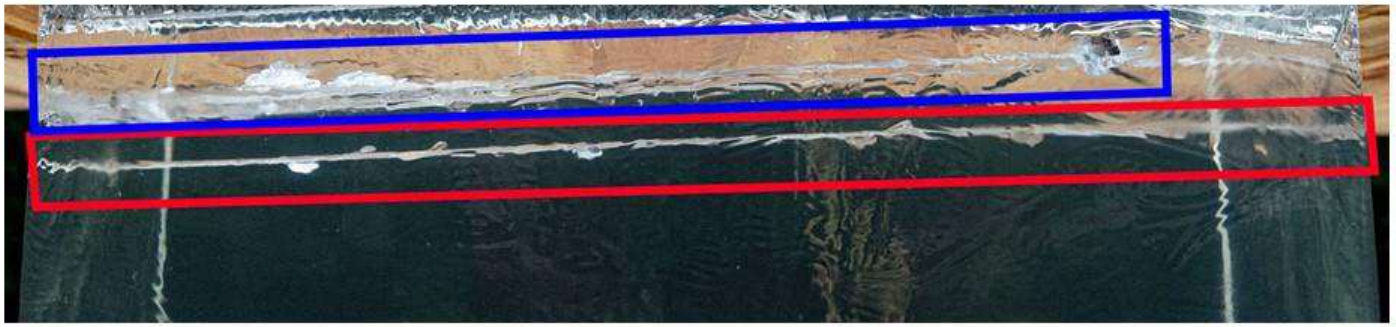
HOLLOW POINT (HP) WOUND PROFILE

AVERAGE HP WOUND DIMENSIONS

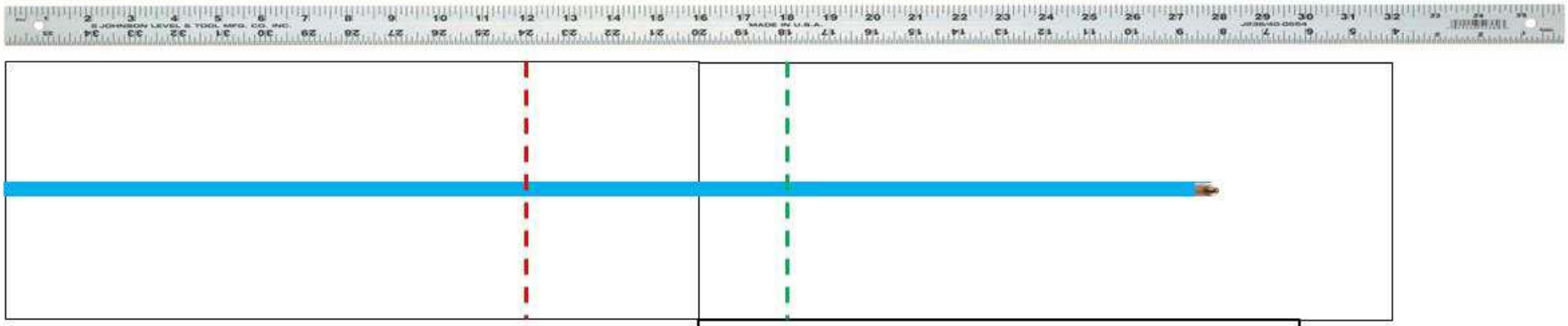
Caliber	Diameter x Penetration Depth
9mm	.6” x 12.5”
40 S&W	.67 x 14.5”
45 ACP	.78 x 14.5”

Light Domestic Barrier Degradation Percentage. Skin, light clothing, plywood, drywall and bones. 20-30% loss

Top blue = HP
Bottom red = FMJ



FULL METAL JACKET (FMJ) WOUND PROFILE

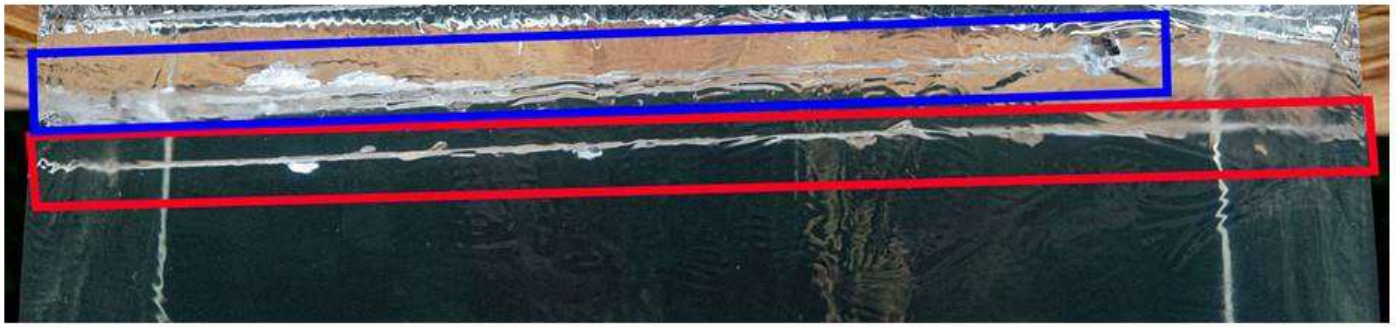


AVERAGE FMJ WOUND DIMENSIONS

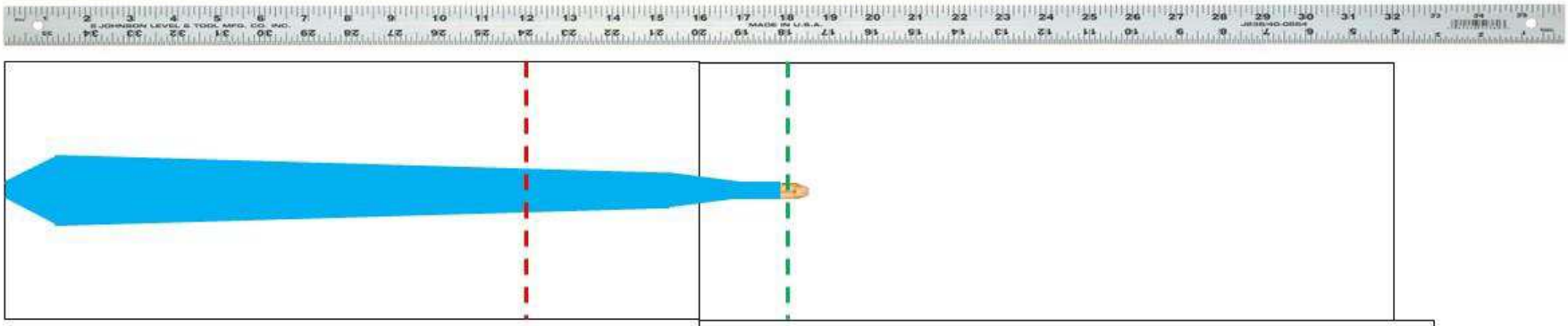
Caliber	Diameter x Penetration Depth
9mm	.35" x 28"
40 S&W	.4 x 31"
45 ACP	.45 x 27"

Light Domestic Barrier Degradation Percentage. Skin, light clothing, plywood, drywall and bones. 5-10% loss

Top blue = HP
Bottom red = FMJ



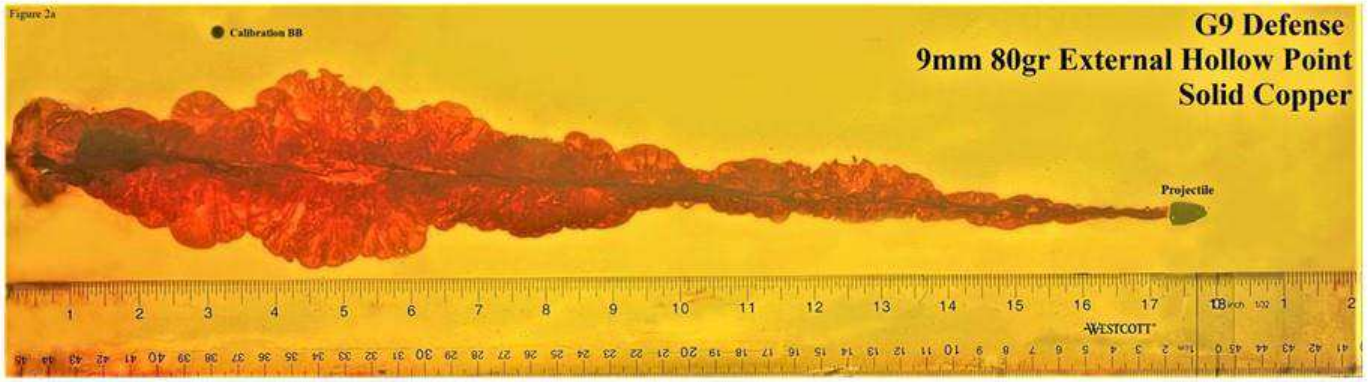
SOLID METAL FLUID TRANSFER (SMFT) WOUND PROFILE



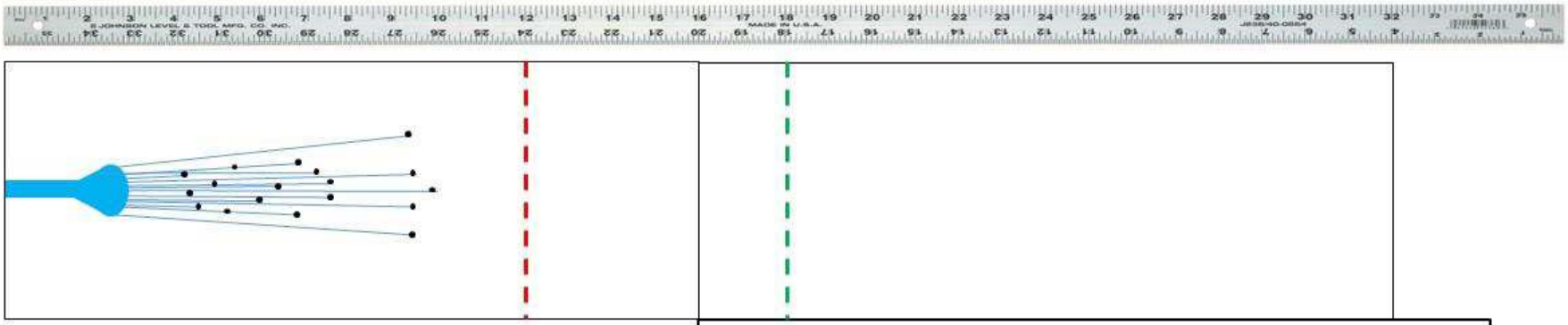
Light Domestic Barrier Degradation Percentage
Skin, light clothing, plywood and bones: 5-15% loss

AVERAGE SMFT WOUND DIMENSIONS

Caliber	Diameter x Penetration Depth
9mm	.93" x 17.1"
40 S&W	1.17 x 18.9"
45 ACP	1.04 x 19.2"



FRANGIBLE WOUND PROFILE



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

AVERAGE FRANGIBLE WOUND DIMENSIONS

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

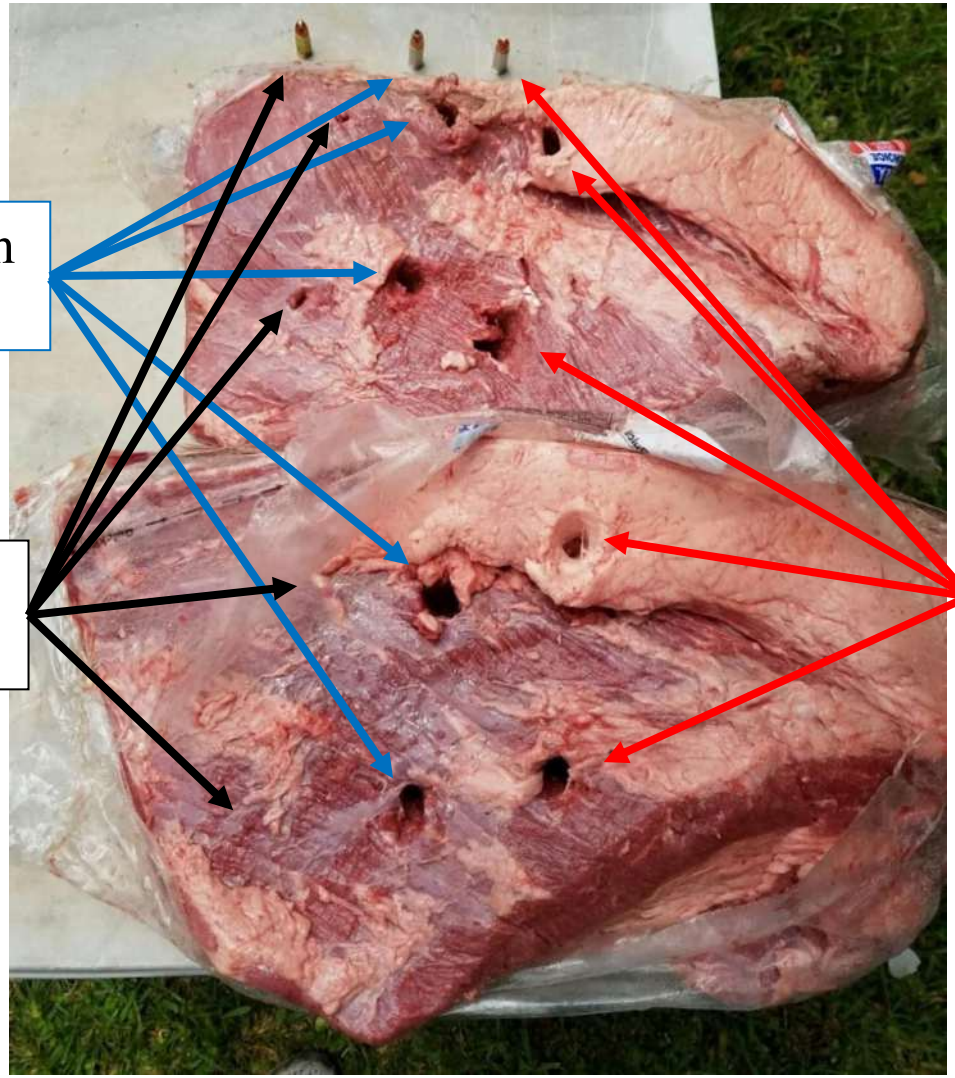
RESULTS

- All our wound ballistics tests documented raw data from each shot in all 6 phases. Averages were calculated and reported
- No conclusions, rank ordering or choosing was accomplished
- All data was graded using the aforementioned 4 grading criteria
- Each agency may use the data as they see fit and can calculate any other grades they wish
- This presentation contains data for 4 bullet types for the main three calibers: 9mm, .40 S&W and .45 ACP
  - For heavy barrier and armor testing please see the section 2 report
  - See sections 3 and 4 for full information and data on the 5.7mm and 4.6mm rounds tested
  - For those wanting data on .380, .357 Sig, and 10mm please see the section 2 report

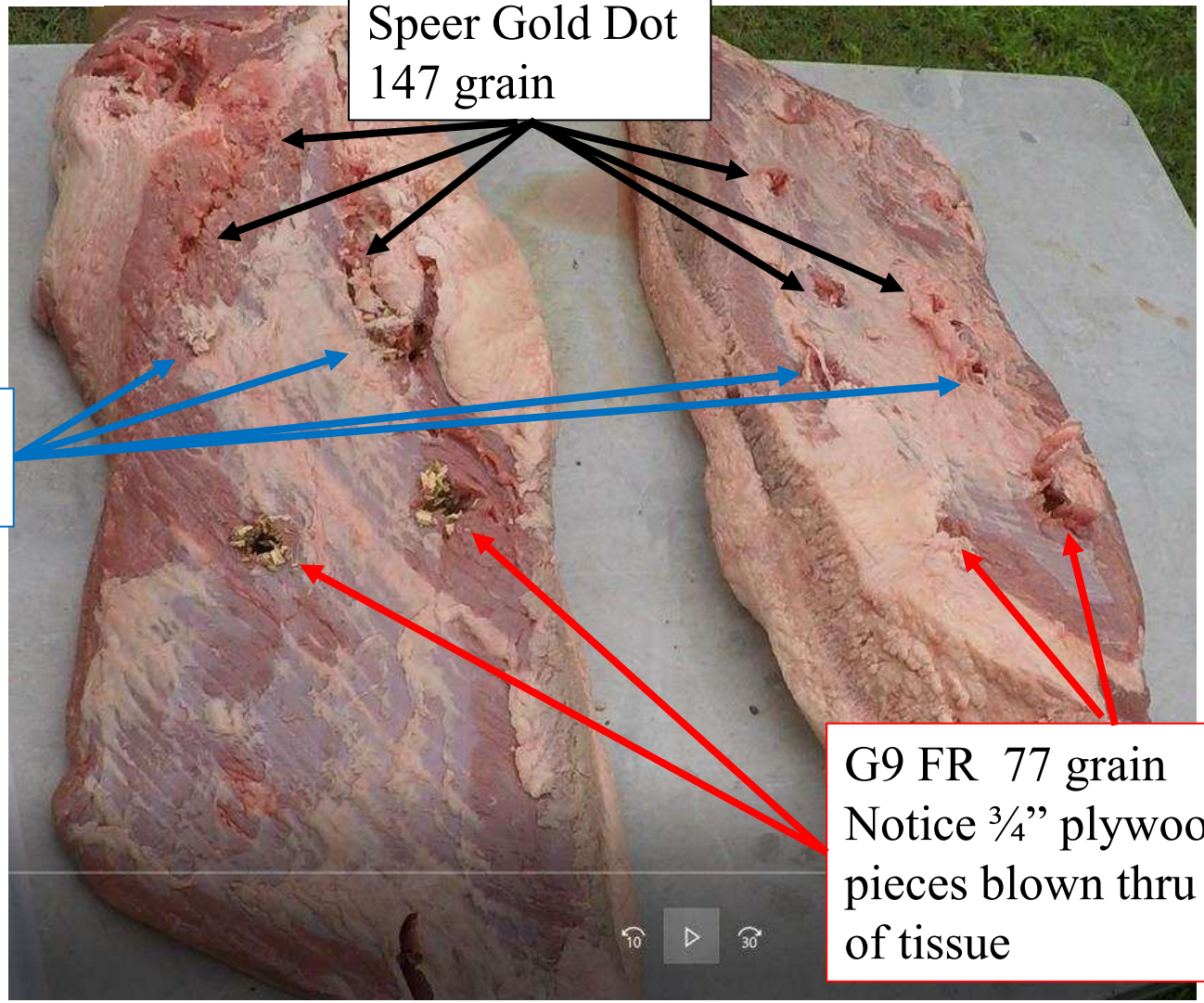
PHASE 4 EXAMPLE

PHASE 4 Measuring 40S&W

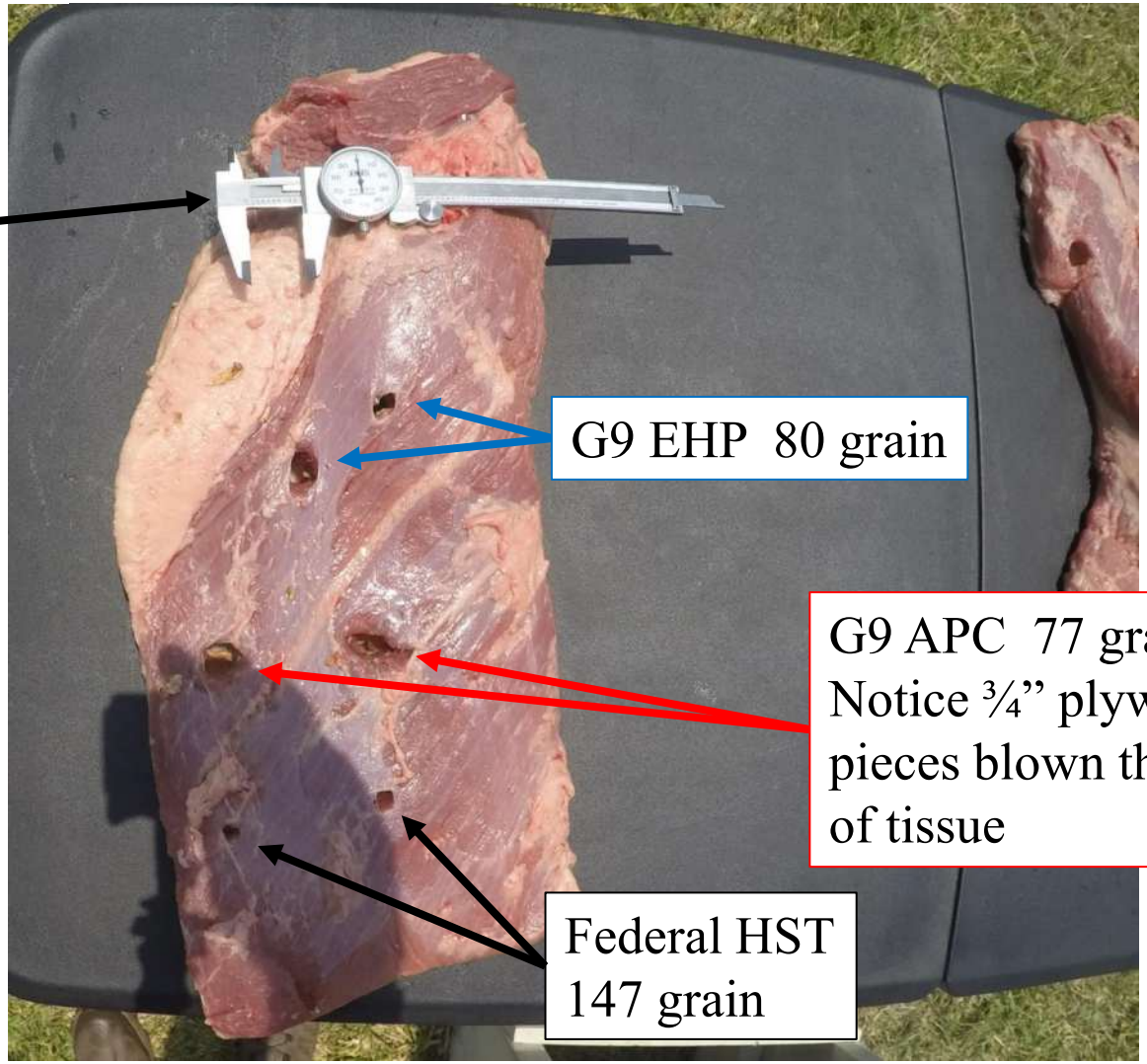
PHASE 4, Brisket 1&2, 9mm



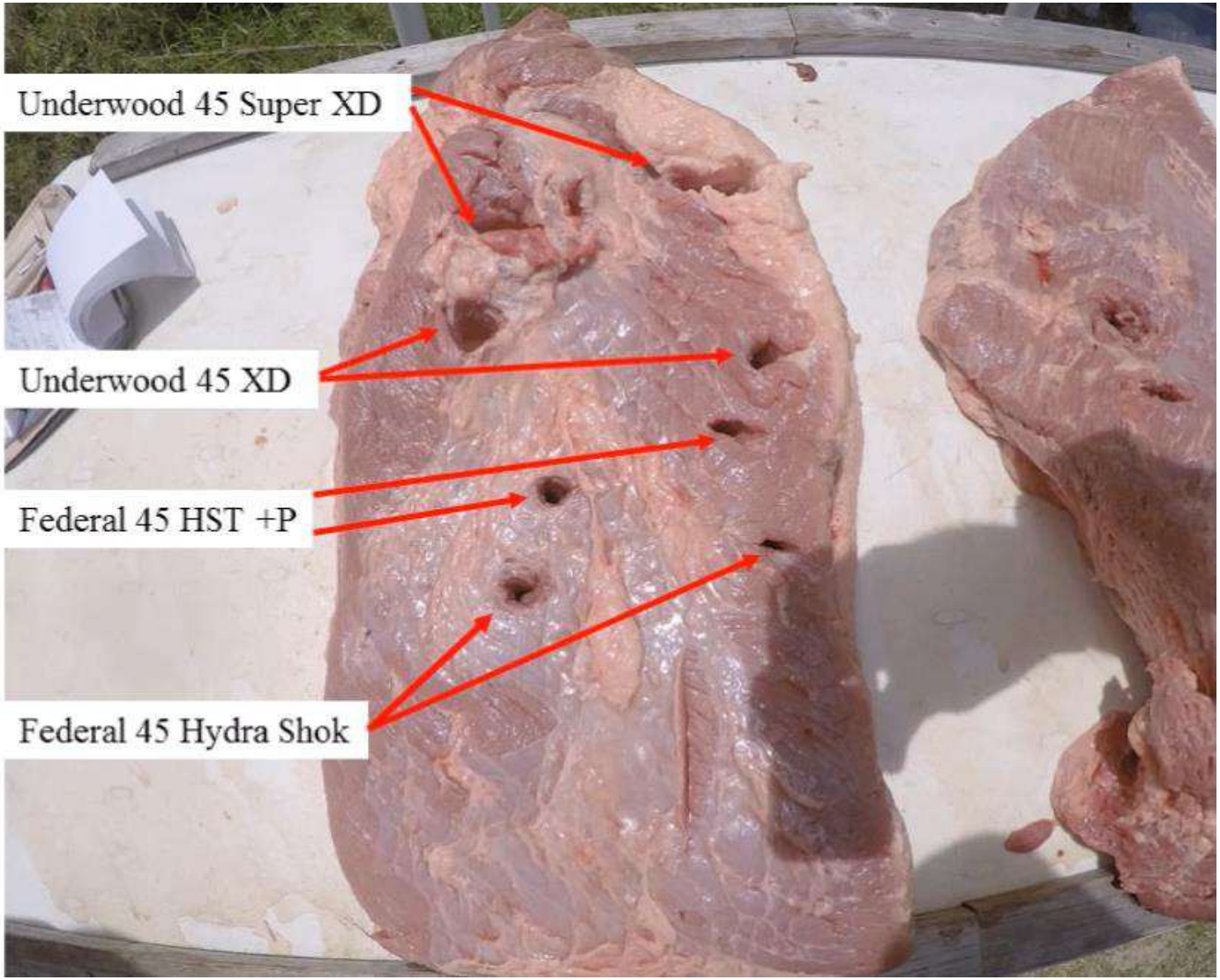
PHASE 4, Brisket 1&2, 9mm



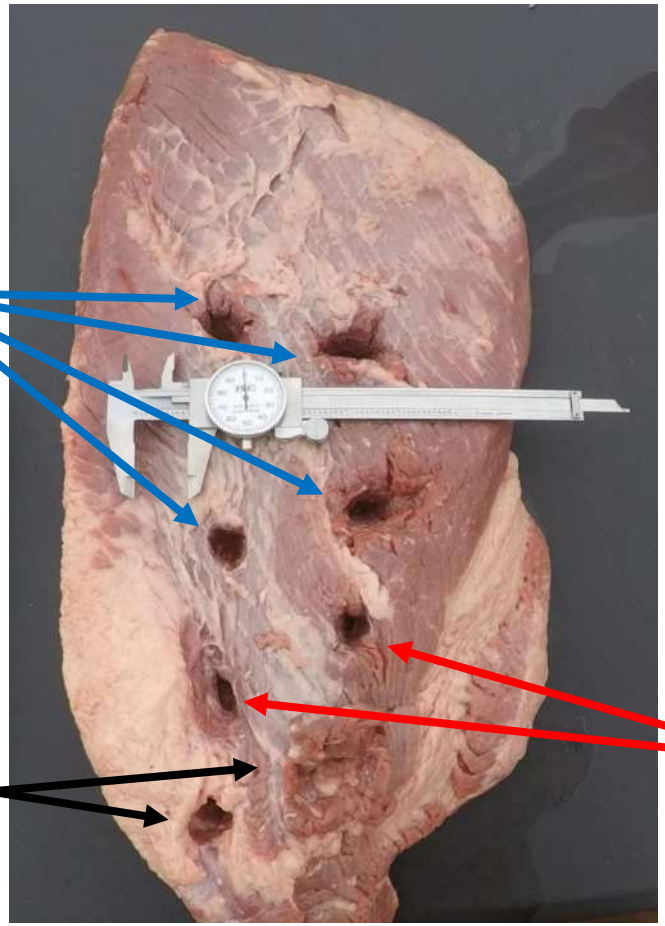
PHASE 5, Brisket 1&2, 9mm



PHASE 4, Brisket 1&2, .45



PHASE 4, Brisket 1, 5.7mm



Vanguard
Black Fang
34 grain

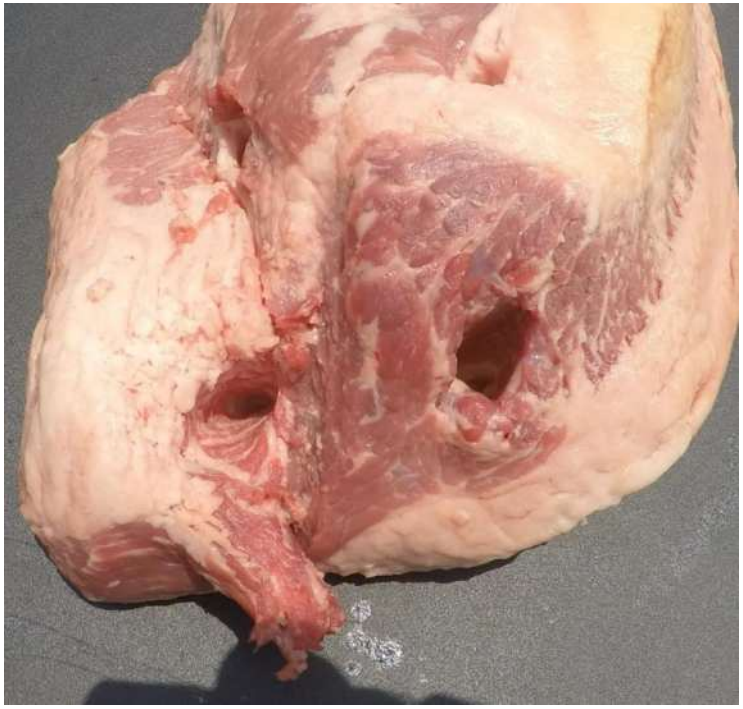
Vanguard
Barnes TSX HP
50 grain

Vanguard
Combined Technology
50 grain

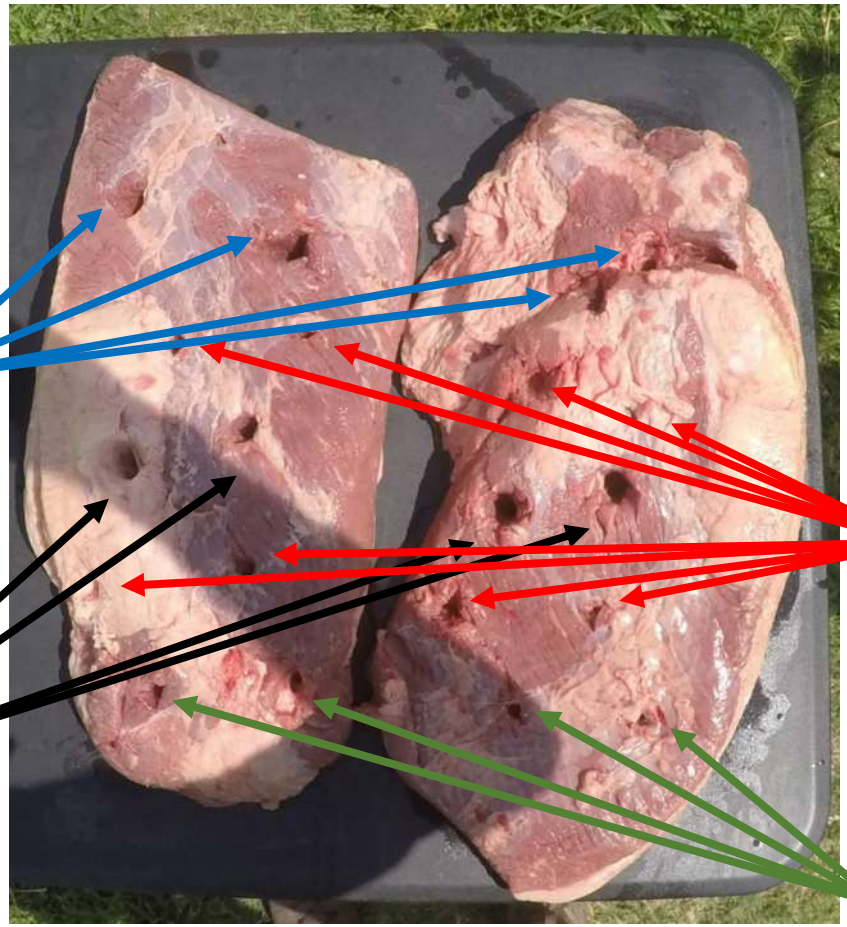
PHASE 5, 5.7mm

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 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

HOW TO CHOOSE A ROUND

1. Understand the 4 projectile characterizes
   - 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
   - By first choosing which bullet type most closely matches your needs you can easily narrow down your search and achieve your desired results
   - Understand the different types of bullets available to you. Knowing the strengths and weaknesses of each design will help you meet your needs
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

DATA TABLE DEFINITIONS

- **Round**- All rounds tested. Listed by caliber with grain weight included
- **Velocity**- From manufacturer and Phase 1 tested velocity (slide 13)
- **Penetration**- Average inches of penetration thru gel (Phase 2/3) (slide 14 and 15)
- **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 (slide 16 and 17) 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 21) 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 effected by passing through a light domestic barrier

9mm RESULTS

VIPER WEAPONS TRAINING LLC

TERMINAL WOUNDS BALLISTICS DATA, CAO AUG 2023

Caliber Type	Round (130)	Box Velocity	Weapon	PHASE 1 Average Velocity	PHASE 2 Gelatin / Denim Penetration	Diameter	PWC	PHASE 3 Gelatin / Plywood / Denim Penetration	Diameter	PWC	PHASE 4 Tissue / Denim Av Hole Area	PHASE 5 Tissue / Plywood / Denim Av Hole Area	VWI Av Pen x Av Area	LDBD%
9mm	31 rounds													
FMJ	Winchester FMJ 124 gr	1140	Sig P 226 / Glock 17	1140	28	0.35	2.7 ci	27	0.35	2.6 ci	0.14	0.12	3.6	10%
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%
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	
Frangible	Interceptor ARX +P 65 gr	1695	Glock 17	1680	12.5	0.9	7.9 ci	12.5	0.8	6.3 ci	0.6	0.5	6.9	17%
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	
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	
HP	American Mun. Sierra 115 gr	1250	Glock 17	1230	9.0	0.5	1.8 ci	10.0	0.4	1.3 ci	0.3	0.25	2.6	21%
HP	CorBon +P 115 gr	1350	Glock 17	1300	9.5	0.6	2.7 ci	7.0	0.5	1.4 ci	0.3	0.16	1.9	48%
HP	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%
HP	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	0.2	2.7	21%
HP	Hornandy C Duty +P 135 gr	1115	Glock 17	1120	13.8	0.5	2.7 ci	13.1	0.5	2.6 ci	0.35	0.31	4.4	12%
HP	OATH Tango 110 gr	1200	Glock 17	1150	5.3	0.8	2.7 ci	4.6	0.8	2.3 ci	Did Not Exit (DNE)	Did Not Exit (DNE)	undet Area	
HP	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%
HP	Remington GS 147 gr	990	Glock 17	980	17.0	0.6	4.8 ci	16.0	0.5	3.1 ci	0.3	0.25	4.5	26%
HP	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	0.4	0.35	5.7	24%
HP	Speer GD +P 124 gr	1220	Glock 17	1200	15.3	0.5	3.0 ci	14.2	0.4	1.8 ci	0.24	0.16	2.9	37%
HP	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%
HP	Underwood Max Exp 105 gr	1175	Glock 17	1160	10.3	0.8	5.2 ci	11.0	0.7	4.2 ci	0.5	0.41	4.8	19%
HP	Winchester RA9TA 127 gr +P+	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%
HP	Winchester Ranger T 147 gr	990	Glock 17	1000	14.5	0.6	4.1 ci	16.0	0.4	2.0 ci	0.3	0.25	4.2	35%
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%
SMFT	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%
SMFT	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%
SMFT	G9 EHP 80 gr	1480	Glock 17	1405	16.5	1.1	15.7 ci	16.0	1	12.6 ci	0.69	0.66	11	12%
SMFT	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	9%
SMFT	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%
SMFT	G9 Woodsman +P 124 gr	1250	Glock 17	1260	34	0.7	13.1 ci	33.0	0.7	12.7 ci	0.42	0.46	14.7	1%
SMFT	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%
SMFT	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	0.6	0.47	8.3	25%
SMFT	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	0.6	0.6	9.8	12%
SMFT	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 RESULTS

VIPER WEAPONS TRAINING LLC														
TERMINAL WOUNDS BALLISTICS DATA, CAO AUG 2023				PHASE 1	PHASE 2			PHASE 3			PHASE 4	PHASE 5	VWI	LDBD%
Caliber Type	Round (130)	Box Velocity	Weapon	Average Velocity	Gelatin / Denim Penetration	Diameter	PWC	Gelatin / Plywood / Denim Penetration	Diameter	PWC	Tissue / Denim Av Hole Area	Tissue / Plywood / Denim Av Hole Area	Av Pen x Av Area	
40 S&W	25 rounds													
FMJ	Winchester FMJ 180 gr	1020	Glock 22	1005	31	0.4	3.9 ci	29.5	0.4	3.7 ci	0.14	0.16	4.5	3%
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	0.2	Did Not Exit (DNE)	undet Area	
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	
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	
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	
HP	Federal HST 180 gr	1000	Glock 22	1000	18.0	0.6	5.1 ci	17.6	0.6	5.0 ci	0.49	0.43	8.2	7%
HP	Hornady C Duty 175 gr	1010	Glock 22	1020	17.9	0.6	5.0 ci	17.2	0.6	4.9 ci	0.4	0.4	7.0	2%
HP	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	
HP	Remington GS 165 gr	1150	Glock 22	1145	15.3	0.5	3.0 ci	17.2	0.4	2.2 ci	0.3	0.2	4.1	25%
HP	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%
HP	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%
HP	Speer Gold Dot 165 gr	1050	Glock 22	1060	14.3	0.7	5.5 ci	16.0	0.5	3.1 ci	0.3	0.24	4.1	32%
HP	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%
HP	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%
HP	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%
Tumbling	Fort Scott 125 g	1320	Glock 22	1290	22.0	0.5	4.3 ci	20.8	0.4	2.6 ci	0.2	0.28	5.1	15%
SMFT	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%
SMFT	G9 EHP 95 gr	1460	Glock 22	1445	19.0	1.0	14.9 ci	18.7	0.9	11.9 ci	0.7	0.66	12.8	8%
SMFT	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%
SMFT	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%
SMFT	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%
SMFT	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	0.9	0.85	16.8	4%
SMFT	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%
SMFT	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%
SMFT	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 RESULTS

VIPER WEAPONS TRAINING LLC														
TERMINAL WOUNDS BALLISTICS DATA, CAO AUG 2023				PHASE 1	PHASE 2			PHASE 3			PHASE 4	PHASE 5	VWI	LDBD%
Caliber Type	Round (130)	Box Velocity	Weapon	Average Velocity	Gelatin / Denim Penetration	Diameter	PWC	Gelatin / Plywood / Denim Penetration	Diameter	PWC	Tissue / Denim Av Hole Area	Tissue / Plywood / Denim Av Hole Area	Av Pen x Av Area	
45 ACP	23 rounds													
FMJ	Winchester FMJ 230 gr	835	Sig P227E / Glock 21	865	27.5	0.45	4.4 ci	27	0.45	4.3 ci	0.18	0.22	5.45	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%
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	
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	
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	
HP	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%
HP	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%
HP	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%
HP	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%
HP	Remington GS 185 gr	1140	Glock 21	1115	15.1	0.7	5.8 ci	13.8	0.6	3.9 ci	0.4	0.36	5.5	21%
HP	Sig Sauer V 230 gr	830	Glock 21	850	15.1	0.7	5.8 ci	16.2	0.7	6.2 ci	0.5	0.42	7.2	8%
HP	Speer Gold Dot 230 gr	890	Glock 21	810	17.5	0.7	6.7 ci	16.5	0.6	4.7 ci	0.5	0.44	8.0	21%
HP	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%
HP	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%
Tumbling	Fort Scott 180 gr	989	Glock 21	1000	22+ FTT	0.5	N/A	22+ FTT	0.48	N/A	0.2	0.28	undet Pen	
SMFT	G9 EHP +P 117 gr	1400	Glock 21	1420	19.2	1.0	15.1 ci	18.8	0.9	12.0 ci	0.74	0.7	13.7	13%
SMFT	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	0.8	15.3	4%
SMFT	G9 First Response 117 gr	1500	Glock 21	1495	20.2	1.4	31.1 ci	19.5	1.4	30.0 ci	0.8	0.85	16.4	1%
SMFT	G9 APC 117 gr 2023	1500	Glock 21	1505	20.0	1.4	30.8 ci	19.8	1.4	30.5 ci	0.84	0.82	16.5	2%
SMFT	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%
SMFT	Underwood XD 120 gr	1320	Sig P227E / Glock 21	1400	18.5	0.9	11.8 ci	17.6	0.8	8.8 ci	0.6	0.42	9.2	28%
SMFT	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%
SMFT	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%

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
- 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 on multiple realistic media

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SECTION TWO

2023 COMPOSITE TERMINAL WOUND BALLISTICS HANDGUN AMMUNITION REPORT

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 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 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 on 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] This determinant is a factor of the shooter's accuracy and the projectile capability.

2. Amount of hits on target is critical. 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.

3. Bullet capability is the wound ballistic profile of that exact ammunition. This 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.

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[1] Wound Ballistic 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, Quantico, VA, September, 1989

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 characteristics, 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]

4. 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 Ballistic 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, 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:"

A. "Penetration. 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 in tissue is preferable."[6] "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] The current Federal Standard for desired penetration depth is 15-21 inches in gel. Other than long range capability, accuracy and armor penetration potential, one of the main reasons why rifle rounds are more effective than handgun rounds is that they produce greater penetration, with the projectile reaching or going through important body parts. That extra penetration is realized even in short range shootings.

B. "Permanent Cavity: The destroyed tissue which is in direct contact with the projectile and any material coming off the bullet such as metal or 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 hole left by the passage of the bullet." This volume is extremely difficult to measure in the case of fragmenting rounds, Solid Metal Fluid Transfer rounds (SMFT) 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 rounds utilizing fluid transfer or tumbling 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-

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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

than-optimal angles is not acceptable. Of those that will penetrate, the edge is always with the bigger hole."[9]

C. "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 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. 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."[11] "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."[12] High speed (>2,600 fps) rifle rounds were tested at some of our events and the animal tissue media was dissected and showed 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 2200 fps.[13] The real velocity (2000 or 2200) doesn't matter and is probably not exact. 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 rifle temporary cavities.)

D. "Fragmentation. Fragmentation can be defined as projectile pieces or secondary fragments of bone which are impelled outward from the permanent cavity and may sever muscle tissue, blood vessels, etc., apart from 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."[14] For these reasons, wounding effects secondary to any handgun caliber bullet fragmentation are

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

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

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

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

considered inconsequential."[15] Fragmentation occurs either intentionally by the use of frangible rounds or accidentally by the unintentional breaking apart of the bullet. Frangible rounds tend to create large wound cavity areas but shallow wound penetration. "Frangible rounds eliminate any reasonable penetration. Such a bullet will break up to fast to penetrate to the vital organs."[16] 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. 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. Accidental fragmentation is most common with hollow point ammunition over any other bullet type. Two distinct characteristics increase accidental fragmentation with hollow points.

1. Velocity. Hollow point rounds traveling 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.
2. 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 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 accidental fragmentation occurs the pieces are generally very close to the PWC which limits additional wounding effects.

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

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

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

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."[17]

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."[18]

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

[18] 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."[19]

2. Nervous: Thin nerve tissue which constitutes the smallest percentage of human tissue. The neural network of the Central Nervous System (CNS). 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 2 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. Testing media during phase 4 and phase 5 is animal tissue to as closely as possible, consistently replicate human muscular and organ tissue.

"The mechanism of formation of the injury includes the compression of tissue by the projectile and their disruption when these compressive forces exceed the elasticity of the tissue."[20] Objects pushed away from the wound track, to include projectile fragments, bone fragments and 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,

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

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

heart, great vessels and bowel, may rupture due to the pressure waves from extremely high velocity projectiles (>2000 feet per second)[21] even without direct contact by the missile."[22] "Temporary cavitation can also cause the tearing of tissues if a very large amount of force is involved. The tensile strength of muscle ranges roughly 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. Gelatin and other less elastic media have much lower tensile strengths; thus, they exhibit more damage after being struck with the same amount of force. At typical handgun velocities, bullets will create temporary cavities with much less than 1 MPa of pressure, and thus are incapable of causing damage to elastic tissues that they do not directly contact."[23]

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 of blood or excessively low blood pressure will shut down voluntary control.[24] 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." [25] "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."[26]

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

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

[23] 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.

[24] 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

[25] 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

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

"Incapacitation results from central nervous system (brain or spinal cord) disruption, massive organ destruction and hemorrhage (critical loss of blood and blood pressure)".[27]

"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 driven 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."[28] 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 PWC caused by the path of the bullet.

"A systematic review of 1400 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."[29] 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."[30]

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 2,000-2200 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

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

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

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

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

projectile. This is well within the elastic limits of tissue."[31] To quote the FBI Firearms Training Unit: "Unlike rifle rounds, there is no temporary wound created by pistol bullets." "Temporary cavity is frequently and grossly overrated as a wounding factor when analyzing pistol wounds."[32]

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). Lastly, the human body is not one solid mass where energy is easily transferred throughout the body. 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. We must also discuss 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. "Increased bullet mass will increase penetration."[33] "Increasing velocity does not increase expansion as almost all hollow points 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. Energy is simply a mathematical formula that has no bearing on projectile capability. 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 isn't the case. "Kinetic energy does not wound. Temporary cavity does not wound. 'Knock down' power is a myth." No emergency room surgeon ever said "I need to repair the energy dump that my patient experienced." Dr's only repair actual wounds. 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.

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

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

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

Hydrostatic shock is the controversial theory that a projectile can produce a pressure wave that causes “remote neural tissue damage" and "rapid incapacitating effects" in living targets.[34] [35] [36] Whereas the temporary stretch cavity is a pressure wave interacting with muscle or organ tissue, hydrostatic shock is that pressure wave interacting with neural tissue which has completely different density and elasticity.[37] The concept was first proposed in 1942 and quickly gained popularity with circumstantial evidence. Later it was debunked by many scientific and medical professionals.[38] [39] 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.[40] 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 2600 -2800 fps (different from different sources) the damage to neurons has been witnessed. One assertion was stated that with a velocity as low as 2200 fps the effect may still be possible. 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 or not 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 2600-2800 fps although one source says it might be possible to have minimal effects as low as 2200 fps. The only Handgun rounds at this velocity are 5.7mm (see section three).

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

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

[36] AK-47: the weapon that changed the face of the war, Larry Kahaner, John Wiley and Sons (2007) p. 32

[37] Firearms Legal Protection. article, “Hydrostatic Shock: Real Or Myth?” Tom Gulley, 2022

[38] Maneater. article, “IS HYDROSTATIC SHOCK REAL?” Jordan Sillars, 2021

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

[40] Terminal Ballistics Research, article, “Effective Game Killing”, 2011

6. 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."[41] Different bullet types yield different wound results as the actual mechanism to destroy tissue is different for each bullet type. The above discussion of weight and velocity vs wound cavity size is for hollow points only as their destructive mechanism is crushing or tearing of tissue through physical contact with the bullet. Other bullet types will yield different weight vs velocity results. See chapter "Five Types of Handgun Projectiles."

"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."[42] "Even shots to the heart are not immediate as stored oxygen may allow for voluntary action for 10-15 seconds after functional heart destruction."[43] "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."[44] 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."[45] "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)."[46] 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."[47]

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

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

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

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

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

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

[47] 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 defensive handgun ammunition. 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. No averages are calculated or reported until at least four rounds are fired in each of the first five phases for each round (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 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 testing being started in 2016, analysis of the major previous 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 of the tests. 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 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:

All caliber Ballistic Ratios were fairly consistent across all 7 tests (All 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

As stated earlier only the 9mm and 45ACP 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 of the above tests and again the results were extremely close. Our duplicated results validated the other tests which in turn validated our testing process.

RESULTS / REPORTS / DATASHEETS:

All of our testing raw data is added to the database and reflected on our data spreadsheets with short narratives for each round that contains reliability, consistency and heavy barrier information and a synopsis of all 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 next chapter for 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 effected 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 4 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.[48]

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 a forensic pathologist, other MD's and a butcher. 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, solid wood and metal. Phase 6

6. Armor products: Various designs of Level 3A soft and hard plates, helmets and shields and, Level 3 hard plates. The results are listed on separate data sheets after the Armor Test Description chapter. Phase 6

We accomplish further armor testing with Armor products including Level 3A (pistol) soft and hard plate, Level 3 ICW, Level 3 (rifle), Level 3+, Level 4 and armored wall board (Level 6) from multiple companies to include: Veterans MFG, Angel Armor, Universal, Safeco, ShotStop and RTS. All shots IAW FBI/DoD protocols using the NIJ .06 standards listed on the Armor Test Data Sheet page.

[48] 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's easy to see how a bullet that scored highly in one test could fail the test conducted by another agency."[49] 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."[50] "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…good luck in that"[1] 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 >30% are common.[51] 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 our spreadsheets. Using penetration data from tests incorporating synthetic clear gel is unprofessional and absolutely leads to poor analysis and ammunition decisions.

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

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

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

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."[52] 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. 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 of 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. This makes gel a poor tissue simulant as hydraulic effects are completely different than in human or animal tissue. The permanent cavity in gel does not replicate or represent human tissue so using it alone does not simulate a real target. 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 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 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."[53]

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 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. Lastly, with rounds that tumble or cause compression, gel results are artificial and are very different from actual tissue tests or post shooting

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

[53] 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.

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. Adding testing in a realistic media (animal tissue) produces results that match real life shootings. Our Phase 4 and 5 use actual animal tissue to make up for the deficiencies in using only gel and getting artificial results. 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. Also cutting into tissue to measure penetration depths, changes the size and dimensions of the wound making 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 2 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 part of the hole) and minor axis (narrowest part 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 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 PS-90 5.7mm, the dissected animal tissue media showed tearing outside of the permanent wound cavity which was never present in any of the handgun rounds.
2. On several occasions' fragments from the light domestic barrier used in phase 5 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 section three for full description of the 5.7mm and 4.6mm rounds)

SIX TEST PHASES:

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 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 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 is needed 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, please 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 into a human target to offer the best chance of striking a major artery or organ." "A penetration of 18 inches is preferable." Currently the FBI and DoD desire 15-21 inches in gel (Federal Standard). *Originally the FBI used 18-inch gel blocks which created the 18-inch maximum. That depth had nothing to do with over-penetration.* 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. 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.

Penetration can be divided into four distinct depths:

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

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

C. Duty (15-21 inches, aka: the federal standard). Rounds providing this penetration depth: Solid Metal Fluid Transfer (Fluted), Tumbling

D. Deep (roughly 24+) since there are no tested rounds between 21 and 24 inches there is a gap. Rounds producing this penetration depth: FMJ, Solid Metal Fluid Transfer (Fluted)

2. Reliability and Consistency: Reliability is a measurement of failure rate. Each of the 5 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 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."[54] 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 typically 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 (plywood, drywall, thick clothing and bone) penetration. We use light domestic barriers in our phase 3 and 5 and the results in comparison to the non-barrier phases (2 and 4) give 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.
3. Heavy barrier (hardwood 2x4's, auto glass and metal car doors) penetration. Testing on heavy barriers yields information where we grade deflection, bullet properties after contact with the barriers and terminal performance for the rounds that pass through the heavy barrier.
4. Armor penetration. We do extensive testing with armor using products from multiple manufacturers and levels of protection using the NIJ levels (listed in the armor data sheet).

Barriers can destroy, degrade and deflect 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 a light domestic barrier and the target area of a human (torso and head) is covered by bone for 70% of that area.

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. It 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 phase. During phases 4 and 5 the area of the holes through the tissue is listed. This is the average of major and minor diameter for each of the two exit holes. 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. Unlike penetration depth, reliability of a round and barrier performance this characteristic can be increased with multiple

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

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 solid metal 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, solid metal rounds which create holes larger than their caliber and tumbling bullets that have holes that vary greatly at different depths. Fluid transfer from the solid metal 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.

"The critical wounding components for handgun ammunition are penetration and permanent cavity."[55]

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. Understand the different types and major designs of bullets 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.

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

Knowing the strengths and weaknesses of each design will help you eliminate rounds that simply cannot meet your needs.

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 (AP) Armor Piercing) will provide a small list of rounds. Then look at Reliability and Consistency to eliminate undesirable rounds and finally comparing Permanent Wound Cavities will yield the best results.

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.

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 phase 2 and 3 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. That diameter 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 (from phases 4 and 5) is multiplied by the penetration depth (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.

FIVE TYPES OF HANDGUN PROJECTILES

Five types of handgun projectiles exist, each with their own specific design. They have radically different characteristics. Projectiles within each type tend to have similar characteristics in regards to function, penetration, reliability, barrier performance and overall purpose.

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 projectile. This is intended to increase drag which limits penetration depth as compared to an FMJ which many falsely consider to over-penetrate. The positive byproduct of the expansion is a larger diameter wound, if the bullet doesn't experience a failure. 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 fail, 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. If a non-liquid fills the cavity, then the 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.[56] 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. Most hollow point rounds are copper jacketed lead, but some monolithic hollow points have no lead. 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. 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. As mass goes up velocity must go down. With increased mass, momentum goes up (the heaviest

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

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. Since HP don't expand more when faster (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, failure to expand and turning (sideways rounds create less drag, smaller holes and deeper penetration). All these failures are detrimental, limiting the round's ability to wound and are not supposed to occur.

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 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 depths due to the lower drag from lack of expansion. 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 15 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."[57] 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 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: When encountering light domestic barriers, duty hollow points in all calibers exhibited a reduced effectiveness of approximately 20-30% and the failure rate went up. When encountering heavy barriers, the reduction was always greater than 50% and there were large deviations in trajectory. No hollow points penetrate level 3A soft or hard armor.

Permanent Wound Cavity: 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 Solid Metal Fluid Transfer round.

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

2. Full Metal Jacket (FMJ): This is the second most common defensive ammunition used and also the most widely used training or practice ammunition. 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 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.

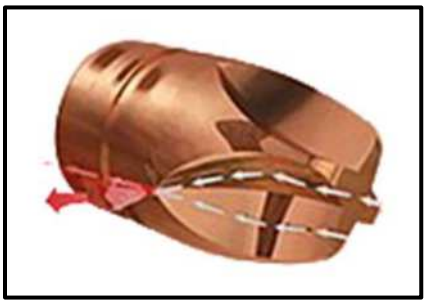
Penetration: FMJs penetrate between 24-31 inches during the FBI series gel tests for determining penetration depth. This is considered to be over-penetration as the current federal standard calls for 15-21 inches of penetration. The FBI, US Law Shield and USCCA all report that not a single reported case in US history has ever occurred from an over penetrating pistol round and given that many agencies and departments have used FMJ as their duty ammunition for decades the myth of pistol overpenetration should cease to exist.

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

Barrier Performance: FMJs exhibited a 5-10% reduction in effectiveness when encountering light domestic barriers. When encountering heavy barriers, the reduction was much greater and there were minor deviations in trajectory. Occasionally 9mm and .357 Sig FMJ will penetrate level 3A soft armor, but will not penetrate 3A hard armor. The 380, .40 S&W, 10mm and .45 ACP FMJ did not penetrate either soft or hard level 3A armor.

Permanent Wound Cavity: 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 Solid Metal Fluid Transfer round.

3. Solid Metal Fluid Transfer (SMFT)-Fluted: These solid copper, brass or steel projectiles have flutes or channels and are non-expanding bullets. 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 the fluid and reducing the dissipation of the liquid by creating a focused jet of high-velocity material. Fluted bullets lower the Terminal Ballistic Coefficient (TBC), which increases cast-off fluid velocity through constriction IAW Bernoulli's principle and the Venturi effect[58]. It is calculated that 96% of the impacted liquified tissue is directly channeled into and down the flutes (working area). 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=.099", 40 S&W=.125"

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

and the 45 ACP=.16") multiplied by the working area of the projectile (96%) is the amount of material vectored into and impacting live tissue adjacent to the path of the bullet. 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. Recent testing has proven that fluted solid metal 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. 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.

This is not energy transfer temporary stretch cavity that does not destroy tissue. Temporary cavity is caused by a low-density **compressible 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[59]. 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.

With this fluted design, given a constant pressure set by the Sporting Arms and Ammunition Manufacturers' Institute (SAAMI) standards, increased weight tends to increase penetration depth, while increased velocity increases 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. Penetration depth is a function of the momentum and drag of the projectile. Given an equal pressure, 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. Making a round lighter and faster increases drag, decreases momentum and therefore decreases penetration depth, but will have a larger wound diameter. The overall volume of the wound may be larger or smaller depending on the above trade-offs.

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, but it also increases the area of the hole created by the tearing nature of the projectile itself. It provides for a wider starting place for where the fluid transfer begins which is the outside edge of the bullet.

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

The coefficient of drag (C_d) of an object stays the same if the shape and media it's traveling through stay the same.[60] FMJ and SMFT are linear, non-profile changing rounds and the 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 a percentage of projectile velocity. Cast-off velocity decreases linearly with projectile deceleration from drag. The cast-off speed is approximately 37% of the projectile speed. 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? Modern Law Enforcement water cannons can propel water at rates up to 20 liters per second, and stream water 67 meters away. The velocity of the water decreases as range increases. The velocity of water where tissue destruction occurs 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). [61] [62] A change of fluid from water to a higher density or viscosity fluid will have a corresponding increase in damaging effects.[63] 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.[64] 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.

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".[65] "Wave propagation

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

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

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

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

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

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

speed of water is approximately 16.2 m/s" (53 fps).[66] "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." [67]

"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)." [68] 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 an SMFT-Fluted round is approximately 1500 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 statistics for the velocity of water required to tear tissue were calculated for law enforcement to ensure that the water does not tear the skin of the target. 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.[69] 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."[70] 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. 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 Solid Metal Fluid Transfer-Fluted round, where the diameter of the wound exceeds the diameter of the projectile through a deeper penetration depth.

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

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

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

[69] 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/

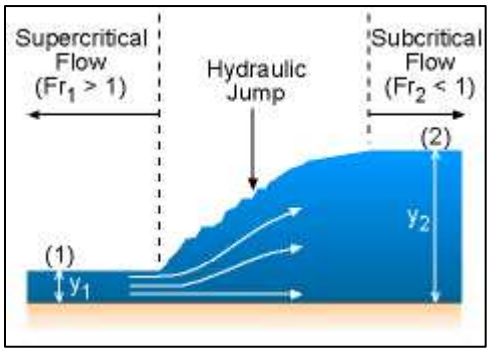
[70] Fackler, M.L., M.D., Director, Wound Ballistics Laboratory, letter: "Bullet Performance Misconceptions", International Defense Review 3, 1987.

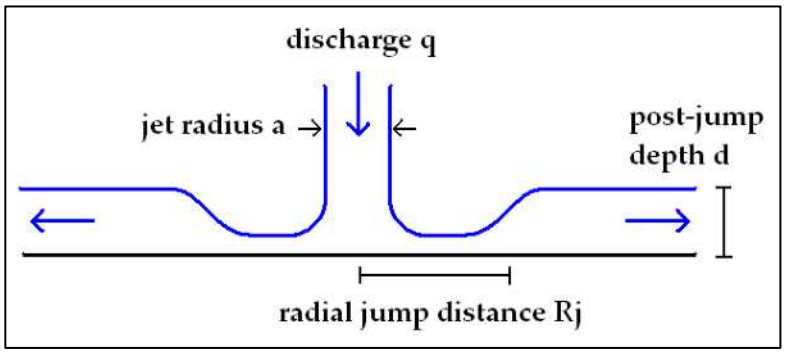
Tissue testing, hunting and human forensics reports have also provided data exhibiting a non-linear 3-dimensional volume of wound increase with an increase in projectile velocity, as noted in the 8 data point APC velocity case study (contact us for that report). Also, the wound pattern during tissue 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." [71] 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 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.

Radial Hydraulic Jump



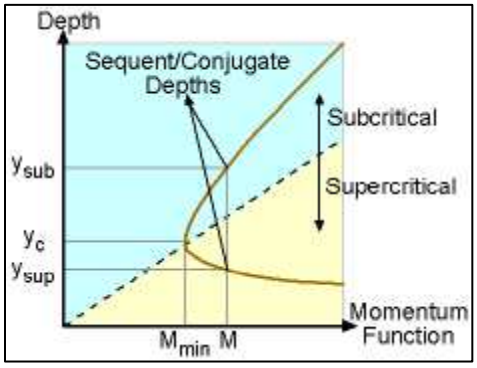


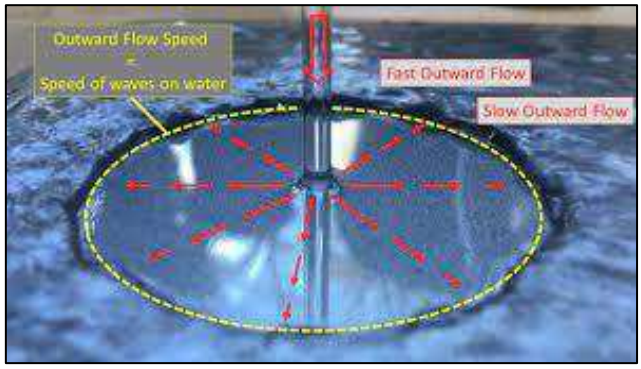
As the velocity of cast-off remains greater than liquid tissue and blood propagation speed (30 fps), the outward flow of the cast-off contacts adjacent tissue not impacted by the bullet at a Supercritical Flow speed which does not allow for a rebound or absorption of the force. The focused cast-off tears 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

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

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)[72] (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. All three charts above show a non-linear increase in the area affected outside the radial jump distance (R_j) and a non-linear velocity decrease. The Momentum Function being non-linear and staying high explains the non-linear increase in wound channel with respect to the velocity increase.

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 changes in focus, direction and velocity non-linearly.

A short video showing a 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

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

Penetration: The penetration depth for these rounds is between 16-20 inches during the FBI series of gel tests for determining penetration depth. Penetration depths are very consistent for all projectile weights and calibers.

Reliability / Consistency: Fluid Transfer rounds have a high reliability (≥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 detrimental.

Barrier Performance: Fluid Transfer rounds exhibited a reduced effectiveness of 5-15% when encountering light domestic barriers. When encountering heavy barriers, the reduction was the least of any of the 5 bullet types, <20%, and there were almost no deviations in trajectory. The armor penetration ability of the Fluid Transfer rounds was varied. Please see attached armor data sheet for complete results.

Permanent Wound Cavity: 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 always 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 in the same caliber, and with the deeper penetration, overall wound volumes (VWI) are greatly more significant than any other projectile type. In non-compressible gel, the cavities created by the hydraulic effect are artificially large, 4-5 times the size of those created by hollow points in the same caliber. However, in actual tissue, the wound volumes are roughly 2.5-3.5 times larger than that of hollow points in the same caliber, as shown during our phase 4 and 5 testing and medical examinations.

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 designed to create large diameter wounds that do not penetrate deeply. In all cases these rounds did not penetrate the required 12 inches of ballistics gel, except for some cores. The average penetration for frangible rounds is 10 inches. The only common failure of frangible rounds is failure to fragment, which is rare. 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 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. If minimal penetration or absolute barrier stoppage is desired, then Frangible rounds are designed for that task.

5. Tumbling: These rounds are designed to have the center of gravity as far back towards the base as possible. This creates an unstable round. The rounds 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. At impact of the target the round immediately starts to slow and any non-symmetrical force applied to it from something denser than air (liquid tissue is more than 1000 times denser than air) starts a yawing motion and the imbalanced center of gravity causes the round to tumble. Since the round is longer than it is wide, the wound channel is substantially larger than an FMJ. The longer and thinner the round is, the easier it is to get the center of gravity so far aft that the tumbling occurs reliably. Also, the higher the speed at impact the more the tumbling reliably occurs as the round cannot simply weather vane and self-correct. At high speed the momentum of the base tumbling forward is too great to be offset by drag. This tumbling is one of the primary kill mechanisms of high-speed rifle rounds, the 5.7x28mm rounds and the 4.6x30mm rounds and is extremely effective. Unfortunately, in normal handgun calibers like the 9mm, .40 S&W, 10mm, .45 ACP and the like the round 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 tumbling. During testing of projectiles 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.

For the 5.7mm and 4.6mm the results of penetration depth varied from 9-21 inches with an average of just over 16 inches. Reliability, consistency, barrier performance and permanent wound cavity are so varied that an average result is not well defined. Light domestic barriers only degraded the tumbling rounds by 5-10%, except for tumbling rounds designed to fragment. Please reference section three 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)

When the bullets tumble there are many substantial benefits. Please see article: Pistol vs Rifle Projectiles.

https://viperweapons.us/blog/f/pistol-vs-rifle-projectiles

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. 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	9-17	65%	LIGHT DOMESTIC	1.9-8.2
FMJ	24-31	95%	HEAVY	3.6-5.45
SMFT (FLUTED)	16-20	90%	HEAVY-ARMOR	6.7-17.0
FRANGIBLE	4-16	85%	NONE	1.85-6.9
TUMBLING	9-21	85%	NONE-ARMOR	2.0-12.9

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.

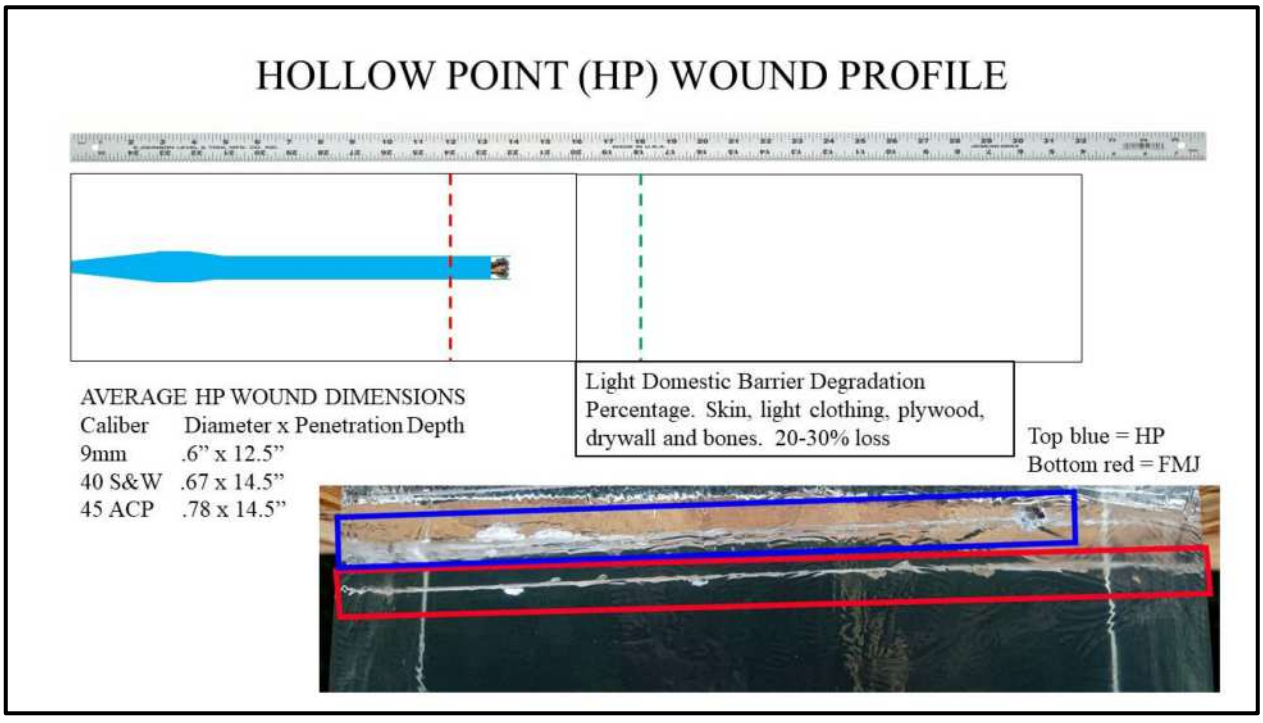
1. Hollow Point (HP)
2. Full Metal Jacket (FMJ)
3. Solid Metal Fluid Transfer (SMFT) - Fluted
4. Frangible
5. Tumbling (5.7mm and 4.6mm)

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

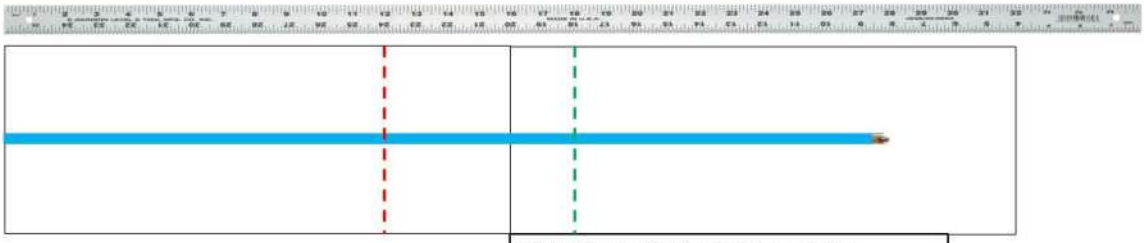
Wound Profile picture derived from the following:

- 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 2023



FULL METAL JACKET (FMJ) WOUND PROFILE

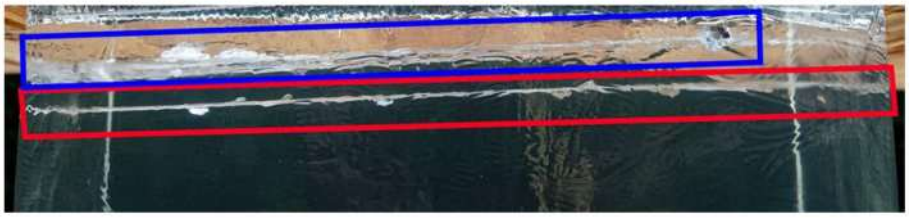


AVERAGE FMJ WOUND DIMENSIONS

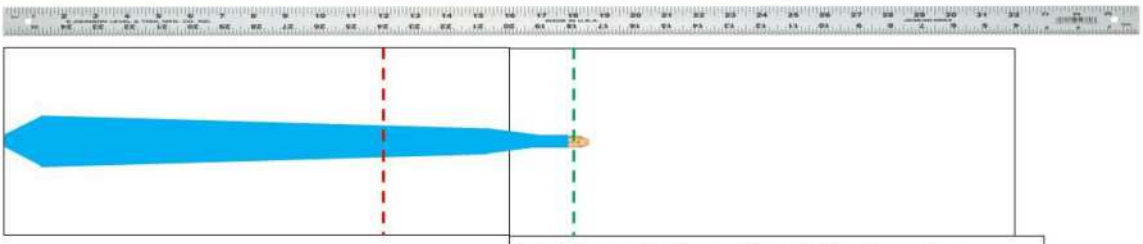
Caliber	Diameter x Penetration Depth
9mm	.35" x 28"
40 S&W	.4 x 31"
45 ACP	.45 x 27"

Light Domestic Barrier Degradation Percentage. Skin, light clothing, plywood, drywall and bones. 5-10% loss

Top blue = HP
Bottom red = FMJ



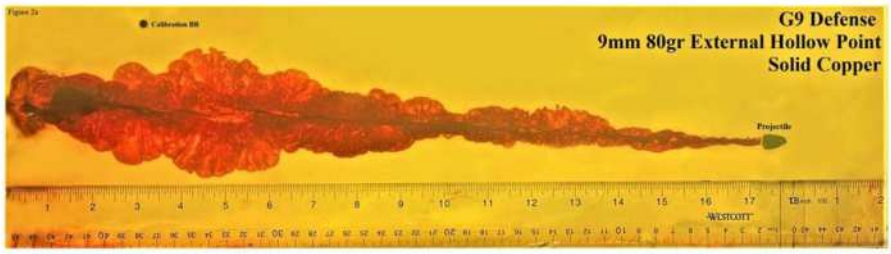
SOLID METAL FLUID TRANSFER (SMFT) WOUND PROFILE



AVERAGE SMFT WOUND DIMENSIONS

Caliber	Diameter x Penetration Depth
9mm	.93" x 17.1"
40 S&W	1.17 x 18.9"
45 ACP	1.04 x 19.2"

Light Domestic Barrier Degradation Percentage
Skin, light clothing, plywood and bones: 5-15% loss



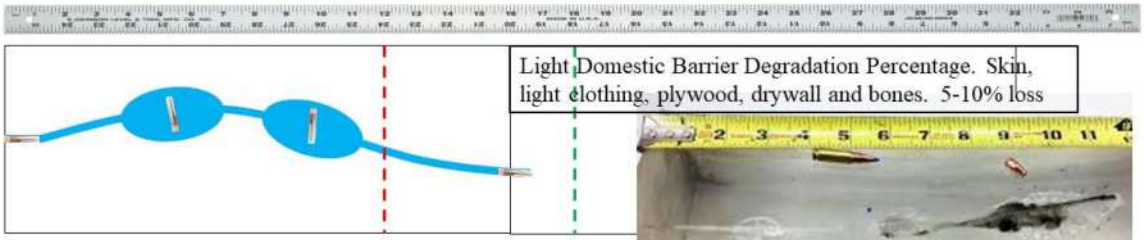
FRANGIBLE WOUND PROFILE

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. 5-10% loss

AVERAGE TUMBLING WOUND DIMENSIONS

Caliber	Diameter x Penetration Depth
4.6mm	.96” x 16.8”
5.7mm	1.17 x 15.7”

For more info information on the wound profiles to include tissue test and forensic results, please contact us.

AMMUNITION TESTED

One hundred and thirty 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. It is current as of August 2023. All 5 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, hollow points and solid metal 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 9mm 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 or tumbling.

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 30-40%, mostly by limiting penetration depths not limiting wound diameter. This round penetrated through Level 3A soft armor. This round did not penetrate through Level 3A hard armor or 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. 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 Level 3A soft or hard armor.

Permanent Wound Cavity: This hollow point had the largest PWC of the fourteen 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: 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 outside of 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 all phases this round was the most

consistent of all fourteen 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 10% degradation from light barriers. In limited testing versus heavy barriers like auto glass, solid wood and metal this round was degraded less than the other 9mm hollow points, but still was deflected, misshaped and fragmented. Through the heavy barriers this round 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 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 is still one of the top choices in 9mm hollow point that trades off some terminal effects for better reliability.

Speer Gold Dot +P 124 grain

Penetration: This hollow point penetrated 15.3 inches during phase 2 and 14.2 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 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 2.9 cubic inches.

Overall: 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 1200 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 limited 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 fourteen 9mm hollow points tested. Its Volume of Wound Index is 5.5 cubic inches.

Overall: A modified 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 metal (brass) 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 Level 3A soft and hard armor products. This round did not penetrate through Level 3 hard armor.

Permanent Wound Cavity: The fluid transfer APC and FR have the largest PWC of all 31 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. The PWC in tissue is realistic and is very large with a diameter wider than any 9mm hollow point. 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 level 3A armor products and is not considered ‘armor piercing’ under BATFE guidelines.

Underwood XD +P 90 grain

Penetration: This solid metal (copper) 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 Level 3A soft or hard armor or 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 9.8 cubic inches.

Overall: This solid metal fluid transfer XD 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. Load variations and pressures may be different between ammunition companies, which could vary the velocity. 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'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, 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.

.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 solid metal 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 or tumbling.

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 30%, 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 9 of the fourteen 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 Level 3A soft or hard 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 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 which reduces effectiveness. FTE was minimal. 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 Level 3A soft or hard 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. 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 Level 3A soft or hard 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 6.0 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. 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 has sufficient penetration, reliability, consistency and barrier performance. 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 Metal (copper) Fluid Transfer round (SMFT) 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 solid metal 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 is still very large with a diameter wider than any .40 S&W hollow point 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 Metal Fluid Transfer rounds (SMFT) 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 15% penetration degradation. Both the brass APC and the copper FR rounds were tested vs armor. The APC went through all level 3A soft and hard armor materials, but did not penetrate through level 3 armor. The First Response (FR) did not penetrate as well through level 3A 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 also the largest PWC and Volume of Wound we have ever tested in any pistol rounds in eight calibers.

Overall: This Law Enforcement and Military only .40 caliber ammunition is reliable and consistent, exhibiting optimum penetration. The PWC in tissue and gel is larger than any other pistol round ever tested. The barrier performance is unapparelled. During concurrent testing of these two rounds, they were almost duplicates until testing in armor.

Underwood XD 100 grain

Penetration: This solid metal (copper) 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 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 25% penetration degradation. This round penetrated through Level 3A soft armor, but did not penetrate through Level 3A or 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 solid metal fluid transfer XD 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 solid metal 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 30%, 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 5.45 cubic inches. As a comparison that wound volume is larger than the wound volume of 11 of the 14 9mm and 3 of 10 .40 S&W hollow points tested from 2016 to present and is significantly larger than the average 9mm hollow point.

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 Level 3A soft or hard 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. 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 almost non-existent as it is for the other calibers offered in this projectile. Limited expansion, which is not a failure was noted on several rounds. 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 Level 3A soft or hard 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. 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: The Speer Gold Dot 230 grain has excellent wound ballistic effects equal to the other three top performers. 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: This round had good consistent reliable penetration. Barriers had some effect on the rounds 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 Metal (brass) Fluid Transfer round (SMFT) which penetrated 20.0 and 19.8 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 level 3A soft and hard armor materials, but did not penetrate through level 3 armor. The copper FR did not penetrate as well through level 3A 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 16.5 cubic inches.

Overall: This Law Enforcement and Military only .45 caliber ammunition (APC) is reliable and consistent, exhibiting optimum penetration. 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 was nearly identical to the APC except when tested vs armor.

Underwood XD +P 120 grain

Penetration: This solid metal (copper) 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 of the Level 3A soft or 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.

Overall: This solid metal fluid transfer XD 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 column.

A low number indicates that particular round was less effected 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 31 Rounds

VIPER WEAPONS TRAINING LLC

TERMINAL WOUNDS BALLISTICS DATA, CAO AUG 2023

Caliber	Round (130)	Box	Weapon	PHASE 1	PHASE 2			PHASE 3			PHASE 4	PHASE 5	VWI	LDBD%
Type		Velocity		Average Velocity	Gelatin / Denim Penetration	Diameter	PWC	Gelatin / Plywood / Denim Penetration	Diameter	PWC	Tissue / Denim Av Hole Area	Tissue / Plywood / Denim Av Hole Area	Av Pen x Av Area	
9mm	31 rounds													
FMJ	Winchester FMJ 124 gr	1140	Sig P 226 / Glock 17	1140	28	0.35	2.7 ci	27	0.35	2.6 ci	0.14	0.12	3.6	10%
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%
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	
Frangible	Interceptor ARX +P 65 gr	1695	Glock 17	1680	12.5	0.9	7.9 ci	12.5	0.8	6.3 ci	0.6	0.5	6.9	17%
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	
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	
HP	American Mun. Sierra 115 gr	1250	Glock 17	1230	9.0	0.5	1.8 ci	10.0	0.4	1.3 ci	0.3	0.25	2.6	21%
HP	CorBon +P 115 gr	1350	Glock 17	1300	9.5	0.6	2.7 ci	7.0	0.5	1.4 ci	0.3	0.16	1.9	48%
HP	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%
HP	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	0.2	2.7	21%
HP	Hornandy C Duty +P 135 gr	1115	Glock 17	1120	13.8	0.5	2.7 ci	13.1	0.5	2.6 ci	0.35	0.31	4.4	12%
HP	OATH Tango 110 gr	1200	Glock 17	1150	5.3	0.8	2.7 ci	4.6	0.8	2.3 ci	Did Not Exit (DNE)	Did Not Exit (DNE)	undet Area	
HP	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%
HP	Remington GS 147 gr	990	Glock 17	980	17.0	0.6	4.8 ci	16.0	0.5	3.1 ci	0.3	0.25	4.5	26%
HP	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	0.4	0.35	5.7	24%
HP	Speer GD +P 124 gr	1220	Glock 17	1200	15.3	0.5	3.0 ci	14.2	0.4	1.8 ci	0.24	0.16	2.9	37%
HP	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%
HP	Underwood Max Exp 105 gr	1175	Glock 17	1160	10.3	0.8	5.2 ci	11.0	0.7	4.2 ci	0.5	0.41	4.8	19%
HP	Winchester RA9TA 127 gr +P+	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%
HP	Winchester Ranger T 147 gr	990	Glock 17	1000	14.5	0.6	4.1 ci	16.0	0.4	2.0 ci	0.3	0.25	4.2	35%
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%
SMFT	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%
SMFT	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%
SMFT	G9 EHP 80 gr	1480	Glock 17	1405	16.5	1.1	15.7 ci	16.0	1	12.6 ci	0.69	0.66	11	12%
SMFT	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	9%
SMFT	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%
SMFT	G9 Woodsman +P 124 gr	1250	Glock 17	1260	34	0.7	13.1 ci	33.0	0.7	12.7 ci	0.42	0.46	14.7	1%
SMFT	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%
SMFT	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	0.6	0.47	8.3	25%
SMFT	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	0.6	0.6	9.8	12%
SMFT	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 25 Rounds

VIPER WEAPONS TRAINING LLC

TERMINAL WOUNDS BALLISTICS DATA, CAO AUG 2023

Caliber	Round (130)	Box	Weapon	PHASE 1	PHASE 2			PHASE 3			PHASE 4	PHASE 5	VWI	LDBD%
Type		Velocity		Average Velocity	Gelatin / Denim Penetration	Diameter	PWC	Gelatin / Plywood / Denim Penetration	Diameter	PWC	Tissue / Denim Av Hole Area	Tissue / Plywood / Denim Av Hole Area	Av Pen x Av Area	
40 S&W	25 rounds													
FMJ	Winchester FMJ 180 gr	1020	Glock 22	1005	31	0.4	3.9 ci	29.5	0.4	3.7 ci	0.14	0.16	4.5	3%
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	0.2	Did Not Exit (DNE)	undet Area	
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	
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	
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	
HP	Federal HST 180 gr	1000	Glock 22	1000	18.0	0.6	5.1 ci	17.6	0.6	5.0 ci	0.49	0.43	8.2	7%
HP	Hornady C Duty 175 gr	1010	Glock 22	1020	17.9	0.6	5.0 ci	17.2	0.6	4.9 ci	0.4	0.4	7.0	2%
HP	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	
HP	Remington GS 165 gr	1150	Glock 22	1145	15.3	0.5	3.0 ci	17.2	0.4	2.2 ci	0.3	0.2	4.1	25%
HP	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%
HP	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%
HP	Speer Gold Dot 165 gr	1050	Glock 22	1060	14.3	0.7	5.5 ci	16.0	0.5	3.1 ci	0.3	0.24	4.1	32%
HP	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%
HP	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%
HP	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%
Tumbling	Fort Scott 125 g	1320	Glock 22	1290	22.0	0.5	4.3 ci	20.8	0.4	2.6 ci	0.2	0.28	5.1	15%
SMFT	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%
SMFT	G9 EHP 95 gr	1460	Glock 22	1445	19.0	1.0	14.9 ci	18.7	0.9	11.9 ci	0.7	0.66	12.8	8%
SMFT	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%
SMFT	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%
SMFT	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%
SMFT	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	0.9	0.85	16.8	4%
SMFT	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%
SMFT	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%
SMFT	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 21 Rounds

VIPER WEAPONS TRAINING LLC

TERMINAL WOUNDS BALLISTICS DATA, CAO AUG 2023

Caliber	Round (130)	Box	Weapon	PHASE 1	PHASE 2			PHASE 3			PHASE 4	PHASE 5	VWI	LDBD%
Type		Velocity		Average Velocity	Gelatin / Denim Penetration	Diameter	PWC	Gelatin / Plywood / Denim Penetration	Diameter	PWC	Tissue / Denim Av Hole Area	Tissue / Plywood / Denim Av Hole Area	Av Pen x Av Area	
45 ACP	23 rounds													
FMJ	Winchester FMJ 230 gr	835	Sig P227E / Glock 21	865	27.5	0.45	4.4 ci	27	0.45	4.3 ci	0.18	0.22	5.45	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%
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	
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	
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	
HP	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%
HP	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%
HP	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%
HP	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%
HP	Remington GS 185 gr	1140	Glock 21	1115	15.1	0.7	5.8 ci	13.8	0.6	3.9 ci	0.4	0.36	5.5	21%
HP	Sig Sauer V 230 gr	830	Glock 21	850	15.1	0.7	5.8 ci	16.2	0.7	6.2 ci	0.5	0.42	7.2	8%
HP	Speer Gold Dot 230 gr	890	Glock 21	810	17.5	0.7	6.7 ci	16.5	0.6	4.7 ci	0.5	0.44	8.0	21%
HP	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%
HP	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%
Tumbling	Fort Scott 180 gr	989	Glock 21	1000	22+ FTT	0.5	N/A	22+ FTT	0.48	N/A	0.2	0.28	undet Pen	
SMFT	G9 EHP +P 117 gr	1400	Glock 21	1420	19.2	1.0	15.1 ci	18.8	0.9	12.0 ci	0.74	0.7	13.7	13%
SMFT	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	0.8	15.3	4%
SMFT	G9 First Response 117 gr	1500	Glock 21	1495	20.2	1.4	31.1 ci	19.5	1.4	30.0 ci	0.8	0.85	16.4	1%
SMFT	G9 APC 117 gr 2023	1500	Glock 21	1505	20.0	1.4	30.8 ci	19.8	1.4	30.5 ci	0.84	0.82	16.5	2%
SMFT	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%
SMFT	Underwood XD 120 gr	1320	Sig P227E / Glock 21	1400	18.5	0.9	11.8 ci	17.6	0.8	8.8 ci	0.6	0.42	9.2	28%
SMFT	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%
SMFT	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 WOUNDS BALLISTICS DATA, CAO AUG 2023

Caliber / Type	Round (130)	Box Velocity	Weapon	PHASE 1 Average Velocity	PHASE 2 Gelatin / Denim Penetration	Diameter	PWC	PHASE 3 Gelatin / Plywood / Denim Penetration	Diameter	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													
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%
HP	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%
HP	Speer GD 90 gr	1040	Glock 42	1055	11.2	0.42	1.5 ci	12.5	0.35	1.2 ci	0.32	0.2	3.1	25%
SMFT	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%
SMFT	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 7 Rounds

VIPER WEAPONS TRAINING LLC

TERMINAL WOUNDS BALLISTICS DATA, CAO AUG 2023

Caliber / Type	Round (130)	Box Velocity	Weapon	PHASE 1 Average Velocity	PHASE 2 Gelatin / Denim Penetration	Diameter	PWC	PHASE 3 Gelatin / Plywood / Denim Penetration	Diameter	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	7 rounds													
FMJ	Winchester FMJ 125 gr	1350	Glock 22 conv barl	1370	22+	0.4	N/A	22+	0.4	N/A	0.15	0.15	undet Pen	
HP	Federal HST 125 gr	1360	Glock 22 conv barl	1375	17.2	0.6	4.9 ci	20	0.5	3.9 ci	0.5	0.4	8.4	20%
HP	Sig Sauer V 125 gr	1356	Glock 22 conv barl	1375	17	0.6	4.8 ci	22	0.4	2.8 ci	0.44	0.32	7.4	35%
HP	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%
SMFT	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%
SMFT	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%
SMFT	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%

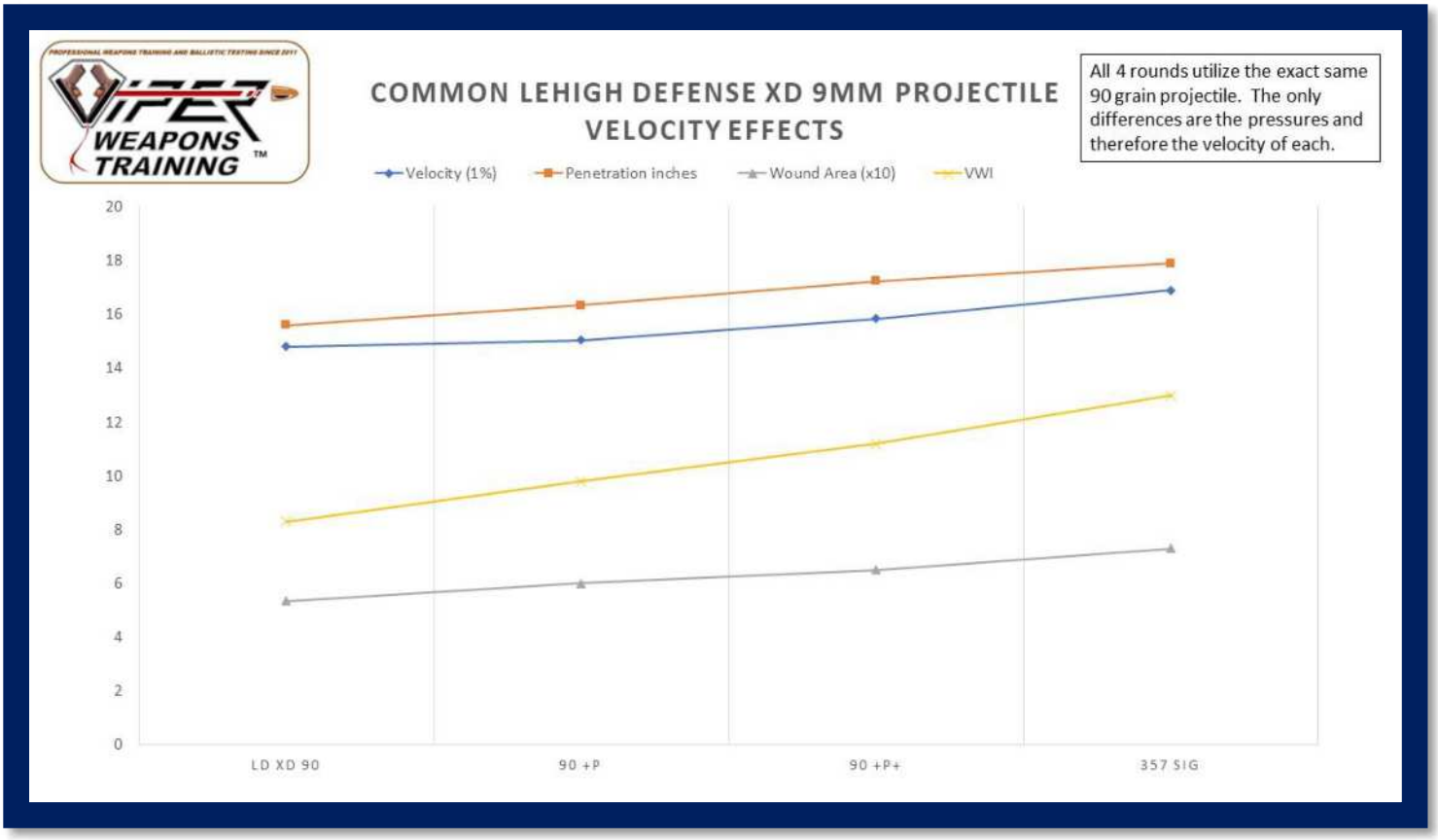
10mm 8 Rounds

VIPER WEAPONS TRAINING LLC

TERMINAL WOUNDS BALLISTICS DATA, CAO AUG 2023

Caliber / Type	Round (130)	Box Velocity	Weapon	PHASE 1 Average Velocity	PHASE 2 Gelatin / Denim Penetration	Diameter	PWC	PHASE 3 Gelatin / Plywood / Denim Penetration	Diameter	PWC	PHASE 4 Tissue / Denim Av Hole Area	PHASE 5 Tissue / Plywood / Denim Av Hole Area	VWI Av Pen x Av Area	LDBD%
10mm	8 rounds													
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	
HP	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%
HP	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%
HP	Sig Sauer 180 gr	1250	Glock 20	1200	16.0	0.6	4.5 ci	15.0	0.6	4.2 ci	0.6	0.36	7.4	23%
HP	Winchester SX 175 gr	1290	Glock 20	1300	14.8	0.6	4.2 ci	18.5	0.5	3.6 ci	0.5	0.4	7.5	17%
SMFT	G9 EHP 95 gr	1500	Glock 20	1490	19.0	1.0	14.9 ci	18.8	0.9	12.0 ci	0.72	0.69	13.3	12%
SMFT	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%
SMFT	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 Solid Metal Fluid Transfer (SMFT) Fluted 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. 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.



ARMOR TEST DESCRIPTION

Armor testing with selected 9mm, .40 S&W and .45 ACP ammunition was conducted 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 3A (Pistol) 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.

ARMOR PRODUCT DESCRIPTIONS:

VETERANS MFG:

3A Soft Plate

3A Hard Plate (1 lb)

ANGEL ARMOR:

3A Soft Plate

SAFECO:

3A Hard Plate

SHOTSTOP:

3A Soft Plate

3A Hard Plate

3 ICW Hard Plate

3+ Hard Plate

UNIVERSAL ARMOR:

3A Hard Plate

RTS:

3A Soft Plate

3+ Steel Plate

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 00101.06 Armor Levels

Level 1: .22 LR and .380 ACP

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

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

Level 3A (standard pistol): .357 Sig, .44 Magnum fired from long barrel handguns. It also provides all of the above protection. All pistol armor (levels 1, 2A, 2 and 3A) is tested at 5 meters

Level 3 (standard rifle): 7.62mm lead core rifle ammunition, tested at 15 meters

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

Non-NIJ rating Level 3 ICW: Plate becomes level 3 when used In Conjunction With a Level 3A soft armor

Non-NIJ rating Level 3+ (Light Armor Piercing): 5.56mm M855 LAP round

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 August 2023		VETERANS MFG		ANGEL ARMOR	SAFECO	SHOTSTOP				UNIVERSAL	RTS			Dry Wall
Caliber		LVL 3A	LVL 3A	LVL 3A	LVL 3A	LVL 3A	LVL 3A	LVL 3 ICW	LVL 3+	LVL 3A	LVL 3A	LVL 3+	LVL 4	LVL 7
Type	Round	Soft	Hard 1 lb	Soft	Hard	Soft	Hard	Hard	Hard	Hard	Soft	Steel	Hard	Hard
9mm	16 rounds													
FMJ	Winchester FMJ 124 gr	PEN	DNP	PEN	DNP	PEN	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP
HP	Federal HST 147 gr	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP
HP	Hornandy C Duty +P 135 gr	DNP	DNP	DNP	DNP	DNP	DNP	DNP		DNP				
HP	Speer Gold Dot +P 124 gr	DNP	DNP	DNP	DNP	DNP	DNP	DNP		DNP				
HP	Speer GD 147 gr	DNP	DNP	DNP	DNP	DNP	DNP	DNP		DNP				
HP	Winchester RA9TA 127 gr +P+	DNP	DNP			DNP	DNP	DNP	DNP		DNP	DNP	DNP	DNP
HP	Winchester Ranger T 147 gr	DNP	DNP	DNP	DNP	DNP	DNP	DNP		DNP				
SMFT	Black Hills HB +P 100 gr	DNP	DNP	DNP	DNP	DNP	DNP	DNP		DNP				
SMFT	Black Hills Subsonic 125 gr	DNP	DNP	DNP	DNP	DNP	DNP	DNP		DNP				
SMFT	G9 EHP 80 gr	DNP	DNP	DNP	DNP	DNP	DNP	DNP		DNP				
SMFT	G9 First Response 77 gr	PEN	DNP	PEN	DNP	PEN	DNP	DNP	DNP	DNP	PEN	DNP	DNP	DNP
SMFT	G9 APC 77 gr (1560 fps)	PEN	PEN	PEN	PEN	PEN	PEN	DNP	DNP	PEN	PEN	DNP	DNP	DNP
SMFT	Underwood XD +P 65 gr	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP
SMFT	Underwood XD 90 gr	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP
SMFT	Underwood XD +P 90 gr	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP
SMFT	Underwood XD +P+ 90 gr	DNP	DNP	PEN	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP

ARMOR RESULTS, CAO August 2023		VETERANS MFG		ANGEL ARMOR	SAFECO	SHOTSTOP				UNIVERSAL	RTS			Dry Wall
Caliber		LVL 3A	LVL 3A	LVL 3A	LVL 3A	LVL 3A	LVL 3A	LVL 3 ICW	LVL 3+	LVL 3A	LVL 3A	LVL 3+	LVL 4	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
HP	Federal HST 180 gr	DNP	DNP	DNP	DNP	DNP	DNP	DNP		DNP				
HP	Hornady C Duty 175 gr	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP
HP	Speer Gold Dot 165 gr	DNP	DNP	DNP	DNP	DNP	DNP	DNP		DNP				
HP	Winchester Ranger T 180 gr	DNP	DNP	DNP	DNP	DNP	DNP	DNP		DNP				
SMFT	G9 First Response 77 gr	PEN	DNP	PEN	DNP	PEN	PEN	DNP	DNP	DNP	PEN	DNP	DNP	DNP
SMFT	G9 APC 77 gr	PEN	PEN	PEN	PEN	PEN	PEN	DNP	DNP	PEN	PEN	DNP	DNP	DNP
SMFT	Underwood XD 100 gr	PEN	DNP	PEN	DNP	PEN	PEN	DNP	DNP	DNP	PEN	DNP	DNP	DNP

ARMOR RESULTS, CAO August 2023		VETERANS MFG		ANGEL ARMOR	SAFECO	SHOTSTOP				UNIVERSAL	RTS			Dry Wall
Caliber		LVL 3A	LVL 3A	LVL 3A	LVL 3A	LVL 3A	LVL 3A	LVL 3 ICW	LVL 3+	LVL 3A	LVL 3A	LVL 3+	LVL 4	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
HP	Federal HST +P 230 gr	DNP	DNP	DNP	DNP		DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP
HP	Hornady C Duty 220 gr	DNP		DNP	DNP		DNP	DNP	DNP		DNP	DNP	DNP	DNP
SMFT	G9 APC 117 gr	PEN	PEN	PEN	PEN	PEN	PEN	DNP	DNP	PEN	PEN	DNP	DNP	DNP
SMFT	Underwood XD +P 120 gr	DNP	DNP	DNP	DNP		DNP	DNP	DNP	DNP	DNP	DNP	DNP	DNP

SECTION 3

5.7MM & 4.6MM TERMINAL WOUND BALLISTICS & ARMOR TEST DATA

THIS DOCUMENT AND THE INFORMATION CONTAINED HEREIN IS FOR LAW ENFORCEMENT / MILITARY AND PARTICIPATING MANUFACTURERS ONLY

NO OTHER DISSEMINATION AUTHORIZED

FOREWORD

The 5.7mm and 4.6mm Terminal Wound Ballistics and Armor Test is a composite analysis including data from the previous "5.7mm Terminal Performance Test and Report" and our 2019 and 2020 5.7mm tests. The most recent tests were conducted from August through November of 2021 and December 2022 through January 2023. It includes 24 rounds from American Eagle, Fiocchi, FNH, Speer, Elite Ammunition and Vanguard Outfitters. From November 2021 through January 2022 seven rounds chambered in 4.6x30mm were tested and reported on. Since there are less weapons chambered in the 4.6mm, some are reserved only for law enforcement and military use, and there are far fewer cartridges in this caliber there is limited information and data presented here on that cartridge. Information and data on these two calibers are included in this section.

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 (available upon request). Additional small-scale testing was accomplished IAW NATO testing protocols for comparative purposes. Following the Terminal Wound Ballistics phases, 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, 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.

SECTION THREE

2023 COMPOSITE TERMINAL WOUND BALLISTICS

HANDGUN AMMUNITION REPORT

5.7MM & 4.6MM DATA

TABLE OF CONTENTS

OVERVIEW FNH 5.7 x 28mm & HK 4.6x30mm

The FNH 5.7 x 28mm is a small-caliber, high-velocity cartridge designed for handgun and personal defense weapon (PDW) applications manufactured by FN Herstal. 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 2002 and 2003, NATO conducted ballistics and terminal wound ballistics testing. 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)[73]
3. Greater range and accuracy
4. Equal or better 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 2 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 that the 5.7×28mm was "undoubtedly the more effective cartridge." "The cartridge was proven to exhibit superior effectiveness in all six desired attributes."

[73] 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.

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.

Currently the MP7 has no civilian variant and is in limited use worldwide. There are a few weapons chambered the 4.6mm, but no pistols.

Although variations exist, the duty 5.7mm and 4.6mm projectiles are designed to exhibit tumbling properties, with the exception of some hollow points. 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. Please see the section two chapter “5 Types of Handgun Bullets” and reference Type 5 Tumbling for information pertaining to these projectiles.

When high-velocity (>2000 fps) projectiles tumble there are many substantial benefits. This applies to rifle rounds as well as 5.7x28mm and 4.6x30mm.

1. High velocity tumbling rounds 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 round should achieve to make sure it goes deep enough to impact or penetrate the vital organs of the target. Penetration Depth is considered the most important component in Terminal Wound Ballistics and the round being able to accomplish its desired results. A tumbling round that has a curved penetration path is passing through and destroying more material. If two rounds penetrate the same depth, the round whose wound path curves has an overall longer path and therefore more damage. Penetration Track Length (PTL) is the measurement of the entire track the projectile took and should be used to determine the overall Permanent Wound Cavity. Both Penetration Depth (PD) and Penetration Track Length (PTL) are important in determining what the round is capable of doing inside a target. Linear pistol rounds do not have a curved path and therefore their PD=PTL. Measuring PTL is extremely difficult and in recent testing in IWBA gel and animal tissue, most tumbling defensive rounds show a PTL that is 10-30% longer than the PD. This increase is inconsistent and typically non-quantifiable but does contribute to increased wounding

due to a larger wound area. All of our data uses penetration depth measurements for all calculations.

2. Tumbling rounds 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. This occurs where the vital organs are located. On the negative side this may reduce external bleeding and depressurization.

4. The extremely high speed (>2000 fps) may cause a shock-wave velocity exceeding what a body part can stretch, meaning the temporary cavity may create torn and damaged tissue. 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 2000-2200 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."[74] "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."[75] A projectile velocity greater than roughly 2,000-2200 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."[76] There are five tested 5.7mm rounds that are $\geq$2200 fps.

5. The low drag nature of a low 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 higher caliber pistol round.

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

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

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

AMMUNITION TESTED

Twenty-four 5.7 x 28mm rounds have been fully tested. One round from American Eagle, three rounds from Fiocchi, four rounds from FNH, one round from Speer, six rounds from Elite Ammunition and nine rounds from Vanguard Outfitters all accomplished a complete >20 shot sample size. An additional seven rounds were minimally tested in 4.6 x 30mm as the request for information on these rounds centered on functionality in the weapon, velocity and penetration depth only.

All twenty-four 5.7mm rounds went through five terminal wound ballistics phases included in this test using 2 FN Five-seveN pistols with factory standard barrels. Following those five phases, many rounds underwent armor testing (phase 6) using thirteen armor products from five manufacturers using both of the above pistols and an FN PS90. Included 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 2023. 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.

<u>FNH 5.7 x 28mm</u>

American Eagle 40 grain

Fiocchi Frangible HP 35 grain

Fiocchi Hyperformance 40 grain

Fiocchi Subsonic 62 grain

FNH SS190 31 grain

FNH SS195LF 28 grain

FNH SS197SR 40 grain

FNH SS198LF 28 grain

Speer Gold Dot HP 40 grain

Elite S4M 28 grain

Elite T6B 27 grain

Elite PenetraTOR 40 grain

Elite ProtecTOR 40 grain

Elite DevastaTOR 2.0 37 grain

Elite DevastaTOR 3.0 27 grain

Vanguard Black Fang 34 grain

Vanguard BDF LE 34 grain

Vanguard BDF HVP LE 34 grain

Vanguard Lightning Fang 25 grain

Vanguard Barnes HP 50 grain

Vanguard Combined Tech 50 grain

Vanguard GPMI 40 grain

Vanguard GPMI DF 35 grain

Vanguard EXP Subsonic 64 grain

<u>HK 4.6 x 30mm</u>

Fiocchi 40 grain FMJ

Sellier & Bellot 40 grain FMJ

Vanguard 31 grain FMJ

Vanguard LE 31 grain FMJ

Barnes TSX 31 grain Hollow Point

Vanguard EXP 31 grain Hollow Point

Vanguard EXP LE 31 grain Hollow Point

FNH 5.7 x 28mm ROUND SUMMARIES

All shots were fired using two FN 5.7 pistols. One was a USG and the other a MK2. Both had stock barrels.

ROUND 1: American Eagle

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. With only two other rounds being slower (both Subsonic) it was amazing to see that this round still tumbled through both gel and tissue. This round is not designed to penetrate heavy barriers or armor and during testing it did not perform well when fired through those barriers. It is perfectly suited in the training role it was designed for.

ROUND 2: Fiocchi Frangible Hollow Point

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 exhibited deformation or fragmentation as designed. It consistently fragmented limiting penetration and created multiple small wound channels near the path of the bullet. It exhibits a smaller permanent wound cavity due to the fragmentation and as such 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.

ROUND 3: Fiocchi Hyperformance

This 40 grain round is the heaviest of the Fiocchi rounds and appears to be very similar to the FNH SS197SR. 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 penetrate heavy barriers or armor. Its overall Volume of Wound was small.

ROUND 4: Fiocchi Subsonic

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 still retained low penetration depths and tumbled as designed. This round is not designed 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

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.

The restricted SS190 performed well with very consistent results. It created the largest wound of the four FN factory rounds and excelled in the barrier tests and armor tests 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 SS195LF

A civilian version of the SS198LF (Round 8) with the same 28 grain projectile but lower velocity. It is designed as a training round.

The rounds lower velocity creates a smaller wound size and penetration depth. This round is not designed to penetrate heavy barriers or armor and during testing it did not perform well through those barriers. 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 graph on page 84.

ROUND 7: FNH SS197SR

This 40 grain plastic tipped round is the heaviest of the factory FN rounds. It is primarily used as a training round.

Due to its heavier projectile, this round had the deepest penetration of the four factory FN rounds. This round is not designed to penetrate heavy barriers or armor and during testing it did not perform well through those barriers. Its overall Volume of Wound was small.

ROUND 8: FNH SS198LF

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 SS195LF (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 defensive ammunition. This round is designed to penetrate heavy barriers and did very well. When shot into armor this round only penetrated older armor products with the pistol and did better with the added velocity from the PS90. It penetrated a few 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 graph on page 84.

ROUND 9: Speer Gold Dot Hollow Point

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's accurate, tough and consistent through all common barriers.

During gel tests this round fairly consistently opened up 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 tumbled. Barriers created larger changes in results than other rounds. As a hollow point it is not designed to penetrate any light domestic, heavy barriers or armor and during testing it did not perform well 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 round.

ROUND 10: Elite S4M

This is a 28 grain bullet similar to factory FN SS195 / 198. This high-pressure round had 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.

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. 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 graph on page 84.

ROUND 11: Elite T6B

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.

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 level 3A armor products. No soft level 3A armor stopped it. This is one of Elite Ammunitions best defensive rounds and should be considered for duty use.

ROUND 12: Elite PenetraTOR

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 round is designed to penetrate heavy barriers and even penetrated some level 3A soft armor. Level 3A hard armor stopped this round consistently.

ROUND 13: Elite ProtecTOR

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.

This round was the only one tested from Elite Ammunition that exhibited deformation or fragmentation. It still penetrated well but created a smaller permanent wound cavity due to the fragmentation. This round is not designed to penetrate heavy barriers or armor and during testing it did not perform well through those barriers. It performed as designed and is a good choice in this caliber for a round with less lethal effects after contacting barriers.

ROUND 14: Elite DevastaTOR 2.0

This 37 grain Law Enforcement/Military only (LE/Mil) round 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 the best when tested vs multiple different types of barriers from armor to wood to auto glass. This round consistently goes through most level 3A armor products. It remains one of the top rounds tested in 5.7mm. Its penetration, reliability and large permanent wound cavity are very impressive. Its overall Volume of Wound was one of the largest tested. This round should certainly be on your list if your agency is selecting duty rounds.

ROUND 15: Elite DevastaTOR 3.0

This Law Enforcement/Military only (LE/Mil) round is a lighter faster redesign of the previous DevastaTOR 2.0 (Round 14). 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 on all media. This projectile went through almost all of the level 3A armor products soft and hard. It has a fantastic penetration depth which is very surprising due to its weight. It also recorded the largest Volume of Wound of any 5.7mm round. It was very consistent with one of the smallest standard deviations between rounds. This is another round to seriously consider for duty use.

ROUND 16: Vanguard Black Fang

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 properties. It was one of the top two rounds tested in 5.7mm during the 206/17 Joint Agency Ballistic Test For Defensive Handgun Ammunition.

This ammunition has very violent unpredictable tumbling leading to large variations in the wound cavity but exhibited impressive results. It penetrated very well, with a large permanent wound cavity and excellent barrier performance, especially through heavy barriers and armor and remains one of the top choices in the 5.7mm. The Black Fang projectile penetrated almost all level 3A armor tested.

ROUND 17: Vanguard BDF LE

This 34 grain Law Enforcement/Military only (LE/Mil) round is an upgrade and redesign of the Vanguard Black Fang (Round 16). 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 was 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 of the level 3A armor. Consider this round as another great choice for duty use.

ROUND 18: Vanguard BDF HVP LE

This 34 grain Law Enforcement/Military only (LE/Mil) round has a harder copper alloy than the Vanguard BDF LE (Round 17). This 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 16).

Utilizing a harder copper alloy, this Law Enforcement/Military only (LE/Mil) ammunition was designed as a comparison with Round 17. 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 of the 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 17 and 18) 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 19: Vanguard Lightning Fang

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 16) that is shorter overall with 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 and almost always the second hole from the back tissue is larger, but with this round that was not the case. Dissection of the tissue showed that the tumbling happened a little earlier than normal 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 20: Vanguard Barnes Hollow Point

This 50 grain hollow point round is designed for deep penetration with expansion. This round intentionally deforms 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 24). It created a large permanent wound cavity with no barriers and had the most reduction in capability when barriers were introduced. As a hollow point it is not designed to penetrate any light domestic, heavy barriers or armor and during testing it did not perform well through those barriers. It performed as designed and is a good choice if you are looking for a round with less lethal effects after penetrating common barriers.

ROUND 21: Vanguard Combined Technology

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 projectile is not designed to penetrate heavy barriers or armor but during testing it did perform well through those barriers. This round is a perfect choice for small animal applications as designed.

ROUND 22: Vanguard GPMI

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 is not designed to penetrate heavy barriers or armor and during testing it did not perform well through those barriers. 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 23: Vanguard GPMI DF

This is a 35 grain lighter weight version of the 40 grain GPMI (Round 22). 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 controlled 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 didn't take that into account, and we 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 24: Vanguard Bonded Subsonic

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 subsonic round went through the normal series of tests and was the best subsonic 5.7 round we have ever tested. The reduction in velocity comes with the penalty in reduced terminal performance as expected. It still retained low penetration depths, good barrier performance and good permanent wound cavity size. This round is not designed to penetrate heavy barriers or armor and during testing it did not perform well through those barriers. 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 column.

A low number indicates that particular round was less effected 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 24 Rounds

VIPER WEAPONS TRAINING LLC

TERMINAL WOUNDS BALLISTICS DATA, CAO AUG 2023

Caliber	Round (130)	Box	Weapon	PHASE 1	PHASE 2			PHASE 3			PHASE 4	PHASE 5	VWI	LDBD%
Type		Velocity		Average Velocity	Gelatin / Denim Penetration	Diameter	PWC	Gelatin / Plywood / Denim Penetration	Diameter	PWC	Tissue / Denim Av Hole Area	Tissue / Plywood / Denim Av Hole Area	Av Pen x Av Area	
5.7mm	24 rounds													
	American Eagle 40 gr	1655	FN 5.7	1575	12.5			11.5			0.3	0.2	3.0	20%
	Fiocchi Frangible HP 35 gr	1750	FN 5.7	1715	13.2			10.5			0.18	0.12	1.8	25%
	Fiocchi Hyperformance 40 gr	1750	FN 5.7	1735	13.5			12.8			0.22	0.24	3.0	0%
	Fiocchi Subsonic 62 gr		FN 5.7	950	10.5			9.0			0.25	0.23	2.3	10%
	FNH SS190 31 gr	2130	FN 5.7	2130	12.0			11.2			0.39	0.39	4.5	3%
	FNH SS195LF 28 gr	2000	FN 5.7	1900	8.9			8.2			0.3	0.25	2.4	12%
	FNH SS197SR 40 gr	1700	FN 5.7	1620	14.0			13.0			0.2	0.2	2.7	4%
	FNH SS198LF 28gr	2150	FN 5.7	2050	10.0			9.1			0.35	0.35	3.3	5%
	Speer Gold Dot HP 40 gr	1800	FN 5.7	1775	14.5			15.0			0.51	0.42	6.9	9%
	Elite S4M 28gr	2650	FN 5.7	2410	12.3			11.5			0.42	0.54	5.7	3%
	Elite T6B 27 gr	2570	FN 5.7	2230	15.2			14.5			0.52	0.52	7.7	2%
	Elite PenetraTOR 40 gr	1900	FN 5.7	1905	17.2			15.9			0.35	0.1	3.7	37%
	Elite ProtecTOR 40 gr	2100	FN 5.7	1910	16.5			15.3			0.13	0.12	2	8%
	Elite DevastaTOR 37 gr		FN 5.7	2005	18.5			18.2			0.61	0.56	10.7	5%
	Elite DevastaTOR 3.0 27 gr		FN 5.7	2310	20.2			19.8			0.62	0.67	12.9	1%
	Vanguard Black Fang 34 gr	2150	FN 5.7	2130	19.0			18.5			0.65	0.46	10.4	16%
	Vanguard BDF LE 34 gr	2150	FN 5.7	2200	19.2			19.0			0.57	0.55	10.7	2%
	Vanguard BDF HVP LE 34 gr	2150	FN 5.7	2190	19.3			19.2			0.55	0.56	10.7	1%
	Vanguard Lightning Fang 25 gr	2350	FN 5.7	2305	17.5			17.7			0.61	0.57	10.4	3%
	Vanguard Barnes HP 50 gr	1725	FN 5.7	1590	16.8			15.0			0.56	0.4	7.6	20%
	Vanguard Comb Tech 50 gr		FN 5.7	1635	17.0			16.2			0.59	0.5	9.0	10%
	Vanguard GPMI 40 gr		FN 5.7	1970	20.5			19.5			0.48	0.43	9.1	9%
	Vanguard GPMI DF 35 gr	2150	FN 5.7	2140	16.2			15.0			0.5	0.4	7.0	14%
	Vanguard EXP Subsonic 64 gr		FN 5.7	1030	13.2			12.4			0.28	0.24	3.3	10%

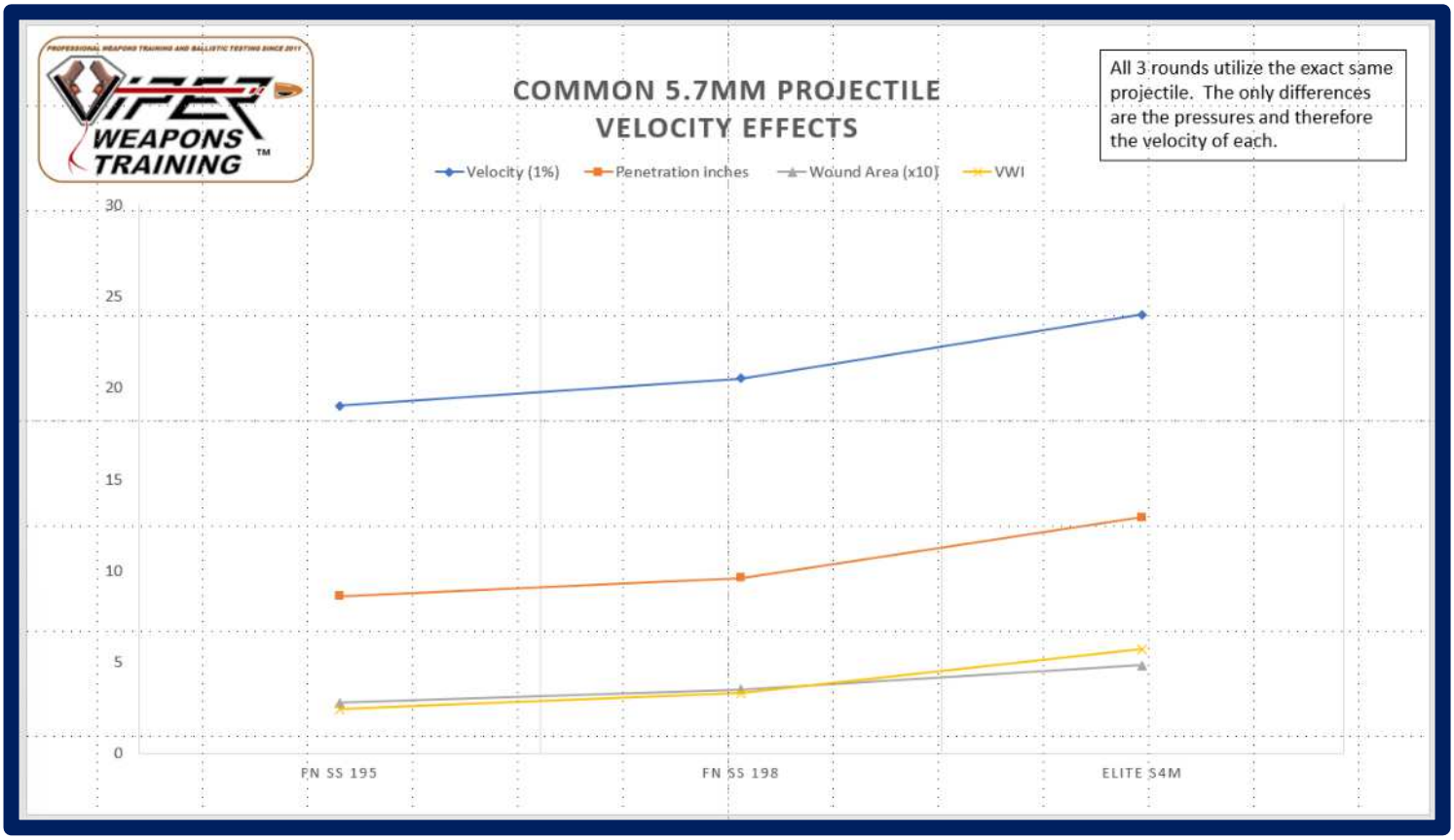
4.6 x 30mm 7 Rounds

VIPER WEAPONS TRAINING LLC

TERMINAL WOUNDS BALLISTICS DATA, CAO AUG 2023

Caliber	Round (130)	Box	Weapon	PHASE 1	PHASE 2			PHASE 3			PHASE 4	PHASE 5	VWI	LDBD%
Type		Velocity		Average Velocity	Gelatin / Denim Penetration	Diameter	PWC	Gelatin / Plywood / Denim Penetration	Diameter	PWC	Tissue / Denim Av Hole Area	Tissue / Plywood / Denim Av Hole Area	Av Pen x Av Area	
4.6mm	7 rounds													
FMJ	Fiocchi 40 gr	1900	HK MP7	1875	19									
FMJ	Sellier & Bellot 40 gr	2067	HK MP7	2020	20.5									
FMJ	Vanguard 31 gr	2250	HK MP7	2130	16.5									
FMJ	Vanguard LE 31 gr	2375	HK MP7	2240	17.2									
HP	Barnes TSX 31 gr	2328	HK MP7	2328	15.2	0.8								
HP	Vanguard EXP 31 gr	2250	HK MP7	2130	14.2	0.7								
HP	Vanguard EXP LE 31 gr	2375	HK MP7	2240	14.8	0.7								

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.



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

Armor testing with 5.7mm ammunition was conducted using 13 different armor products from 5 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 Lvl 2+ (3A-) soft plate

Ballistic Lvl 2 (3A-) hard plate

Helmet Lvl 2+

3A Soft Plate

3A Hard Plate (1 lb.)

Titanium 3A

AR/AK Rifle Plate Lvl 3-

ANGEL ARMOR:

3A Soft Plate

SAFECO:

3A Hard Plate

SHOTSTOP:

3A Soft Plate

3A Soft Clipboard

3 ICW Hard Plate

UNIVERSAL ARMOR:

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 00101.06 Armor Levels

Level 1: .22 LR and .380 ACP

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

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

Level 3A (standard pistol): .357 Sig, .44 Magnum fired from long barrel handguns. It also provides all of the above protection. All pistol armor (levels 1, 2A, 2 and 3A) is tested at 5 meters

Level 3 (standard rifle): 7.62mm lead core rifle ammunition, tested at 15 meters

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

Non-NIJ rating Level 3 ICW: Plate becomes level 3 when used In Conjunction With a Level 3A soft armor

Non-NIJ rating Level 3+ (Light Armor Piercing): 5.56mm M855 LAP round

Viper Weapons Training 2023 Armor Results	ARMOR PRODUCTS																					
	VETERANS MFG									ANGEL ARMOR		SAFECO		SHOTSTOP						UNIVERSAL ARMOR	
	LVL 2 (3-) Soft	LVL 2 (3-) Hard	LVL 2 + Helmet	LVL 3A Soft		LVL 3A Hard 1 lb		LVL 3A Titanium	AR/AK Rifle Plate	LVL 3A Soft		LVL 3A Hard		LVL 3A Soft		LVL 3A Clipboard		LVL 3 ICW Hard		LVL 3A 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
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 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.

None of the rounds penetrated.

SECTION FOUR

5.7mm LE/MIL

Armor Test Presentation

LAW ENFORCEMENT / MILITARY ONLY

ANGEL ARMOR 3A SOFT

(All Shots with FN 5.7 pistol)

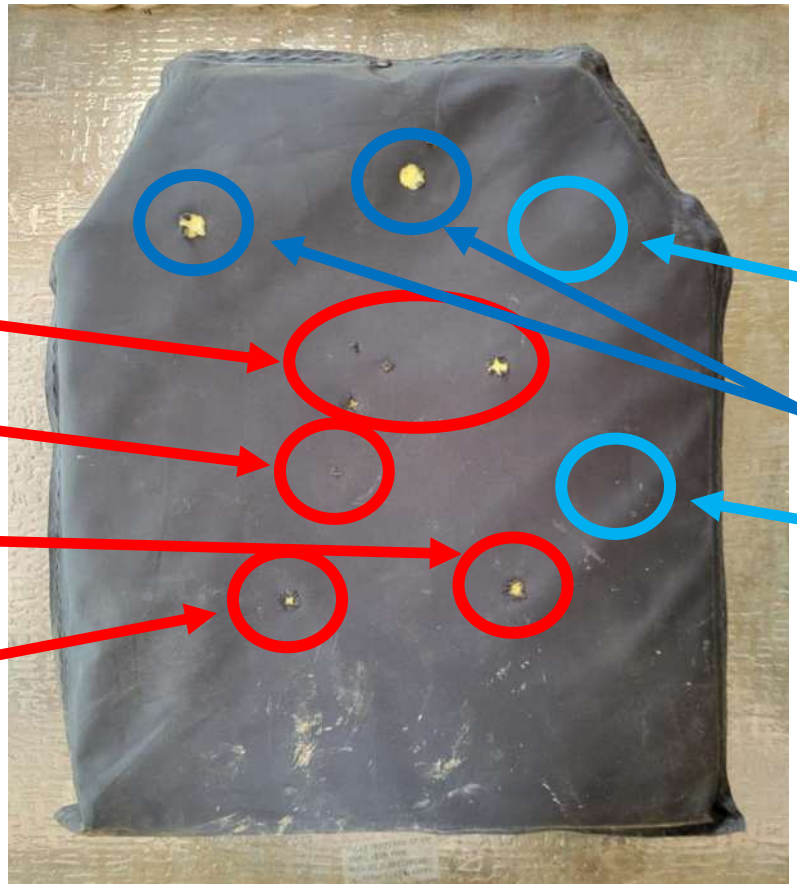
PENETRATIONS

Elite S4M (4)

Elite T6

FN SS190

Vanguard Black Fang



STOPPED BY ARMOR

FN SS195

FN SS198 (2)

Speer Gold Dot HP

SAFECO 3A HARD

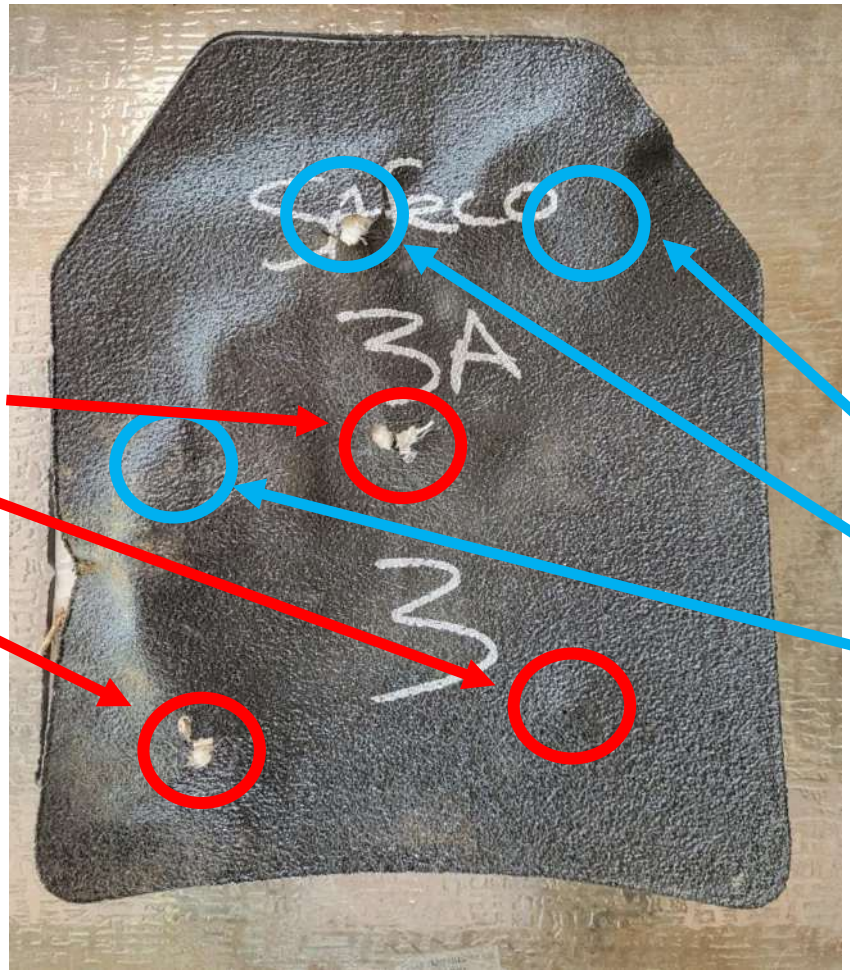
(All Shots with FN 5.7 pistol)

PENETRATIONS

Elite S4M

FN SS190

Vanguard Black Fang



STOPPED BY ARMOR

FN SS195

FN SS198

Speer Gold Dot HP

LAW ENFORCEMENT / MILITARY ONLY

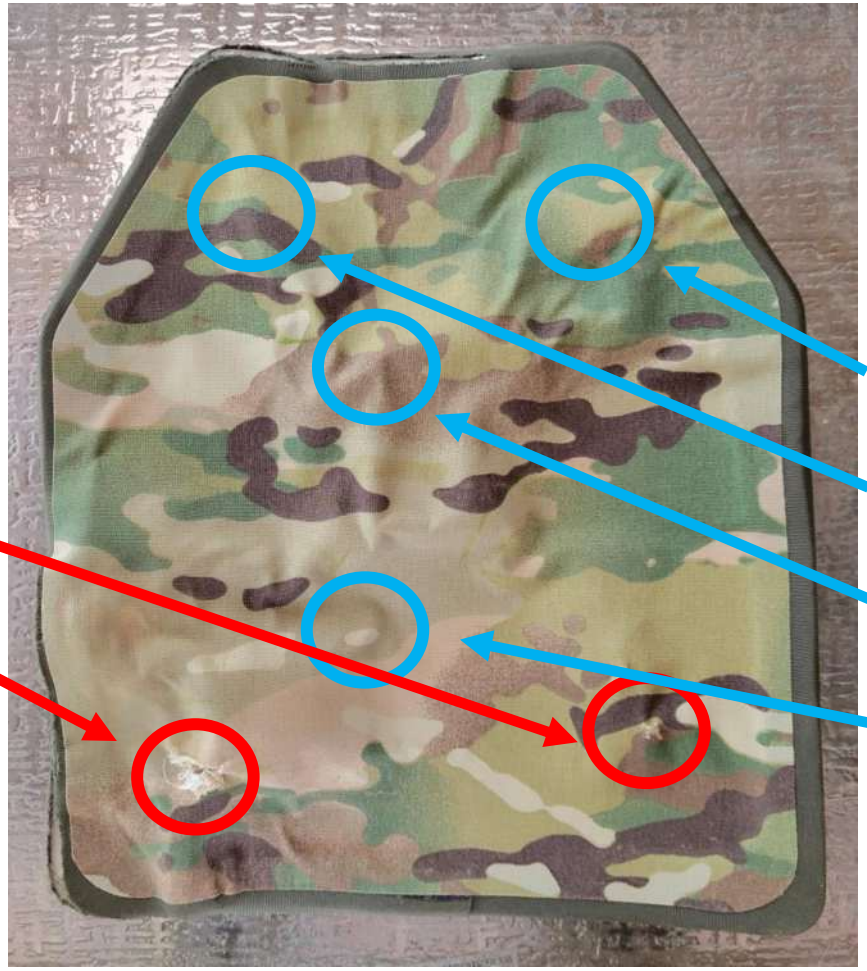
UNIVERSAL 3A HARD

(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

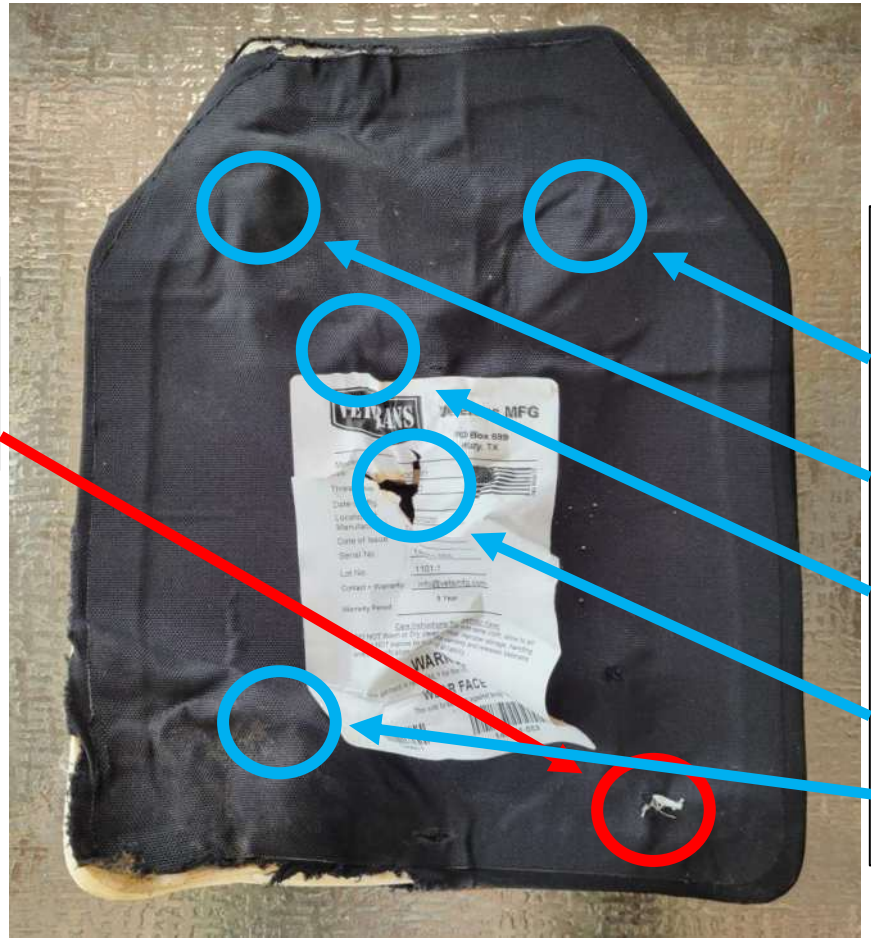
LAW ENFORCEMENT / MILITARY ONLY

VETERANS MFG 3A 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

LAW ENFORCEMENT / MILITARY ONLY

VETERANS MFG 3A SOFT

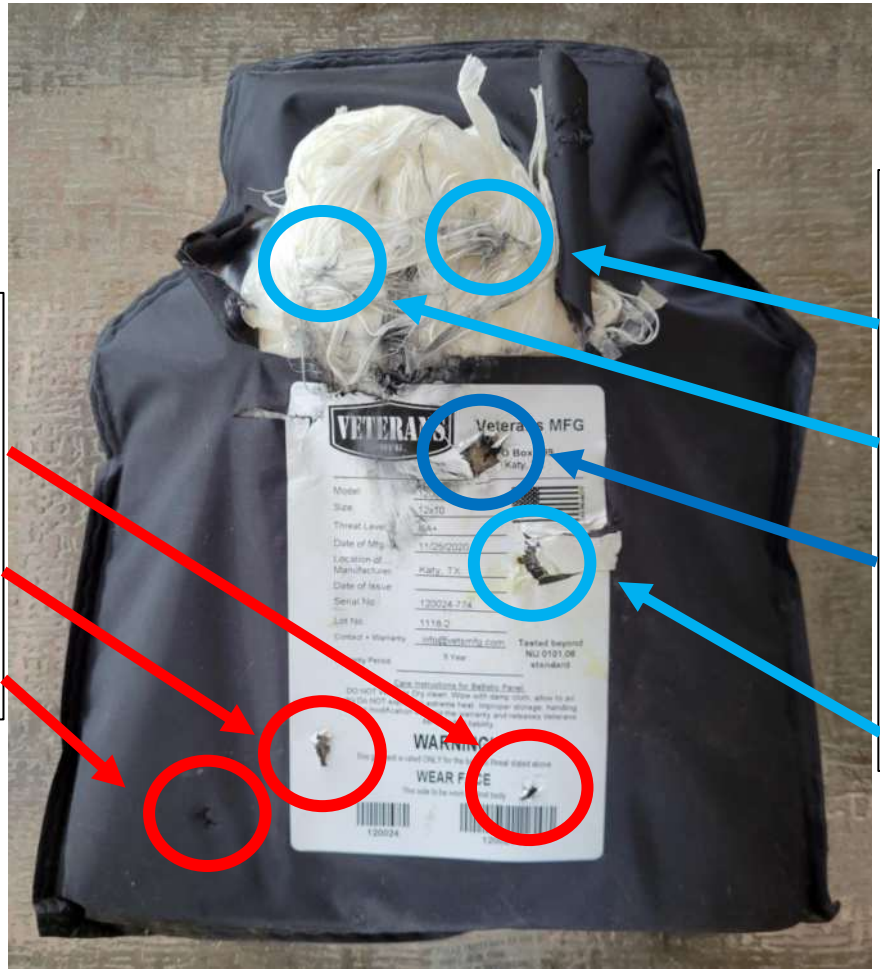
(All Shots with FN 5.7 pistol)

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

LAW ENFORCEMENT / MILITARY ONLY

SHOTSTOP 3A SOFT

(All Shots with FN 5.7 pistol)

PENETRATIONS

Vanguard BDF LE

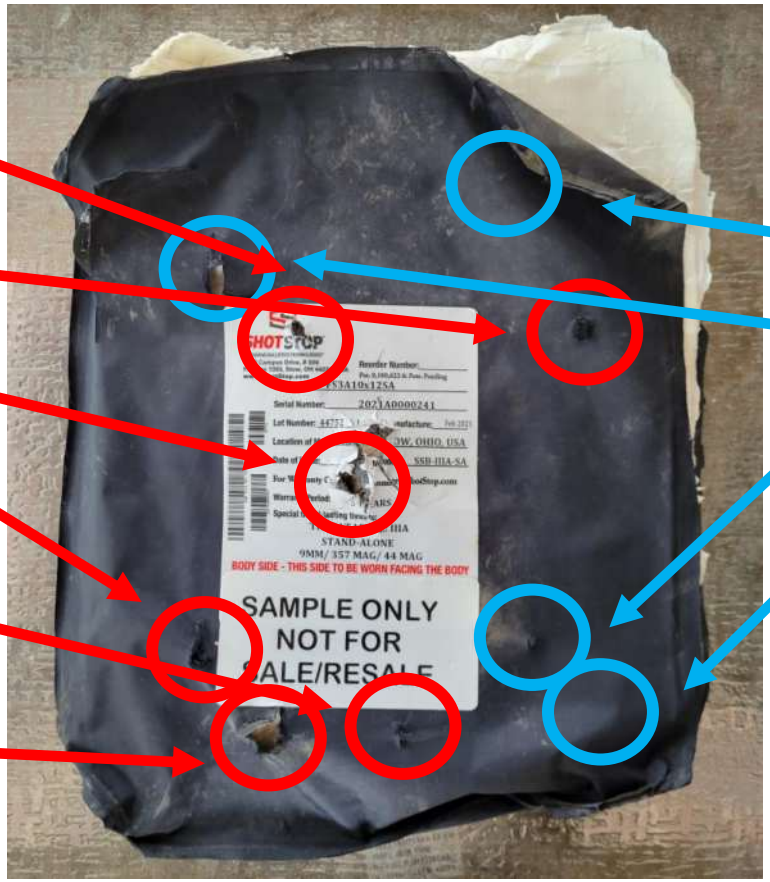
Vanguard BDF HVP LE

Elite Devastator

Elite T6

FN SS190

Vanguard Black Fang



STOPPED BY ARMOR

FN SS195

FN SS198

Elite S4

Speer Gold Dot HP

LAW ENFORCEMENT / MILITARY ONLY

SHOTSTOP 3A CLIPBOARD

(All Shots with FN 5.7 pistol)

PENETRATIONS

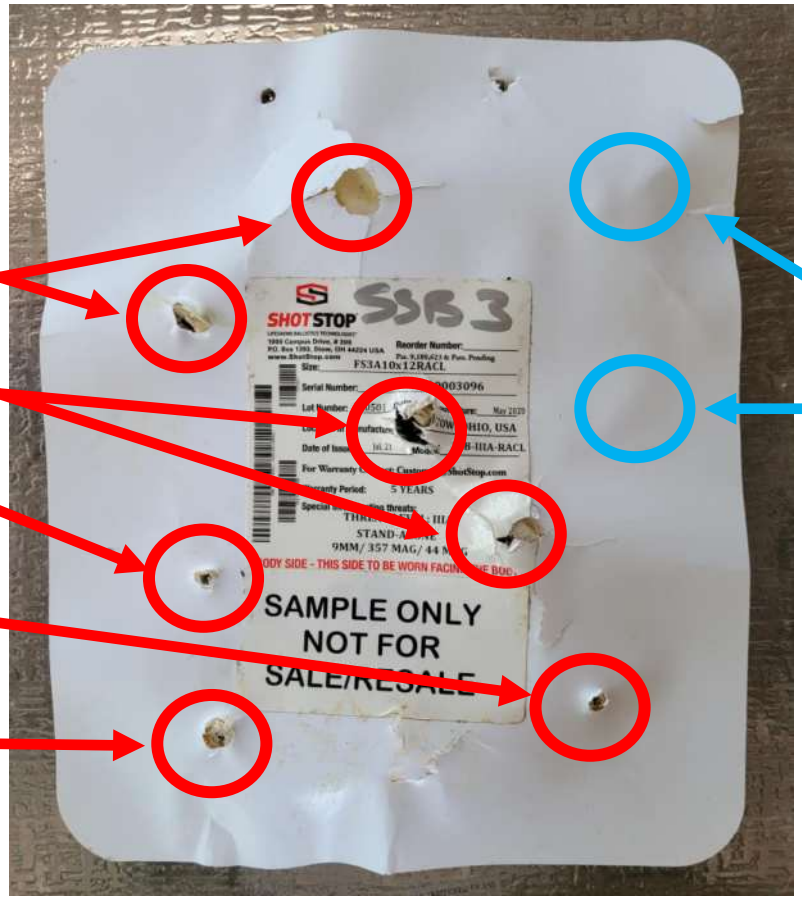
FN SS198

Elite S4

Elite T6

FN SS190

Vanguard Black Fang



STOPPED BY ARMOR

FN SS195

Speer Gold Dot HP

LAW ENFORCEMENT / MILITARY ONLY

SHOTSTOP 3 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

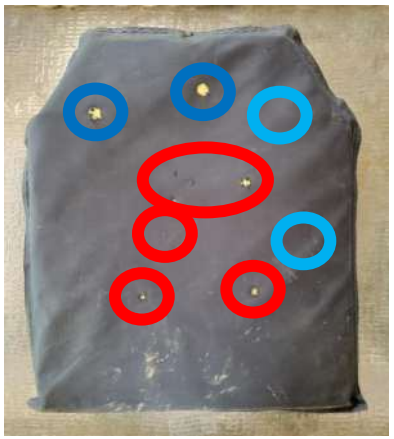
Elite T6

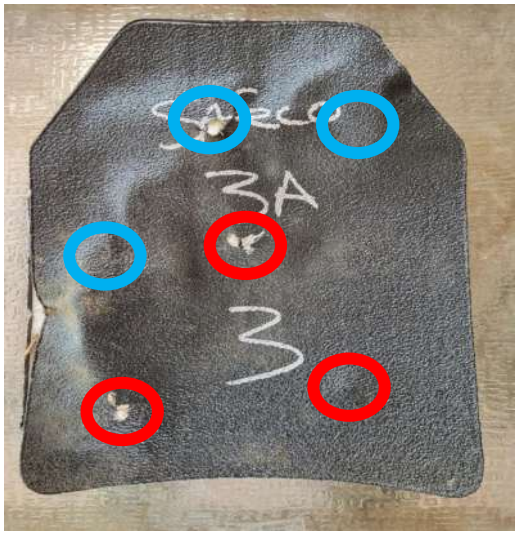
FN SS190

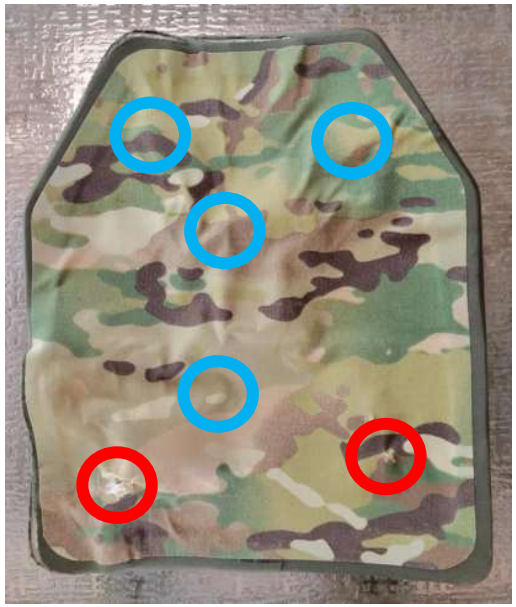
Vanguard Black Fang

LAW ENFORCEMENT / MILITARY ONLY

5.7mm LE/Mil Armor Test







LAW ENFORCEMENT / MILITARY ONLY

ACKNOWLEDGEMENTS

This report is 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, NASA, Marshalls, and multiple state DPS's and local police, sheriff and constables' offices, a local gun store and two training schools. One local grocery store chain gave a great discount on the brisket 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.

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 that provides all of our gunsmithing and Slick Shot Gun Lubricants that provides us with all our training gun grease, oil and cleaning solvents and Triple T Holsters.

Also, 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 reviewing this document, 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 on multiple realistic media.

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