2016/17

JOINT AGENCY

BALLISTICS TEST FOR DEFENSIVE HANDGUN AMMUNITION

FOR AGENCY / LAW ENFORCEMENT

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TABLE OF CONTENTS

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FORWARD

The 2016/17 Joint Agency Ballistic Test For Defensive Handgun Ammunition was conducted by several Federal, State and Local government agencies as well as security teams, contractors and ballistics experts. It is being hosted by a private training company and includes testers and experts from these multiple agencies. The training company ensured continuity, consistency and accuracy of all tests and generated the final report for all involved.

This report brings together the most credible information regarding wound ballistics. It combines the knowledge and results of previous federal wound ballistics tests, verifies those results and uses medically recommended animal tissue media to create new relevant realistic data. The comparison of effective handgun ammunition for federal, state and local agencies is critical and complex. Representative data of a real target is needed for instruction and selection. The individual shot data produced during this test has all been measured and recorded and is included in the full agency/LE version of the report. A set of compilation data sheets is also included to better compare shot results and averages.

No conclusions or choices have been made and none will be included in this report. The test was conducted only to produce and record raw data and describe rounds in regards to four wound ballistics characteristics. Any agency wishing to use this report and the data to make conclusions must first understand their needs and be able to quantify their requirements using the four characteristics described herein.

Data from rounds failing to function as designed on target were not thrown out as has been done in other familiar tests. Any ammunition failures in the weapon or failure to fire were recorded but are not described in this report. The only failures included were wound ballistics failures to function on target.

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TACTICAL REALITIES

There are four main subjects involved in stopping power. Shot placement (wound placement), amount of shots, bullet capability (wound ballistic profile) and the target being shot.

Proper wound placement is the most important determinant to stopping/ incapacitating a human target. However, shot placement is NOT wound placement and where a shot hits the target does not always determine the path of the bullet through the target due to barriers (clothes, bones and outside items) and bullet performance/failures. 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.

Amount of hits on target is critical and any agency considering choosing a new weapon, caliber or ammunition should certainly take into account how many rounds the weapon contains, recoil and ease of follow up shots and lastly the weight of the weapon and ammunition to be carried.

Bullet capability, which is the wound ballistic profile of that type of ammunition is what was measured and documented in this test. It quantifies the performance of a single round in regards to four wound ballistics characteristics. Penetration Depth, Reliability/Consistency, Barrier Performance and Permanent Wound Cavity (PWC).

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.

MECHANICS OF PROJECTILE WOUNDING

There are four components to projectile wounding.

1. Penetration. The overall distance traveled by the bullet through the selected media. All agencies that took part in this test agreed that Penetration is the most important component of projectile wounding.
2. Permanent Wound Cavity (PWC). The volume measured in cubic inches of the space created by the bullet after it goes through the media. This is the destroyed part of the target. It is calculated by multiplying the depth (penetration) of the wound and the area (not diameter) of the hole left by the passage of the bullet. The area is extremely difficult to measure in the case of fragmenting rounds with multiple projectiles, solid copper rounds which create holes larger than their caliber and tumbling bullets that have holes that vary greatly at different depths.
3. Temporary Stretch Cavity. The expansion and temporary displacement of media or tissue due to the transfer of kinetic energy to the target. This stretch cavity only causes wounding in high velocity rounds greater than 2,000 feet per second (fps) and for all rounds that do not exceed that velocity inside of the target does not contribute at all to any wounding effects or incapacitation. The displaced tissue is not destroyed and in most cases is not even damaged. Most human tissue (other than brain and liver tissue) can be stretched as much as 6 times its normal size before overexpansion and tearing occurs. Also, human tissue can expand extremely rapidly and outward force caused by the kinetic energy transfer is typically <15% of the velocity of the projectile causing the displacement. Exceeding roughly 2,000 fps causes an outward force velocity exceeding the maximum rate of expansion for most human tissue which in turn causes a tearing wound. Since none of the rounds tested exceeded 2,000 fps inside of the target by even 10%, temporary stretch cavity caused minimal damage and therefore was not to be considered of any importance. High speed (>3,000 fps) rifle rounds were tested at some events and the animal tissue media was dissected and showed tearing which was never present in any of the handgun rounds <2,000 fps further confirming that Temporary Stretch Cavity has no effect on wounding a target with <2,000 fps projectiles. Unfortunately it is still used by non-experts during assessment.

4. Fragmentation. Projectile pieces or secondary fragments of bone or other barrier. Each fragment path must be included in the calculation of the PWC. Fragmentation occurs either intentionally by the use of frangible or pre-fragmented rounds or accidentally by the breaking apart of the projectile. Frangible rounds tend to create large wound cavity areas but shallow wound penetration. The overall Permanent Wound Cavity (PWC) is generally less than a non-fragmenting round due to the smaller mass of each fragment, larger surface area after fragmentation resulting in greatly increased drag. 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 CNS tissue does little in the way of incapacitation. This is why all agencies that took part in this test agreed that Penetration is the most important characteristic of projectile wounding. Given that the FBI and DoD protocols call for a minimum gel penetration of 12 inches with a goal of around 18 inches, low penetrating fragmenting rounds did not qualify by exhibiting any reasonable penetration depths. Accidental fragmentation takes place in a higher percentage of time with hollow point ammunition than with Full Metal Jacket (FMJ) or solid copper rounds. Two distinct characteristics increase accidental fragmentation with hollow points.
    a. Velocity. Rounds traveling at over 1,200 fps had an alarmingly higher rate of accidental fragmentation in this test. Rounds below 1,100 fps had a relatively low fragmentation rate. Between 1,100-1,200 fps the rate was abnormally high but not as catastrophic as over 1,200 fps.
    b. 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.

    These two characteristics which cause accidental fragmentation greatly reduced the penetration, consistency, reliability, barrier performance and overall Permanent Wound Cavity size. In the cases where accidental fragmentation occurred the pieces were generally very close to the PWC which limited additional wounding effects.

Projectiles incapacitate by destroying or seriously damaging Central Nervous System (CNS) tissue, causing organ failure or causing blood loss. All projectile wounds combine the above four components to a greater or lesser degree.

THE 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. Skin is extremely strong. The resistance of skin to projectile penetration is equal to about 3-4 inches of IWBA calibrated ballistics gelatin.
2. Nervous. Thin nerve tissue which constitutes the smallest percentage of human tissue.
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 was used in 2 phases of this test as a consistent barrier IAW IWBA standards.
4. Muscular. Made up mostly of muscle tissue and of most internal organs. It is the most common type of human tissue in the thoracic cavity which is the target area or center of mass. In this test during phase 4 and phase 5 we used multiple standard size beef briskets to as closely as possible consistently replicate human muscular tissue.

The average human male is 10" thick. Most human tissue is elastic. Organs, skin, muscle, intestines and blood vessels are capable of substantial stretching with minimal damage. Medical and military studies have shown that the outward velocity of tissue caused by the temporary stretch cavity is between 8-15% of the velocity of the projectile at the depth the stretch is created. Furthermore in these studies it was shown that human muscular tissue (other than brain or liver tissue) can stretch much faster than that velocity. Also, the distance created by the stretch cavity does not exceed the capability of the muscular tissue to stretch without tearing. At greater than around 2,000 fps it was tested, seen and measured that our test tissue did show signs of over-stretching and damage. This was noted on the rounds that were extremely high speed at impact (>2,000 fps). It was difficult to measure but is a contributing factor to overall wounding.

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. Even shots to the heart are not immediate as stored oxygen may allow for voluntary action for 5-15 seconds after functional heart destruction. 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. Important tissue destruction equals stopping power.

Common "One Shot Stop" and "Knock Down Power" are both myths perpetuated by the uninformed. The actual impact of the projectile onto a target is less than the recoil of the weapon.

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 rounds <2,000 fps to cause any damage except for brain and liver tissue. Secondly, the human body can absorb a great amount of energy without being damaged. Thirdly, 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.

We must also discuss Energy vs Momentum. During this test and the 6 other major federal handgun ballistics tests it was conclusively found that the heaviest bullets in each caliber average larger Permanent Wound Cavities (PWC) than lighter bullets in the same caliber. Using hollow points as the example because they were the only type of rounds tested in the aforementioned 6 tests, there were 6, 7, 3, 6, 6, 5 and 5 calibers tested in each of the 7 tests, to include ours. The 9mm and 45 ACP were the most common tested rounds and were tested in each of the 7 tests. The 40S&W was tested in 6 of the tests. In 6 of 7 tests the heaviest 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) bullets averaged the largest PWC over any other weight 45. In all cases the heavier bullets in any caliber have less energy than the lite weight bullets in that caliber that have the highest energy.

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 <u>energy calculations have no bearing or indicators to bullet performance.</u> Otherwise the fastest bullets in any particular weight/caliber would be the best and that simply isn't true.

True bullet performance must be measured in a consistent media. Realistic animal tissue media yields better analysis to real world shootings. Mathematical calculations without shooting are not tests and have no bearing on reality.

AMMUNITION SELECTION CRITERIA

Four types of ammunition were tested.

1. Hollow Point. The most common defensive ammunition used by all the agencies that took part in this test. These rounds are intended to expand to increase the frontal area of the projectile. This will create a larger diameter wound and also increase drag which limits penetration depth as compared to a FMJ.
2. Full Metal Jacket (FMJ). The second most common ammunition used by all the agencies that took part in this test. This is also the most widely used training or practice ammunition. They create deeper wounds of less diameter.
3. Solid Copper. These rounds have the most varied designs. Some performed extremely well, while others were simply gimmicks. Some of them behave similar to hollow points, while others are non-expanding, their designed destructive mechanism varied greatly between bullets.
4. Frangible. These rounds are designed to break apart and fragment upon striking a target either immediately at the surface or after minimal penetration. They are designed to create large diameter wounds that do not penetrate deep. In all cases these rounds did not penetrate the required 12 inches of ballistics gel, except for some cores. If your agency requires minimal penetration or absolute barrier failure than these rounds are designed for that task. Some have an extremely high reliability rate and consistently break apart on contact and should be considered. Other frangible rounds were less consistent and sometimes failed to break apart during barrier and tissue tests and should be avoided. Since this test was concerned with defensive ammunition and all agencies that took part in the test agreed that > 12 inches penetration in IWBA ballistics gel is a requirement and the most important characteristic in determining projectile effectiveness, frangible rounds were superficially tested.

Prior to the beginning of the test all the agencies involved listed what they believed were the most important characteristics in wound ballistics. The unanimous most critical component of projectile wounding is Penetration. After that a combination of reliability, consistency, barrier performance and overall Permanent Wound Cavity were listed and were generally thought to be of equal importance. If your agency

believes in putting these characteristics in 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 using these characteristics separately so each agency can use the criteria best suited for their purposes.

A bullet must penetrate deep enough to pass through and destroy vital organ tissue. This must be accomplished from different target body angles and through common barriers such as clothes and bone. Side shots through an arm must penetrate greater than 10 inches to contact the heart and frontal shots must penetrate at least 7 inches to reach the back of the abdominal cavity. These above figures ARE NOT ballistics gel depths, but rather human tissue penetration depths. All of the agencies in this test require a minimum of 12 inches of penetration in ballistics gel. Some of the agencies involved desire 15-18 inches and other agencies desired 18 inches $\pm$10% (16-20 inches) of overall calibrated ballistics gel penetration. With the desired 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 frontal area change (Area = л x Radius squared).

The Over-Penetration Myth:

Fear that a bullet will pass through a target body and damage a bystander are unfounded. First, approximately 40% of all shots fired in the day do not hit any target at all and even less bullets hit the target at night. That's cause for real concern. Secondly, shots passing through the target torso do not have sufficient remaining penetration capabilities. Lastly, there haven't been any cases where this has actually happened. No recorded medical reports or lawsuits come from a bystander wounding resulting from over-penetrating handgun bullets through the torso of a target. For the purposes of this test we used International Wound Ballistics Association (IWBA) 18x6x6 inch calibrated gel blocks with a sideways block backstop providing an overall maximum measured depth of 24 inches. Only Full Metal Jacket rounds and rounds that failed exceeded penetrating that depth.

PREVIOUS TESTS

There have been several large scale reliable Wound Ballistics tests. This is the first large scale multi agency test to accomplish two items.

1. The testing of four different types of defensive ammunition instead of only testing hollow points.
2. The use in two of the five 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 this test being started 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 federal 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. BR is calculated separately for each test. All rounds in a test have a PWC calculated in cubic inch volume. 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. 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.

Largest average PWC 9mm by grain has a BR of 1.0

Raw data comparisons from different tests between rounds or calibers cannot be used do to inconsistencies in media. 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

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

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

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 example the 147 grain 9mm with an average PWC of 3.0 cu inches is 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).

Six large scale tests from US Federal Government agencies and independent organizations have been completed prior to this test. Each of the six 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.

SIX PRIOR TEST RESULT OBSERVATIONS:

All caliber Ballistic Ratios were fairly consistent across all 6 tests (All within 5%)

The average 147 grain 9mm won 5 of 6 competitions for Best 9mm PWC size

The average 230 grain 45ACP won all 6 competitions for best 45ACP

The 45ACP won all 6 competitions for largest average PWC between all calibers

As stated earlier only the 9mm and 45ACP were in all 6 tests. The Ballistic ratios shown below are the average for that caliber regardless of how many tests that caliber was included in.

CALIBER	6 TEST BALLISTIC RATIO (BR) AVERAGE
45ACP	1.5
10mm	1.3
40SW	1.22
.357SIG	1.1
9mm	1.0
.357 Mag	.98
.38 Spl	.79
.380	.48

NOTE: In three of the six tests, rounds which failed on target due to failure to expand and accidental fragmentation were included. The 10mm, 357 SIG and 357 Mag had an extremely high failure rate due to excessive velocity. This was also verified in our test. That is why the BR for those calibers is so low. In the other three 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 results question whether the failures were included.

Our ballistics gel test results were compared to each of the above mentioned tests and the results were all very consistent (within 5%-10% for each caliber in each test). Our duplicated results validated the other tests which in turn validated our testing process.

If any agency would like a copy of our "Federal Tests of Pistol Hollow Points" 6 test comparison report, please let us know and we will provide the Power Point presentation with all of the data.

TEST PROTOCOLS, PHASES AND GRADING CRITERIA

PURPOSE:

The 2016/17 Joint Agency Ballistic test is being conducted to compare defensive handgun ammunition. Six defensive calibers will be included. All four bullet types will be included.

It will be conducted in 5 separate phases.

It will be graded using 4 criteria.

No conclusions or selections shall be made.

Raw data will be averaged and may be used independently depending on the criteria desired by each receiving agency.

AMMUNITION TYPES:

The 2016/17 Ballistic test will compare all types of defensive ammunition

It will include not only Hollow Points (HP) like the preceding federal tests. Round types will include:

Hollow Points

Full Metal Jacket (FMJ)

Solid Copper

Frangible

Six defensive calibers will be included. 9mm, 357 Sig, .40, 10mm, .45 and 5.7mm

PROTOCOLS:

We have several federal, state and local agencies, contractors and weapons instructors involved. All phases and tests were conducted with at least 1 cameraman, one chief tester and one assistant for quality control and multiple measurements. No averages will be provided unless at least 4 rounds fired per phase for all rounds that pass each phase. All failures to function are included in the data with no "flyers" or failures being removed.

At the conclusion of the entire test a report will be available for all agencies. A sanitized civilian report will be made available but with the participant information removed. A PowerPoint brief will also be created for agency use to aid in selection, training and instruction.
A few videos of individual tests are being published by the civilian side of the test, but an overall video will not be made.

ALTERNATE TESTING:

Testing will take place at multiple facilities.

If test team members are present and can certify the authenticity of the media, ammunition, weapons and raw data then it will be included in the overall test report.

If any of the above cannot be validated then that particular test will be used only as a control and verification of results but the raw data will not be included in the test report.

This will take place when individual agencies want to conduct a test to compare their chosen rounds and to validate our test. If test team members are present and verify the test then that data will be included, otherwise the data will only be for the testing agencies use.

5 PHASES:

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

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 Overall Penetration Depth. FBI standard 12" minimum and 18" desired. Rounds not meeting the minimum will be annotated and may not remain in the test for the remaining phases.

Measuring Reliability and Consistency.

Measuring Overall PWC. Measured in cubic inch volume.

3. IWBA Calibrated FBI 10% ordnance gelatin with a single ¾ inch thick AA fir plywood panel IAW FBI / DoD protocols and a standard denim barrier. All rounds fired at least 4 times into media. Recovered rounds inspected for failures, retained weight and overall dimensions.

Measuring Overall Penetration Depth

Measuring Reliability, Consistency and Barrier Performance

Measuring Overall PWC. Measured in cubic inch volume.

4. Animal Tissue with a standard denim barrier. All rounds fired at least 4 times into Animal Tissue with a denim barrier. Rounds not recovered.

Measuring Overall Wound dimensions. Exit wound channels from each of the two briskets measured for min and max diameter then averaged. Average diameter converted to area and recorded.

Measuring Reliability and Consistency.

5. Animal Tissue with a single ¾ inch thick AA fir plywood panel and a standard denim barrier. All rounds fired at least 4 times. Rounds not recovered.

Measuring Overall Wound dimensions. Exit wound channels from each of the two briskets measured for min and max diameter then averaged. Average diameter converted to area and recorded.

Measuring Reliability, Consistency and Barrier Performance

MEDIA:

IWBA Calibrated FBI 10% ordnance gelatin. Proper recipe, temperature and BB depth calibration immediately prior to shot.

Single ¾ inch thick AA fir plywood panel IAW FBI / DoD protocols

Denim barrier consists of layers of standardized material

Animal Tissue consists of 2 boneless hanging briskets
7-8" thick. (Average human male is 10" thick)
36±2 pounds. Fat side out, back to back. Point side up on one and down on the other to provide equal thickness.

Animal Tissue consisting of 2 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, epithelial, connective and nervous. Cow brisket closely represents human muscle tissue and organs. It is a compressible realistic consistent media.

Media Problems:

IWBA Calibrated FBI 10% ordnance gelatin- Gel was originally used because it is consistent and easy to use/measure. It allowed a comparative study to take place with replicable results. Never advertised or designed to be a simulation of any human or animal tissue. Gel is a fluid and is non-compressible unlike human material. Temporary Stretch Cavity does not represent any damaged or destroyed material. Although density and resistance is similar to human tissue gels inability to be compressed makes it an extremely poor tissue simulant as hydraulic effects in gel are completely different than in animal tissue or a human target. This required a new more realistic media to be used. Our Phase 4/5 used actual animal tissue to make up for the deficiencies in using only gel and getting artificial results. This was never a problem in hollow point testing as recovered bullet diameter equaled gel wound diameter which is similar to results in actual tissue. With rounds that tumble or cause compression gel results are very artificial and were very different from actual tissue tests or medical reports post shooting.

4 GRADING CRITERIA:

1. Penetration using Phase 2 data for a desired 18” and a minimum of 12”.
2. Reliability and Consistency. Failure to perform as designed (Failure to open/tumble, fragmentation and jacket separation) will be noted and included in the data. Standard Deviation for each shot tested within a Phase.
3. Barrier Performance. Percent of penetration and PWC size lost from non-barrier shots to barrier shots from Phase 2/3 and Phase 4/5.
4. Permanent Wound Cavity. Measured in cubic inches for the Ballistics gel tests of Phase 2/3. Measured as average hole area from Phase 4/5.

RESULTS / REPORTS:

The 2016/17 Joint Agency Ballistic Test will document and report all raw data from each shot in each phase. Averages will be calculated and reported.

Please note data in Phase 2/3 is:

1. Penetration in inches.
2. Diameter of the wound.
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.

No conclusions, rank ordering or choosing will be accomplished. All data will be 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.

A government / manufacturer report will be produced and sent to all participants and requestors. Pictures, videos and Power Point presentation of certain tests are available for any agency upon request.

A condensed report will be made available to the public scrubbed of any test team names and agencies.

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.

PHASE 1

All rounds fired at least 4 times chronographed and averaged. Testing advertised box velocity vs. actual tested average velocity, consistency and reliability. Table also includes description of which pistols were used for all of the phases.

CALIBER	ROUND	BOX VEL	PISTOL	AV VEL
9mm	Winchester FMJ 124 gr	1140	Sig P 226 / Glock 17	1140
	Winchester Ranger T 147 gr	990	Glock 17	1000
	Remington GS +P 124 gr	1180	Glock 17	1170
	Remington GS 147 gr	990	Glock 17	980
	Speer GD +P 124 gr	1220	Glock 17	1200
	CorBon +P 115 gr	1350	Glock 17	1300
	Hornady C Duty +P 135 gr	1115	Glock 17	1120
	Sig Sauer V 124 gr	1165	Sig P 226 / Glock 17	1150
	Federal HST 147 gr	1000	Sig P 226 / Glock 17	1005
	Fort Scott 80 gr	1350	Sig P 226 / Glock 17	1405
	OATH Tango 110 gr	1200	Glock 17	1150
	Underwood XD 90 gr	1400	Sig P 226 / Glock 17	1480
	Underwood XD +P 90 gr	1475	Sig P 226 / Glock 17	1505
	Underwood XD +P+ 90 gr	1550	Sig P 226 / Glock 17	1585
	Underwood Max Exp 105 gr	1175	Glock 17	1160
	Glaser Blue +P 80 gr	1500	Glock 17	1465
	G2 RIP 92 gr	1265	Glock 17	1295
357 SIG	Winchester FMJ 125 gr	1350	Glock 22 conv barl	1370
	Speer GD 125 gr	1350	Glock 22 conv barl	1385
	Sig Sauer V 125 gr	1356	Glock 22 conv barl	1375
	Federal HST 125 gr	1360	Glock 22 conv barl	1375
	Underwood XD 65 gr	2100	Glock 22 conv barl	2060
	Underwood XD 90 gr	1700	Glock 22 conv barl	1690
40 S&W	Winchester FMJ 180 gr	1020	Glock 22	1005
	Winchester Ranger T 180 gr	990	Glock 22	1000
	Remington GS 165 gr	1150	Glock 22	1145
	Remington GS 180 gr	1015	Glock 22	1020
	Speer GD 165 gr	1050	Glock 22	1060
	Hornady C Duty 175 gr	1010	Glock 22	1020
	Sig Sauer V 165 gr	1090	Glock 22	1070
	Federal HST 180 gr	1000	Glock 22	1000
	Fort Scott 125 g	1320	Glock 22	1290
	OATH Tango 125 gr	1250	Glock 22	1225
	Underwood XD 115 gr	1400	Glock 22	1425
	Underwood Max Exp 140 gr	1050	Glock 22	1060
	Glaser Blue 115 gr	1400	Glock 22	1355
	G2 RIP 115 gr	1080	Glock 22	1100

PHASE 1

CALIBER	ROUND	BOX VEL	PISTOL	AV VEL
10mm	Winchester FMJ 200 gr	1050	Glock 20	1020
	Winchester SX 175 gr	1290	Glock 20	1300
	Hornady C Duty 175 gr	1160	Glock 20	1180
	Sig Sauer 180 gr	1250	Glock 20	1200
	Federal Hydra Shok 180 gr	1030	Glock 20	1005
	Underwood XD 115 gr	1700	Glock 20	1750
45 ACP	Winchester FMJ 230 gr	835	Sig P227E / Glock 21	865
	Winchester Ranger T 230 gr	880	Glock 21	910
	Remington GS 185 gr	1140	Glock 21	1115
	Speer Gold Dot 230 gr	890	Glock 21	810
	Hornady C Duty +P 220 gr	975	Glock 21	960
	Sig Sauer V 230 gr	830	Glock 21	850
	Federal Hydra Shok 230 gr	900	Sig P227E / Glock 21	860
	Federal HST +P 230 gr	950	Sig P227E / Glock 21	950
	Fort Scott 180 gr	989	Glock 21	1000
	OATH Tango 163 gr	1100	Glock 21	1105
	Underwood XD 120 gr	1320	Sig P227E / Glock 21	1400
	Underwood XD +P 120 gr	1420	Sig P227E / Glock 21	1460
	Underwood XD Super 120 gr	1600	Sig P227E / Glock 21	1550
	Underwood Max Exp 174 gr	1050	Glock 21	1035
	Glasr Blue +P 145 gr	1350	Glock 21	1330
	G2 RIP 162 gr	960	Glock 21	995
5.7mm	American Eagle 40 gr	1655	FN 5.7	1575
	SS195LF 28 gr	2000	FN 5.7	1900
	SS197SR 40 gr	1700	FN 5.7	1620
	SS198LF 28gr	2150	FN 5.7	2050
	Elite S4M 28gr	2650	FN 5.7	2410
	Elite T6B 28 gr	2570	FN 5.7	2230
	Elite PenetraTOR 40 gr	1900	FN 5.7	1905
	Elite ProtecTOR 40 gr	2100	FN 5.7	1910
	Elite DevastaTOR 37 gr		FN 5.7	2005
	Vanguard Black Fang 34 gr	2150	FN 5.7	2130
	Vanguard Barnes 50 gr HP	1725	FN 5.7	1590
	Vanguard Comb Tech 50 gr		FN 5.7	1635

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.

CALIBER	ROUND	PENETRAION	DIAMETER	PWC
9mm	Winchester FMJ 124 gr	24+	.37	2.6 ci
	Winchester Ranger T 147 gr	14.5	.63	4.5 ci
	Remington GS +P 124 gr	13	.58	3.5 ci
	Remington GS 147 gr	17	.55	4.0 ci
	Speer GD +P 124 gr	15.3	.51	4.0 ci
	CorBon +P 115 gr	9.5	.57	2.5 ci
	Hornady C Duty +P 135 gr	14.5	.52	3.1 ci
	Sig Sauer V 124 gr	13.8	.55	3.3 ci
	Federal HST 147 gr	15.2	.57	3.9 ci
	Fort Scott 80 gr	19.5	.42	2.7 ci
	OATH Tango 110 gr	5.25	.85	3.0 ci
	Underwood XD 90 gr	16	.76	7.2 ci
	Underwood XD +P 90 gr	16.75	.87	9.9 ci
	Underwood XD +P+ 90 gr	17.5	.95	12.4 ci
	Underwood Max Exp 105 gr	10.25	.8	5.1 ci
	Glaser Blue +P 80 gr	6	Unable to measure	
	G2 RIP 92 gr	4 trocars/14 core	.39 core	2.1 ci
357 SIG	Winchester FMJ 125 gr	24+	.38	2.7 ci
	Speer GD 125 gr	17.6	.57	4.5 ci
	Sig Sauer V 125 gr	17	.6	4.8 ci
	Federal HST 125 gr	17.2	.61	5.0 ci
	Underwood XD 65 gr	17.5	1.0	13.7 ci
	Underwood XD 90 gr	18.3	1.0	14.4 ci
40 S&W	Winchester FMJ 180 gr	24+	.43	3.5 ci
	Winchester Ranger T 180 gr	13.5	.68	4.9 ci
	Remington GS 165 gr	15.5	.46	4.6 ci
	Remington GS 180 gr	17.2	.61	5.0 ci
	Speer GD 165 gr	14.3	.67	5.0 ci
	Hornady C Duty 175 gr	17.9	.61	5.2 ci
	Sig Sauer V 165 gr	16	.64	5.1 ci
	Federal HST 180 gr	18	.6	5.2 ci
	Fort Scott 125 g	22	.48	4.0 ci
	OATH Tango 125 gr	7.75	.85	4.4 ci
	Underwood XD 115 gr	18.5	.9	11.8 ci
	Underwood Max Exp 140 gr	8.5	.95	6.0 ci
	Glaser Blue 115 gr	7	Unable to measure	
	G2 RIP 115 gr	5 trocars/11.5 core	.45 core	2.6 ci

PHASE 2

CALIBER	ROUND	PENETRATION	DIAMETER	PWC
10mm	Winchester FMJ 200 gr	24+	.45	3.8 ci
	Winchester SX 175 gr	14.8	.66	5.2 ci
	Hornady C Duty 175 gr	22	.55	5.2 ci
	Sig Sauer 180 gr	16	.64	5.1 ci
	Federal Hydra Shok 180 gr	16.6	.65	5.5 ci
	Underwood XD 115 gr	19.3	1.02	15.7 ci
45 ACP	Winchester FMJ 230 gr	24+	.47	4.2 ci
	Winchester Ranger T 230 gr	16.5	.66	5.7 ci
	Remington GS 185 gr	15.1	.72	6.1 ci
	Speer Gold Dot 230 gr	17.5	.64	5.6 ci
	Hornady C Duty +P 220 gr	16	.7	.62 ci
	Sig Sauer V 230 gr	15.1	.73	6.3 ci
	Federal Hydra Shok 230 gr	15	.71	6.0 ci
	Federal HST +P 230 gr	15.5	.72	6.3 ci
	Fort Scott 180 gr	24+	.5	4.7 ci
	OATH Tango 163 gr	9	.9	5.7 ci
	Underwood XD 120 gr	18.5	.85	10.5 ci
	Underwood XD +P 120 gr	19	.9	12.0 ci
	Underwood XD Super 120 gr	20	.98	15.1 ci
	Underwood Max Exp 174 gr	9	1.2	10.2 ci
	Glaser Blue +P 145 gr	7.25	Unable to measure	
	G2 RIP 162 gr	4.5 trocars/16 core	.49 core	3.8 ci
5.7mm	American Eagle 40 gr	12.5	Unable to measure accurately due to tumbling, compression and intentional fragmentation in some cases. Reference Phase 4/5 data for wound dimensions.	
	SS195LF 28 gr	8.9		
	SS197SR 40 gr	14		
	SS198LF 28gr	10		
	Elite S4M 28gr	12.3		
	Elite T6B 28 gr	15.2		
	Elite PenetraTOR 40 gr	17.2		
	Elite ProtecTOR 40 gr	16.5		
	Elite DevastaTOR 37 gr	18.5		
	Vanguard Black Fang 34 gr	19		
	Vanguard Barnes 50 gr HP	16.8		
	Vanguard Comb Tech 50 gr	17		

PHASE 3

All rounds fired ≥ 4 times into IWBA Calibrated FBI 10% ordnance gelatin with a single ¾ inch thick AA fir plywood panel and a standard denim barrier. Recovered rounds inspected for failures, retained weight and overall dimensions.

CALIBER	ROUND	PENETRAION	DIAMETER	PWC
9mm	Winchester FMJ 124 gr	24+	.38	2.7 ci
	Winchester Ranger T 147 gr	16	.4	2.0 ci
	Remington GS +P 124 gr	12	.5	2.4 ci
	Remington GS 147 gr	16	.5	3.1 ci
	Speer GD +P 124 gr	14	.44	2.1 ci
	CorBon +P 115 gr	7	.5	1.4 ci
	Hornady C Duty +P 135 gr	13.5	.5	2.7 ci
	Sig Sauer V 124 gr	16.5	.42	2.3 ci
	Federal HST 147 gr	15.5	.52	3.3 ci
	Fort Scott 80 gr	18.6	.42	2.6 ci
	OATH Tango 110 gr	4.75	.78	2.3 ci
	Underwood XD 90 gr	15.2	.7	5.8 ci
	Underwood XD +P 90 gr	16	.83	8.5 ci
	Underwood XD +P+ 90 gr	16.6	.93	11.3 ci
	Underwood Max Exp 105 gr	11	.72	4.48 ci
	Glaser Blue +P 80 gr	5.5	Unable to measure	
	G2 RIP 92 gr	3.5 trocars/12.5 core	.38	1.8 ci
357 SIG	Winchester FMJ 125 gr	24+	.37	2.6 ci
	Speer GD 125 gr	14.8	.48	2.7 ci
	Sig Sauer V 125 gr	22	.4	2.7 ci
	Federal HST 125 gr	20	.44	3.0 ci
	Underwood XD 65 gr	16.5	.98	12.5 ci
	Underwood XD 90 gr	17.4	1.0	13.7 ci
40 S&W	Winchester FMJ 180 gr	24+	.43	3.5 ci
	Winchester Ranger T 180 gr	12.7	.64	4.1 ci
	Remington GS 165 gr	17.2	.42	2.4 ci
	Remington GS 180 gr	16.4	.55	3.9 ci
	Speer GD 165 gr	16.2	.48	2.9 ci
	Hornady C Duty 175 gr	17.2	.6	4.8 ci
	Sig Sauer V 165 gr	16.5	.58	4.4 ci
	Federal HST 180 gr	17.6	.57	4.5 ci
	Fort Scott 125 g	20.8	.46	3.5 ci
	OATH Tango 125 gr	6.75	.8	4.2 ci
	Underwood XD 115 gr	18.1	.9	11.5 ci
	Underwood Max Exp 140 gr	9.5	.88	5.8 ci
	Glaser Blue 115 gr	6.5	Unable to measure	
	G2 RIP 115 gr	5 trocars/11.2 core	.44 core	2.5 ci

PHASE 3

CALIBER	ROUND	PENETRATION	DIAMETER	PWC
10mm	Winchester FMJ 200 gr	24+	0.45	3.8 ci
	Winchester SX 175 gr	18.5	0.44	2.8 ci
	Hornady C Duty 175 gr	16	0.58	4.2 ci
	Sig Sauer 180 gr	15	0.6	4.2 ci
	Federal Hydra Shok 180 gr	17.4	0.48	3.2 ci
	Underwood XD 115 gr	18.8	0.97	13.9 ci
45 ACP	Winchester FMJ 230 gr	24+	0.48	4.3 ci
	Winchester Ranger T 230 gr	15.4	0.61	4.5 ci
	Remington GS 185 gr	13.8	0.64	4.4 ci
	Speer Gold Dot 230 gr	16.5	0.62	5.0 ci
	Hornady C Duty +P 220 gr	17.2	0.66	5.9 ci
	Sig Sauer V 230 gr	16.2	0.7	6.2 ci
	Federal Hydra Shok 230 gr	17.2	0.62	5.2 ci
	Federal HST +P 230 gr	16	0.71	6.3 ci
	Fort Scott 180 gr	24+	0.48	4.3 ci
	OATH Tango 163 gr	11.25	0.75	5.0 ci
	Underwood XD 120 gr	17.6	0.8	8.8 ci
	Underwood XD +P 120 gr	18.4	0.88	11.2 ci
	Underwood XD Super 120 gr	19.2	0.95	13.6 ci
	Underwood Max Exp 174 gr	7.5	1.05	6.5 ci
	Glaser Blue +P 145 gr	7	Unable to measure	
	G2 RIP 162 gr	8.75 FTE	0.63	2.7 ci
5.7mm	American Eagle 40 gr	11.5	Unable to measure accurately due to tumbling, compression and intentional fragmentation in some cases. Reference Phase 4/5 data for wound dimensions.	
	SS195LF 28 gr	8.2		
	SS197SR 40 gr	13		
	SS198LF 28gr	9.1		
	Elite S4M 28gr	11.5		
	Elite T6B 28 gr	14.5		
	Elite PenetraTOR 40 gr	15.9		
	Elite ProtecTOR 40 gr	15.3		
	Elite DevastaTOR 37 gr	18.2		
	Vanguard Black Fang 34 gr	18.5		
	Vanguard Barnes 50 gr HP	15		
	Vanguard Comb Tech 50 gr	16.2		

PHASE 4/5

Phase 4- Animal Tissue with a standard denim barrier. See pages 16/17.
Phase 5- Animal Tissue with a single ¾ inch thick AA fir plywood panel and a standard denim barrier. Rounds not recovered.

Caliber	Round	P3 Shots	P3 Av Area	P4 Shots	P4 Av Area
9mm	Winchester FMJ 124 gr	6	.14	6	.12
	Winchester Ranger T 147 gr	5	.3	4	.25
	Remington GS +P 124 gr	4	.25	4	.17
	Remington GS 147 gr	4	.3	4	.25
	Speer GD +P 124 gr	4	.24	4	.16
	CorBon +P 115 gr	4	.3	4	.16
	Hornady C Duty +P 135 gr	4	.35	4	.31
	Sig Sauer V 124 gr	4	.4	4	.35
	Federal HST 147 gr	6	.42	4	.35
	Fort Scott 80 gr	4	.27	4	.25
	OATH Tango 110 gr	2	DNE	2	DNE
	Underwood XD 90 gr	5	.6	4	.47
	Underwood XD +P 90 gr	5	.6	4	.6
	Underwood XD +P+ 90 gr	8	.62	6	.72
	Underwood Max Exp 105 gr	2	.5	2	.41
	Glaser Blue +P 80 gr	2	DNE	2	DNE
	G2 RIP 92 gr	2	.15	2	.13
357 SIG	Winchester FMJ 125 gr	6	.15	6	.15
	Speer GD 125 gr	4	.28	6	.16
	Sig Sauer V 125 gr	4	.44	4	.32
	Federal HST 125 gr	6	.5	6	.4
	Underwood XD 65 gr	4	.78	4	.71
	Underwood XD 90 gr	8	.78	6	.68
40 S&W	Winchester FMJ 180 gr	8	.14	8	.16
	Winchester Ranger T 180 gr	6	.42	6	.36
	Remington GS 165 gr	4	.3	4	.2
	Remington GS 180 gr	6	.44	6	.36
	Speer GD 165 gr	4	.3	4	.24
	Hornady C Duty 175 gr	6	.4	4	.4
	Sig Sauer V 165 gr	4	.45	4	.41
	Federal HST 180 gr	6	.49	6	.43
	Fort Scott 125 g	4	.2	4	.28
	OATH Tango 125 gr	2	DNE	2	DNE
	Underwood XD 115 gr	8	.635	8	.575
	Underwood Max Exp 140 gr	2	.69	2	.58
	Glaser Blue 115 gr	2	DNE	2	DNE
	G2 RIP 115 gr	2	.2	2	DNE FTE

PHASE 4/5

Caliber	Round	P3 Shots	P3 Av Area	P4 Shots	P4 Av Area
10mm	Winchester FMJ 200 gr	8	.16	6	.16
	Winchester SX 175 gr	4	.5	4	.4
	Hornady C Duty 175 gr	4	.44	4	.42
	Sig Sauer 180 gr	4	.6	4	.36
	Federal Hydra Shok 180 gr	4	.54	4	.44
	Underwood XD 115 gr	6	.8	6	.74
45 ACP	Winchester FMJ 230 gr	4	.18	4	.22
	Winchester Ranger T 230 gr	4	.48	4	.48
	Remington GS 185 gr	4	.4	4	.36
	Speer Gold Dot 230 gr	4	.5	4	.44
	Hornady C Duty +P 220 gr	4	.52	4	.44
	Sig Sauer V 230 gr	4	.5	4	.42
	Federal Hydra Shok 230 gr	6	.31	4	.32
	Federal HST +P 230 gr	6	.55	6	.45
	Fort Scott 180 gr	4	.2	4	.28
	OATH Tango 163 gr	2	.61	2	.53
	Underwood XD 120 gr	6	.6	6	.345
	Underwood XD +P 120 gr	4	.65	4	.61
	Underwood XD Super 120 gr	8	.825	8	.71
	Underwood Max Exp 174 gr	2	.79	2	.79
	Glaser Blue +P 145 gr	2	DNE	2	DNE
	G2 RIP 162 gr	2	.18	2	.24
5.7mm	American Eagle 40 gr	4	.3	4	.2
	SS195LF 28 gr	4	.3	4	.25
	SS197SR 40 gr	4	.2	4	.2
	SS198LF 28gr	4	.35	4	.35
	Elite S4M 28gr	4	.4	4	.55
	Elite T6B 28 gr	5	.5	7	.49
	Elite PenetraTOR 40 gr	4	.35	4	.1
	Elite ProtecTOR 40 gr	4	.13	3	.12
	Elite DevastaTOR 37 gr	7	.61	5	.56
	Vanguard Black Fang 34 gr	4	.69	4	.46
	Vanguard Barnes 50 gr HP	4	.56	4	.4
	Vanguard Comb Tech 50 gr	6	.59	4	.5

HOLLOW POINT SUMMARY

All hollow points are designed to expand after contact with the target/media. Some are designed to open slowly or less amount to aid in barrier performance and to provide deeper penetration, while others are designed to open more rapidly to cause the largest diameter/area wound.

Results from the six previous tests and this test showed there are four main characteristics to hollow point performance in order.

1. Caliber. The larger the caliber hollow point the deeper the average penetration depth, the more reliable the rounds were with a lower failure to function percentage, better barrier performance and the largest average PWC. In all four grading criteria the largest caliber hollow point rounds did the best when compared to other hollow points.
2. Weight. In each of the 5 calibers that hollow points were tested the heaviest weight in each caliber did the best in all four graded characteristics.
3. Bullet Design. Certain bullet designs outperformed other designs. This was the third most important characteristic after caliber and weight.
4. Velocity. In all hollow points velocities less than 800 fps resulted in larger failure to expand percentages in all 7 tests. Between 800-900 fps the percentage decreased and ceased to be a problem above 900 fps. Velocities over 1,200 fps resulted in extremely high failures due to jacket separation and fragmentation. The reliability rate was slightly better between 1,100-1,200 fps and accidental fragmentation happened far more rarely below 1,100 fps. The sweet spot for hollow point reliability is between 900-1,100 fps. Remember hollow points are designed to expand and function properly with 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. For the other three types of ammunition tested increased velocity always produced better results, not true for hollow points.

Overall:

1. Penetration. Most hollow points penetrated at least 12 inches in IWBA gel. None of the hollow points exceeded 24 inches except during failure to expand occurrences. In all cases increasing bullet weight increased penetration. While increasing velocity did a number of factors and none of them reliably.

2. Unfortunately, of all 4 types of rounds tested hollow points recorded the worst reliability and the worst consistency. Hollow point bullets in this test expanded approximately 75% of the time in the Phase 2 gel test. (In the six tests previously mentioned it was recorded that hollow points failed to function properly about 30% of the time which is slightly worse than our data). Reliability and consistency continued to degrade as a barrier was added in Phase 3 and as we shifted testing to tissue in Phase 4 and then finally the worst results in Phase 5 barrier and tissue. Factors in this include the caliber, velocity, target media, barriers and bullet design. This means that at least 1 out of every 4 shots resulted in a failure! In realistic tissue with barriers such as clothes and bone 1 out of every 3 hollow point shots resulted in failure to function. This is extremely poor reliability and consistency.
3. Barriers greatly affected the hollow points tested. Hollow points are neither barrier blind nor barrier fail. Results varied from shot to shot.
    a. 9mm hollow point rounds recorded an average of a 30% degradation in penetration and PWC due to barriers.
    b. 357 SIG hollow points recorded an average of a 35% degradation due to barriers. The higher velocity caused more cases of accidental fragmentation as evidenced in both Phase 3 and Phase 5.
    c. The 40 S&W recorded an average of 15% degradation due to barriers.
    d. The 10mm hollow points recorded an average of 20-25% degradation in penetration and PWC due to barriers because of accidental fragmentation caused by excessive velocity similar to the 357 SIG.
    e. The 45 ACP recorded an average of 10% degradation due to barriers.
4. Permanent Wound Cavities were generally larger than almost all types tested with the exception of some of the rounds from the Solid Copper category. Compared to some massive expansion solid copper rounds and frangible rounds hollow points still had the largest PWC due to a good combination of expansion resulting in larger diameter wounds and deep penetration.

FULL METAL JACKET (FMJ) SUMMARY

FMJs are the second most used by all the agencies involved in this test. They are also the most used training ammunition. They are typically not the first choice for defensive ammunition but they do have three very good characteristics.

1. FMJs penetrate very deeply. In 5 of the 6 tested calibers (not the 5.7mm) the FMJs tested all penetrated completely through the 24 inches of gel and all barriers that were used. If you are looking for extremely deep penetration regardless of barriers then FMJs or Solid Copper rounds would be your choice.
2. Excellent Reliability, Consistency and weapons function. Every round did almost exactly what it was supposed to do and did it every time. We had no problems with feeding or function on any of the tested calibers FMJs.
3. Barrier Performance. Almost completely barrier blind like only some of the other ammunition tested they did extremely well and are a great choice if your agency considers barrier performance to be one of the top criteria in ammunition selection. They easily exceeded the capability of all the hollow points and frangibles and some of the solid coppers when it came to barrier performance. Given that hollow points fail 25%-35% of the time and are unreliable versus barriers consider Full Metal Jacket rounds.
4. In each caliber tested the FMJ rounds produced the smallest Permanent Wound Cavity size.

Overall if extremely deep penetration and barrier performance is important while small diameter wounding is acceptable on your agency criteria list as it was for a couple of the involved groups then FMJs are a logical choice. Though, even hollow points that failed to function tended to produce larger PWCs.

SOLID COPPER PROJECTILE SUMMARY

Solid Copper bullets are a non-standard category of projectiles with vastly varying designs. Defining or lumping all of these rounds together is very problematic as they are not similar to each other as is found in the hollow point and FMJ categories. Since the results varied to such a high degree each design needs to be discussed separately. There are two main sub-categories in Solid Copper projectiles; Extreme Expansion and Non-expanding.

1. Extreme Expansion. These rounds could certainly be considered as hollow points and any agency wishing to include them in that category is more than welcome to as the data sheets do not have categories. For the purpose of this summary we have included the Underwood Maximum Expansion and OATH Tango in the Solid Copper category. Another Solid Copper round, the G2 RIP was included in the Frangible category as its main design characteristic is fragmentation.
    a. Penetration. Neither of these rounds in any caliber met the minimum requirement for penetration for any agency involved in this test. None of the rounds tested exceeded 12 inches in IWBA gel. Some of the rounds tested did not make it through the tissue media used in Phase 4/5.
    b. Reliability and Consistency. These rounds tended to be reliable and produce fairly consistent results. For the amount of expansion exhibited this is very impressive. We had no failures to expand although some of the expansion was not as designed. Several of the rounds turned sideways greatly reducing the diameter of the wound channel. Only rarely did we see any of the rounds fragment.
    c. Barrier Performance. The expansion and shape of the recovered round was changed by barriers. These rounds are not stopped by barriers but are not barrier blind. Barriers limited the amount of penetration that was already extremely low. In 9mm and .40 the Underwood ME round had some fragmentation issues which resulted in smaller wound diameters but deeper penetration. These two solid copper extreme expansion rounds behaved exactly like hollow points when it came to barriers.
    d. Permanent Wound Cavity. The two extreme expansion rounds tout themselves as creating maximum sized wound channels which we found to be true. Some of the largest diameter wounds produced were from these

rounds. Unfortunately, the penetration depth was so shallow that the overall PWC size did not rank among the largest in some calibers.

Overall these rounds performed well. Given that Penetration was judged to be the most important characteristic, these rounds fall short of even the minimum and PWCs can be matched or exceeded by the best hollow points and other solid copper rounds available.

2. Non-expanding. These designs are non-deforming rounds designed to use a specific technology to create a larger than FMJ wound cavity. Tumbling or hydraulic compression tissue redirection are the two mechanisms used to create larger wounds. Because gel is non-compressible and human tissue is compressible results from these rounds are larger in the Phase 2/3 gel tests than in Phase 4/5 tissue tests. Hollow point wound diameters are very similar when comparing gel to tissue with and without barriers. These Solid Copper non-deforming/non-expanding rounds created larger wound channels in gel which was not replicated in tissue. There are 3 types of rounds tested that fall into this sub-category: Fort Scott, Underwood Xtreme Defender (XD) and the 5.7mm rounds. Because of the incredible differences in results between these rounds we will discuss them independently.

   The Fort Scott uses tumbling as its destructive mechanism. Unfortunately, this rounds tumbling reliability was low in gel and very low in tissue. If the Fort Scott doesn't tumble then you have in essence an FMJ. The 9mm Fort Scott tumbled 4 out of 8 shots into tissue in Phase 4/5. The .40 tumbled 3 out of 8 shots and the .45 only tumbled 1 out of 8 shots into tissue in Phase 4/5.

   a. Penetration. The Fort Scott penetrated very deeply and went through all 24 inches of IWBA gel on all failures to tumble.
   b. Reliability and Consistency. We recorded the highest amount of failure to function (tumble) with this round between gel and tissue tests.
   c. Barrier Performance. This round went through all barriers extremely well with no deformation and minimal degradation regardless of function.
   d. PWC. In all 3 calibers with more than 50 rounds tested the average PWC was very small and barely exceeded that of FMJ rounds. PWCs were of good size when tumbling did occur but still smaller than the best hollow points.

The Underwood XD uses the Lehigh Defense Xtreme Defense Technology bullet. They are the same bullet and in some cases Underwood uses slightly higher pressure which produces more velocity. The radial flutes increase tissue pressure and direct the tissue outward to increase wound diameter. There is one main characteristic to XD performance…. Velocity. The faster this round goes the larger the wound diameter. We tested the 9mm XD, 9 +P, 9+P+ and the 357 SIG in multiple tests in gel and tissue. That's 4 of the exact same projectiles with the only difference being velocity. The wound channel size increased exactly in proportion to increase in velocity. Unlike hollow points which are designed for a certain impact velocity to best perform as designed, the XD always works better when faster.

The data sheet shows results from Phase 2/3 with enormous wound diameters. The radial flutes work perfectly in fluid/gel. Calculated PWCs are the largest ever recorded in all calibers!

Many of our testers wondered if vectoring real compressed tissue sideways into tissue would actually destroy that adjacent tissue that is not directly in the path of the projectile. For those who think this will only work in a non-compressible fluid like gel as we initially did, we can confirm that this technology works extremely well in actual animal tissue with or without barriers. Remember that hollow points expand because tissue which fills the hole in the hollow point is compressed to such a point that the outward pressure inside the bullet pushes and tears the metal and forces it outward where friction then takes over to complete the expansion. If tissue can be compressed to the point of tearing metal (hollow point) then tissue can certainly be compressed to the point of tearing tissue. The Phase 4/5 tissue tests confirmed that in over 100 shots the measured wound channel was not only larger than that of an FMJ but in most cases was the largest wound channel produced in that caliber compared to all other rounds to include fully functioning hollow points.

a. Penetration. All rounds in all calibers tested penetrated 15.2 – 20 inches with and without barriers.
b. Reliability and Consistency. Every single shot did roughly the same thing. There is a 0% chance of failure to function because there can be no failure to tumble or expand (because they don't) and no chance to fragment. This was the most Reliable and Consistent round tested.

c. Barrier Performance. The XD round, the 5.7 mm rounds and FMJs were the most barrier blind rounds tested. Not only did barriers not deflect the round it didn't change the wound diameter much and only slightly reduced penetration depth. XD Barrier degradation was approximately 5%.
d. PWC. In the Phase 4/5 realistic tissue tests the XD produced the largest wound areas and with the incredible penetration depth exhibited in the Phase 2/3 gel tests the XD recorded the largest overall PWC in all calibers. As noted the PWC numbers are inflated in the Phase 2/3 gel tests due to non-compressible gel, but the penetration depths are more realistic to compare.

Overall: This was by far the most impressive round tested. After over a year of testing this round became the most requested round to test after some of the agencies reviewed draft shot data. In continued testing this round became the most measured and compared round in this test. We had more XD data points than any other round. Because the XD relies so heavily on velocity the results showed that the 357 SIG, 10mm and 9mm were the best calibers in this round followed by the .45 and then the .40, the exact opposite of the hollow point results.

The 5.7 mm rounds are solid copper and use tumbling and velocity as its destructive mechanism. The 5.7mm round is similar to the 5.56 mm but weighs less and has lower velocity, but believe it or not the projectile is longer than the 5.56 making the center of gravity (CG) farther aft which greatly aids in its ability to tumble reliably and consistently. Since this type of rifle-like projectile is only available in 5.7 mm we will cover the specifics in the 5.7 Caliber Summary.

FRANGIBLE ROUND SUMMARY

Frangible bullets are designed to break apart, fragment or disintegrate into small pieces upon striking any solid object either immediately on target contact or after minimal penetration. They were created to minimize penetration and to be less likely to cause injury or damage to unintended objects. They are designed to create large diameter wounds and not penetrate deeply. During this test in all cases the Frangible rounds did not penetrate the required 12 inches of ballistics gel, except for the core of one type of round. Since this test was mostly concerned with defensive ammunition and all agencies that took part in the test agreed that > 12 inches of penetration in ballistics gel (Phase 2) is a requirement and that penetration is the most important characteristic in determining projectile effectiveness, frangible rounds were only superficially tested.

Rounds included in this category are the Glaser Blue and the G2 RIP.

1. Frangible rounds are not supposed to penetrate deeply and they don't. The Glaser Blue penetrates between 5.5 – 7.25 inches in gel in all calibers. The G2 RIP is difficult to judge because the petals/trocars in all calibers only penetrate between 3.5 – 5 inches and the core independently penetrates 11 – 16 inches in gel. Remember that the resistance of skin to projectile penetration is equal to about 3-4 inches of IWBA calibrated ballistics gelatin. The Glaser never penetrated through the tissue in either Phase 4 or Phase 5. The RIP Phase 4/5 tissue tests showed the core would penetrate completely through the tissue except on rounds that failed to expand.
2. Reliability and Consistency. The Glaser Blue had extremely consistent numbers and reliably opened on every test shot in all phases. The RIP round had Failures To Expand (FTE on the data sheet) on 4 occasions out of 21 shots.
3. Barrier Performance. Frangible rounds are supposed to be Barrier Fail rounds. All Glaser shots properly opened in contact with barriers. When the RIP Failed To Expand it was during barrier tests and the penetration was limited, yet when functioning properly the core went through the barrier.
4. The Permanent Wound Cavity size of frangible rounds 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. The G2 RIP

PWC in the Phase 2/3 gel tests was calculated by adding the PWC of the core alone to the PWC caused by the trocars.

Overall: If your agency requires minimal penetration or absolute barrier failure than these rounds are designed for that task. Some have an extremely high reliability rate and consistency to break apart on contact and should be considered. Other frangible rounds were less consistent and sometimes failed to break apart during barrier and tissue tests and should be avoided.

9mm SUMMARY

The 9mm is the most used ammunition in the world and was the most used caliber by all the agencies involved in this test. The most used type of 9mm ammunition is the hollow point followed by the FMJ. The 9mm is used as the Ballistic Standard for calculations of Ballistic Ratio which compares results from different ballistic tests.

9mm hollow points tend to have sufficient penetration but have one of the lowest reliability, consistency and barrier performance of all the hollow points. Permanent wound cavity size of the 9mm was the smallest of all the calibers tested. These results are also recorded and verified in the other 6 tests mentioned earlier. The 9mm hollow point tends to be degraded about 30% by the barriers used.

FMJs create a wound diameter roughly the size of the caliber and all caliber FMJs penetrate very deeply. So the 9mm and 357 SIG FMJs have the smallest PWC with equal penetration, reliability, consistency and barrier performance to other calibers.

The solid copper rounds available in 9mm present some of the best bullets available in this caliber. The jump in performance and wounding capability between hollow points and solid copper is the largest of any caliber. Deeper more consistent penetration, great barrier performance and the largest PWC was recorded with a solid copper round.

Frangible rounds have a very specific function and since low penetration and barrier failure is a must the typical 9mm problems disappear. If frangible rounds are required or desired the 9mm is an excellent choice.

357 SIG SUMMARY

The 357 SIG cartridge is used by multiple law enforcement agencies. Feed reliability is typically very high with bottleneck cartridges. All known agencies utilize hollow points in their 357 SIGs.

357 SIG hollow points tend to have excellent deep penetration but suffer from the lowest reliability and consistency numbers. Sometimes the deep penetration is caused by the fails. The small size and extremely high velocity of this hollow point caused the most fail to functions in the test. This was exasperated by barriers. 357 SIG hollow points recorded an average of a 35% degradation due to barriers. The higher velocity caused more cases of accidental fragmentation as evidenced in both Phase 3 and Phase 5 barrier data. Permanent wound cavity size of the best 357 SIG hollow points was bigger than the 9mm and a little smaller than the .40. Our results are also recorded and verified in the other 6 tests mentioned earlier.

FMJs create a wound diameter roughly the size of the caliber and all FMJs penetrate very deeply. 357 SIG and 9mm FMJs have the smallest PWC with equal penetration, reliability, consistency and barrier performance to other calibers.

The solid copper rounds available in 357 SIG present the best bullets available in this caliber. The jump in performance, reliability and wounding capability between hollow points and solid copper rounds is very large. More consistent penetration, reliability, great barrier performance and the largest PWC was recorded with a solid copper round.

40 S&W SUMMARY

The 40 S&W cartridge is used by multiple federal, state and local agencies as well as security firms. It is the second most used ammunition in the US and by all the agencies involved in this test. The most used type of .40 ammunition is the hollow point.

40 S&W hollow points tend to have average penetration, reliability, consistency and barrier performance of all the hollow points. Reviewing all 7 tests the permanent wound cavity size of the 40 S&W was larger than the 9mm by about 20% and smaller than the .45 by about 20%. The 40 S&W hollow point tends to only be degraded about 15% by the barriers used. It is almost directly in between the 9mm and 45ACP in every measurable characteristic.

FMJs create a wound diameter roughly the size of the caliber and all caliber FMJs penetrate very deeply. So the .40 FMJs have an average PWC and equal penetration, reliability, consistency and barrier performance to other calibers.

The solid copper rounds available in 40 S&W present some of the best bullets available in this caliber although the jump in overall capability from hollow point to solid copper is not as exaggerated as in other calibers. The excellent solid copper rounds require high velocities and the 357 SIG and 9mm actually have better overall PWC size over the .40. Deeper more consistent penetration, great barrier performance and the largest PWC was recorded with a solid copper round in the 40 S&W.

Frangible rounds have a very specific function and there are some available to perform that function.

10mm SUMMARY

The 10mm was first selected for service by the Federal Bureau of Investigation in 1989 from the aftermath of the 1986 FBI Miami shootout, following the first full scale federal ballistics test (one of the 6 previous tests referred to earlier). The cartridge was later decommissioned after their Firearms Training Unit eventually concluded that excessive recoil and pistols chambered for the cartridge were too large for some agents. Currently none of the federal, state, local agencies or security firms involved in this test field the 10mm.

10mm hollow points tend to have excellent penetration, on par with the 45ACP. Reliability and consistency issues have resulted from extremely high velocities. Like the 357 SIG velocities over 1,200 fps result in excessive impact pressures which cause jacket separation and accidental fragmentation which lowers effectiveness by shrinking wound diameter and making penetration numbers very inconsistent which averages don't show. The 10mm hollow points recorded an average of 20-25% degradation in penetration and PWC due to barriers. This ranks it 3rd of 5. Reviewing all 7 tests the permanent wound cavity size of the 10mm is about the same size as the 40 S&W (5% larger) and smaller than the .45 by about 15%.

FMJs create a wound diameter roughly the size of the caliber. The 10mm due to its fantastic sectional density has the deepest penetration. Its FMJs exhibits average PWC, reliability, consistency and barrier performance to other calibers.

The solid copper rounds available in 10mm showed the most impressive results, with excellent penetration, 100% reliability, better consistency and the largest PWC size in this caliber. The best solid copper round requires high velocities and the 10mm provides that.

45ACP SUMMARY

The 45ACPs are the largest, heaviest and slowest rounds tested. This helps with some ammunition types and hurts in others. Many of the agencies involved in this test use this cartridge.

45ACP hollow points have traditionally recorded the best results when grading penetration and PWC when compared to all other calibers. The penetration results from this test match the previous 6 tests. The 45 and the 10mm have the best penetration and the 45 has the most consistency. It also demonstrates the most reliability by having the lowest fail to function percentage. The design features the largest meplat resulting in better functioning. The 45ACP recorded an average of only 10% degradation due to barriers which are the best numbers for any hollow point. The 45ACP hollow points have a PWC which is larger than all other calibers. Also, like the other calibers hollow points the 45ACPs results are best when utilizing the heaviest grain available. Lastly, on average after 7 tests the 45 hollow point creates an average PWC size 50% larger than a 9mm and 15-30% larger than the other calibers in both gel and actual tissue media.

FMJs create a wound diameter roughly the size of the caliber and all caliber FMJs penetrate very deeply. So the 45ACP FMJ has the largest PWC with equal penetration, reliability, consistency and barrier performance to other calibers.

The area of the 9mm/357 SIG is .1 and the area of a 45 is .16. So with an FMJ or an unexpanded hollow point if both the 9mm/357 SIG and 45 penetrate the same depth the 45 will create a PWC that is 60% larger! The area of a 40S&W/10mm is .12.

The solid copper rounds available in 45ACP exhibit excellent qualities. The best hollow points almost match the best solid copper round. Solid copper rounds require high velocity unlike hollow points and the 45 solid copper are the slowest rounds in that ammunition category resulting in minimal improvement over hollow points. Deeper penetration, great barrier performance and a large PWC was recorded with a solid copper round.

Frangible rounds have a very specific function and since low penetration and barrier failure is a must the typical 45 frangible round has only minimal improvement over the other calibers.

5.7mm SUMMARY

The 5.7mm is a small-caliber, high-velocity, rebated rim, bottlenecked, rifle cartridge. They are the fastest, smallest and lightest rounds tested. They are the only rifle rounds included and only because this chambering has a pistol that employs it. Designed and proven to have better wound ballistic terminal performance than the 9mm, better barrier performance especially versus armor with low recoil and lightweight it is a misunderstood and controversial cartridge. This is the first large scale test involving the 5.7 alongside other more traditional calibers hollow points in the U.S. Only a couple of agencies involved in this test use this cartridge.

Starting in 2002, NATO conducted several tests to replace the 9×19mm cartridge. The tests compared the FNH 5.7×28mm cartridge and the HK 4.6×30mm cartridge. The NATO group recommended the 5.7×28mm cartridge, recording vastly superior performance in testing. Comparing the results of the NATO test and one other federal test with this test has confirmed our results.

5.7mm rounds use tumbling and velocity as its destructive mechanism. The 5.7mm round is similar to the 5.56mm in form and function but weighs less and has lower velocity, but the projectile is longer than the 5.56 making the center of gravity (CG) farther aft which greatly aids in its ability to tumble reliably and consistently and increase its wound size. The variances in design and capability of the tested rounds was vast. Results were the most varied of any caliber tested. There were 4 duty rounds that demonstrated superior characteristics over the others in all grading criteria. Many of the other rounds are simply training rounds. Great penetration, reliability, consistency and barrier performance proved to be very easy to grade.

1. Penetration was surprisingly deep and consistent for the duty rounds regardless of barriers in Phase 2/3 and very close to the best from the 45ACP and 10mm hollow points averaging just over 17 inches.
2. The rounds exhibited near perfect reliability with no tested rounds failing to function/tumble in any phase regardless of media/barriers. None of the rounds fragmented unless designed to do so. Shot to shot consistency was extremely high similar to the solid copper rounds and the FMJs. Each wound channel looked completely different but the measurements were very close and consistent.
3. Barrier degradation was almost zero. 5.7 rounds are the closest thing to barrier blind that was tested. During a couple of the test shoots certain agencies

introduced different more robust barriers and the 5.7 continued its flawless minimal degradation results.

4. Measuring the Permanent Wound Cavity (PWC) in gel proved to be very difficult. High speed, tumbling rounds create a compression which results in larger than actual wound channels in non-compressible IWBA gel similar to what some of the solid copper rounds did only worse. Also, the rounds normally followed a fairly linear path but in some instances wound paths were curved. Lastly, the wound diameter is small while the bullet is in line but is much wider during tumbling, requiring almost infinite measurements to be made to accurately calculate the actual PWC in gel similar to the frangible rounds. Averages could be made but all our other measurements were so exact and rechecked that we decided to not estimate and be inaccurate. It was decided that wound channel dimensions would be more accurate and realistic in Phase 4/5 in actual tissue where exact measurements could be made and tissue dissection could verify tumbling and overall damage. The Phase 4/5 results were extremely surprising and much extra testing was done as many agencies wanted to be present for comparisons to more traditional rounds. Measurements taken on over 100 shots verified that wound channels through tissue with or without barriers equaled or exceeded that of hollow points in all calibers! There was a solid copper round that produced larger average wound dimensions. As previously mentioned rounds over 2,000 fps can create stretches that exceed the body's limits. In a few select tests rifle rounds >3,000 fps were tested to analyze the wounds in tissue. Dissection showed tearing, which increases overall wounding. Only minimal tearing was ever witnessed during 5.7mm testing and we believe the effects were nominal and did not contribute to any measurements or data.

PENETRATION GRADING CRITERIA SUMMARY

Penetration is the overall distance traveled by the bullet through the selected media or target. All agencies that took part in this test agreed that Penetration is the most important characteristic of projectile wounding.

The average human male is 10" thick front to back. A bullet must penetrate deep enough to pass through and destroy vital organ tissue. This must be accomplished from different target body angles and through common barriers such as clothes and bone. Side shots through an arm must penetrate greater than 10 inches to contact the heart and frontal shots must penetrate at least 7 inches to reach the back of the abdominal cavity. These are human tissue penetration depths, not ballistics gel depths.

All of the agencies in this test require a minimum of 12 inches of penetration in IWBA calibrated ballistics gel. Some of the agencies involved desire 15-18 inches and other agencies desire 18 inches ±10% (16-20 inches) of overall calibrated ballistics gel penetration. FBI and DoD protocols call for a minimum penetration of 12 inches with a goal of around 18 inches.

Grading Penetration was accomplished using Phase 2 (IWBA gel and denim) data for a desired 18” and a minimum of 12”. Also, Penetration using Phase 3 (IWBA gel with denim and plywood) barrier data was important for all agencies. Many agencies averaged the Phase 2 and 3 penetration depths for their assessment.

In order the best penetration depths were observed by some of the solid copper rounds in all calibers that consistently penetrated 15.2 – 20 inches with and without barriers. The duty 5.7mm rounds averaged over 17 inches of penetration. The 45ACP and 10mm were the best penetrating hollow points tested. Reference the data sheets for exact rounds and measurements. Penetration depth consistency should be considered very important and is referenced in the caliber and bullet type summaries.

RELIABILITY AND CONSISTENCY GRADING CRITERIA SUMMARY

After the primary importance of penetration was determined by all of the involved agencies the other three characteristics were agreed to be of roughly equal importance with individual groups ranking them differently. All involved stressed how important Reliability and Consistency was and demanded that it be addressed and reported. Most of the other tests do not reference this critical benchmark.

Reliability: In this test reliability was defined and graded as to whether the round performed as designed or failed to function properly. Function depended on the type of round. Failure to perform as designed (Failure to open/tumble, accidental fragmentation and jacket separation) will be noted and included in the data and in the caliber summaries.

1. Hollow Points. They are designed to expand and retain weight. Rounds of this type that either failed to expand or accidentally fragmented were ruled as a failure and that counted against the round in terms of Reliability. In these cases, regardless of the cause, penetration depth and permanent wound cavity (PWC) size was greatly affected. Of all 4 types of rounds tested hollow points recorded the worst reliability. Hollow point bullets in this test failed approximately 25% of the time in the Phase 2 gel test. (30% in the previous tests). Reliability continued to be degraded as barriers were added in Phase 3. Tissue testing in Phase 4/5 showed even more reliability issues. Failure factors include the caliber, velocity, target media, barriers and bullet design. In realistic tissue with barriers such as clothes and bone almost 35% of hollow point shots resulted in failure to function.
    a. Failure to expand was particularly noted for low speed rounds less than 900 fps. Barriers also caused failures to expand especially in the 9mm and less so as the caliber and weight were increased.
    b. Fragmentation was noted in high speed hollow points like the 357 SIG and 10mm resulting in much smaller PWC. Also, the smaller the caliber the more cases of fragmentation that occurred.
2. Full Metal Jacket. These rounds are not designed to do anything except retain weight. No failures were noted since none of the rounds tested fragmented or deformed enough to alter the results. All FMJ rounds tested had excellent reliability.

3. Solid Copper Rounds. The Extreme Expansion subcategory had failure rates that were better (lower) than the hollow points. We had no failures to expand although some of the expansion was not as designed. Several of the rounds turned sideways greatly reducing the diameter of the wound channel. Only rarely did we see any of the rounds fragment. These rounds were less reliable in the tissue tests and when barriers were present they were similar to the hollow points. The Non-Expanding subcategory was a mixed bag with one round failing to function by tumbling only about half the time in all phases and the XD having complete reliability in all phases. Also, the 5.7mm showed excellent reliability by tumbling as designed on virtually every shot and only fragmenting when designed to do so.
4. Frangible Rounds. The Glaser Blue had extremely consistent numbers and reliably opened on every test shot in all phases. The G2 RIP round had Failures To Expand (FTE on the data sheet) on 4 occasions out of 21 shots.

Consistency: In this test consistency was defined and graded as to whether the rounds penetration and PWC numbers were reliable and persistent. The standard deviation for each shot tested within a Phase. Large changes in the values showed rounds to perform differently shot to shot which was deemed low consistency. Obviously failure rates were the largest cause of inconsistency but some rounds were inconsistent even while functioning. Generally speaking hollow points, Extreme Expansion solid copper rounds and some of the frangible rounds exhibited the lowest consistency. The FMJs and XD were the most consistent followed by the duty 5.7mm rounds.

Overall: Reliability to function on target as designed cannot be overstated. All agencies involved agreed that choosing a round with excellent characteristics really doesn't matter if it fails to function. Most agreed that round reliability rates under 80-90% are serious problems. Consistency is also important but less so then reliability. Bullet type summaries and caliber summaries contain more detailed information on reliability and consistency. There were some rounds that were extremely reliable (nearly 100%) and very consistent in the solid copper and FMJ categories and the 5.7mm. Agencies wishing to review all the individual shot data of some particular rounds for more detail on reliability and consistency should contact us and we will provide the data requested.

BARRIER PERFORMANCE GRADING CRITERIA SUMMARY

The main target area to stop/incapacitate a human target is the upper thoracic cavity and head. Bone protects over 70% of that area and in most conditions clothes cover about the same percentage. Barriers are encountered on about 2 of 3 shots taken. Bone tissue is an excellent protective barrier and is similar but stronger than the plywood that was used in 2 phases (Phase 3 and 5) of this test as a consistent barrier IAW IWBA standards. Shot placement is NOT wound placement and where a shot hits the target does not always determine the path of the bullet through the target due to barriers (clothes, bones and outside items) and bullet performance/failures. Many common defensive rounds are easy to defeat/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 and how much a round is degraded by going through barriers.

Barrier performance was graded by comparing the results from Phase 2 to Phase 3 and comparing the data from Phase 4 to Phase 5 where the only differences were the addition of a single ¾ inch thick AA fir plywood panel IAW FBI / DoD protocols.

Penetration and PWC degradation: Percent of penetration and PWC size lost from non-barrier shots to barrier shots from Phase 2/3 and Phase 4/5.

1. Hollow Points.
    a. 9mm- 30% degradation due to barriers.
    b. 357 SIG- 35% degradation due to barriers.
    c. 40 S&W- 15% degradation due to barriers.
    d. 10mm- 20-25% degradation due to barriers.
    e. 45ACP- 10% degradation due to barriers.
2. Full Metal Jacket. No measureable degradation in penetration or PWC. Barrier Blind.

3. Solid Copper.
    a. Extreme Expansion- The expansion and shape of the recovered round was changed by barriers. Barriers limited the amount of penetration that was already extremely low. In 9mm and .40 the Underwood ME round had some fragmentation issues which resulted in smaller wound diameters but deeper penetration. The two solid copper extreme expansion rounds behaved exactly like hollow points when it came to barriers.
    b. Non-Expanding- 5% degradation in penetration and PWC regardless of caliber.
    c. The 5.7 exhibited almost zero degradation due to barriers. Barrier Blind
4. Frangible. Frangible rounds are supposed to be Barrier Fail rounds. All Glaser shots performed as designed by functioning and opening due to contact with barriers. The RIP Failed To Expand (FTE on the data sheet) on 4 of 12 barrier shots and the penetration was limited.

Overall: The ultimate goal is for a round to be either barrier blind or barrier fail, that way the shooter will know the capability of the rounds and not have unexpected results. 5.7mm, some solid copper rounds and all FMJs were barrier blind, while the Glaser Blue was barrier fail as designed. For hollow points the 45ACP had the least degradation due to barriers.

PERMANENT WOUND CAVITY GRADING CRITERIA SUMMARY

Penetration was judged the most important characteristic of a defensive handgun bullet. Permanent Wound Cavity (PWC) is a mathematical calculation comprised of penetration depth and wound diameter converted to area and is expressed in cubic inches of destroyed material. Literally it's how big a hole was made by the bullet. Whereas this seems to be extremely important, there are four issues with concentrating solely on this number.

1. A large PWC that doesn't destroy any important body tissue because the wound is to shallow is virtually meaningless. Since the important organs are deep within the body this drives up the importance of penetration. Destroying a lot of skin and subcutaneous material does little to stop/incapacitate a human target.
2. Many rounds that create large PWC are less reliable or inconsistent. Many of the hollow points that open extremely far tend to do it inconsistently or accidentally fragment often.
3. Most of the PWC calculations are done using IWBA gel. Human tissue is compressible and gel is non-compressible which creates results that don't represent reality. Using a media closer to human tissue is required to get actual realistic data.
4. About 70% of the target area of a human is covered by clothes and bones. So 2/3^{rds} of the shots are going to encounter barriers which are not considered for most PWC calculations. Barriers greatly lowered some PWC figures.

For this test we did the normal PWC calculations for comparison purposes with other tests and we also did measurements and grades with actual animal tissue and barriers along with calculating reliability and consistency. That way a more realistic overall picture of bullet capability on a human target could be achieved.

Challenges with calculating PWC: The previous 6 tests only graded hollow points, where wound channel diameter is generally the same as recovered round diameter. This is the same when testing FMJ rounds. Two issues were encountered when the other 2 types of ammunition were included in this test.

1. Tumbling rounds (5.7mm and one solid copper round), non-expanding rounds (one solid copper round) and frangible rounds that create intentional

fragmentation and multiple tiny difficult to measure wound channels, change diameter of wounding throughout the wound path making measurement very inaccurate.
2. Rounds that generate a large amount of compression due to velocity or design (5.7mm and one non-expanding solid copper round) create wound channels in gel that are unrealistic and overestimate their effectiveness, due to compression.

It is recommended that wound areas in tissue (Phase 4/5) be used for these rounds and if comparison between ammunition types is to be done that Phase 4/5 data be used for wound area and Phase 2/3 data be used for penetration.

1. Hollow Points. The PWC of hollow points were some of the biggest seen along with some solid copper rounds and the 5.7mm. Reference the data sheet for particular rounds and exact numbers.
2. FMJ. The PWCs measured were the smallest of all 4 bullet types.
3. Solid Copper. Several of the solid copper rounds produced the largest wound areas, but some of them had extremely low penetration depths that limit the overall size of the PWC. One of the solid coppers, the Underwood XD had excellent realistic wound diameters/areas in animal tissue and very deep reliable consistent penetration in both gel tests with and without barriers in all calibers. The duty 5.7mm ammunition produced very large wound areas in realistic Phase 4/5 tissue testing and had very deep reliable consistent penetration in both gel tests with and without barriers.
4. Frangible. Results varied depending on ammo. Some large wound channels were observed but difficult to measure due to fragmentation creating multiple wound paths. Also, since penetration depth was so low the overall PWC was smaller than some of the other bullet types.

Overall: PWC is important but should not be overestimated and the data used should be from a realistic media, should include barriers and must take into account the reliability and consistency of the wounding by looking at a great many shots. Lastly, the PWC has to be deep enough to actually account for the destruction of important organs/material and not just superficial tissue.

ACKNOWLEDGEMENTS

There are so many agencies and people to credit with the amazing amount of data that was measured and calculated in this report. So many new things were accomplished and considered like Ballistic Ratio, consulting of medical professionals to create the first large scale test using realistic animal tissue as a primary media and the testing of all four types of ammunition instead of just hollow points.

People involved in this 2016-17 Joint Agency Ballistics Test For Defensive Handgun Ammunition came from the Department of Defense, Department of Justice, Marshalls, two Texas State departments, 4 police and Sherriff departments, 2 security firms, 3 local gun stores and 2 training schools. We had 2 companies that sponsored some of the tests by providing supplies and food. One local grocery store chain gave great discount on brisket used in Phase 4/5. The tests were accomplished at 4 outdoor ranges starting in March of 2016 and finishing in October of 2017. Ammunition was provided by multiple sources ranging from the manufacturers to gun stores and finally most provided by the agencies involved. No ammunition manufacturers were allowed to sponsor or attend any test. They were only allowed to provide ammunition and nothing else.

The people involved were active, retired and by the end some of the active retired! Many wished to remain anonymous and it was agreed that two final reports would be made. One only for the agencies involved and one for general use that would have all specific agencies, individuals and companies information removed, with the exception of the company compiling and disseminating the final report. No agency, company or individual received any financial or gift compensation of any kind for testing or the report. A very special thanks to all the volunteers who helped set up, tear down, film, photograph, measure, re-measure, document, calculate and check all the data. Only through their diligent thorough work could this much accurate data be generated.

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The individual test reports were written by many testers, chapters were written and reviewed by many and final composition and editing was accomplished by the training company that provided continuity of testing and scheduling: Viper Weapons Training LLC.

There are no conclusions in this test. Testing was accomplished only to provide raw data on a large scale with an enormous sample size on multiple media with 4 predetermined quantifiable grading criteria. Each agency should first determine which characteristics are important to them in order, before using the data for ammunition determination or for ballistics training.

A 2019 test is being scheduled to include newer rounds, more direct competitions of rounds by requested agencies and more tissue dissection data. The same protocols will be maintained in that test so that comparisons and combined sample sizes may be accomplished.

There were a few videos produced to promote the test to different agencies that are available for viewing on youtube from Viper Weapons Training LLC.

https://www.youtube.com/channel/UCv9CSMeBybM65XiHHFd-EBA

A power point presentation is available for any agency wishing to have this report in that format.

Any agency wanting more information please make a request to viperweaponstraining@gmail.com

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