# DEFENSIVE HANDGUN AMMUNITION

# CHARACTERISTICS AND BULLET TYPES

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# FOREWORD

There are five main types of handgun bullets each with a distinct design and purpose. There are also four main characteristics or qualities a bullet has in regards to wounding. This report will define and discuss the four individual characteristics of all five bullet types.

This report brings together the most credible information regarding terminal wound ballistics. It combines the knowledge and results of many federal wound ballistics tests. Research into wound ballistics includes both industry accepted ballistic gelatin and medically recommended animal tissue media to create 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.

No specific ammunition will be discussed rather this is an overview of bullet characteristics and types. No conclusions or choices will be included in this report. Any agency wishing to use this report to make conclusions must first understand their needs and be able to quantify their requirements using the four characteristics described herein. Any agency wishing to discuss either in person or remotely the contents of this report or more detailed information need only contact us.

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# 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 hits 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 caliber 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 shooters 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. 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. "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

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

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 type of 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 characteristics.

1. Penetration Depth
2. Reliability/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.

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

[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

## THE HUMAN TARGET

There are four main kinds of human tissue.

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."[5]

Nervous: Thin nerve tissue which constitutes the smallest percentage of human tissue.

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.

Muscular: Muscle tissue and most internal organs are the most common type of human tissue in the thoracic cavity which is the target area or center of mass. In our testing during phase 4 and phase 5 we use animal tissue to as closely as possible consistently replicate human muscular tissue.

"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. The second, or stretch mechanism is the temporary cavity formed by the tissues being driven outward. The crush mechanism, the result of penetration and permanent cavity, is the only handgun wounding mechanism which damages tissue. Temporary cavity has no reliable wounding effects in elastic body tissue and is nothing more than a stretch of the tissues."[6]

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

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

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

occurs. The distance created by the stretch 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. "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."[7] 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 rifle 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."[8]

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. 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."[9] "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

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

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

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

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. The much discussed 'shock' of a bullet impact is a fable and 'knock down' power is a myth. 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."[10] 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.

"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."[11] "Even shots to the heart are not immediate as stored oxygen may allow for voluntary action for 10-15 seconds after functional heart destruction."[12] "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

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

[11] Fackler, M.L., M.D., Director, Wound Ballistics Laboratory, Letterman Army Institute of Research, Presidio of San Francisco, CA, letter: "Bullet Performance Misconceptions", International Defense Review 3; 369-370, 1987.

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

oxygen is the only way to cause reliable incapacitation." [13] 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."[14] "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)."[15] 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."[16]

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

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

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

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

# 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.

IWBA calibrated ballistics gelatin has several good and some bad properties.

The good: It is consistent yielding similar results from shot to shot with the same projectile, so when inconsistencies exist it is an indicator of poor bullet design or unreliability. It is easy to purchase, create and handle. It shows what happens as the projectile goes through the media by being clear enough to see through and witness the effects. After the shot the effects are retained and can be measured. Its density and drag does mimic some 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.

The bad: IWBA gel is a non-compressible liquid unlike 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 (covered in the next chapter) 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 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. 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.

Realistic target media is required exactly the same as realistic barriers. Adding testing in a realistic media (animal tissue) produces results that match real life

shootings. 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.

To calculate VWI we use the 2 gel tests (phase 2 and 3) to determine the penetration part of the formula. Phase 2 is IWBA gel with 4 layers of denim (exact same test the FBI and DoD use). Phase 3 is the same as phase 2 except we add a layer 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. Currently it's 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 BULLETS

Five types of handgun bullets exist.

1. Hollow Points. The most common defensive ammunition used. These rounds are intended to expand upon impact to increase the frontal area of the projectile. This will create a larger diameter wound (if the bullet doesn't turn) and also increase drag which limits penetration depth as compared to an FMJ. 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. Some of the lead-free hollow points are only copper but will be considered hollow points because their design is identical to other hollow points and the only difference is the material. Hollow points are generally not designed to fragment, but rather have weight retention. This will keep the mass high to allow for deeper penetration. Some common hollow point failures include but are not limited to: fragmentation, jacket separation, failure to expand and turning. All these failures are detrimental limiting the round's ability to wound and are not supposed to occur.

2. Full Metal Jacket (FMJ). The second most common defensive ammunition used and also the most widely used training or practice ammunition. This is typically a copper jacketed round that is solid and 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. About the only 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.

3. Solid Metal Rounds (copper or brass). Also called fluid transfer rounds, these projectiles have varied designs, most are fluted. Some perform extremely well, while others are simply gimmicks. For the purpose of this discussion the solid metal type is comprised of non-expanding bullets. Their designed destructive mechanism is tearing and fluid transfer through the Venturi Effect. Recent testing has proven that fluted solid metal bullets transfer fluid (castoff speed) as high as 30% projectile velocity. This is compared to less than 10% from hollow points or FMJ (see chapter "The Human Target"). Fluted bullets lower the Terminal Ballistic Coefficient, increasing drag, which increases cast off fluid velocity through

constriction. This high-volume high-speed liquid tissue cast off destroys adjacent tissue through direct impact. This is not energy transfer temporary stretch cavity which doesn't destroy tissue. This fluid transfer is direct contact high-speed fluid on live tissue. Since they are solid and don't expand about the only failure is tumbling which stops the designed fluid transfer. A tumbling round of this type will create a substantially smaller wound diameter and also less deep penetration than normal. The solid metal rounds designed as hollow points are included in the hollow point category.

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. The only common failure of frangible rounds is failure to fragment. If minimal penetration or absolute barrier failure is desired, then these 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. At impact of the target the round immediately starts to slow 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 with a sample size or over 60 shots none of the 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, tumbling traditional pistol caliber rounds are simply a gimmick and are completely unreliable.

## FOUR CHARACTERISTICS OF BULLET WOUNDING

There are four main characteristics or qualities of handgun projectile wounding. Each of these can be quantitatively graded. Before picking a bullet type or specific ammunition these four characteristics must be understood. Decide what value is needed for each characteristic. From there determine the best bullet type and specific round that matches your requirements for each characteristic for your application.

1. Penetration. The overall distance traveled by the bullet through the target or media. This is generally accepted as the single most important characteristic in projectile wounding. "A projectile must penetrate deeply enough into the body to reach the large vital organs, namely heart, lungs, aorta, vena cava and to a lesser extent liver and spleen, in order to cause rapid blood loss. It has long been established by expert medical professionals, experienced in evaluating gunshot wounds, that this equates to a range of penetration of 12-18 inches, in tissue, depending on the size of the individual and the angle of the bullet path (e.g., through arms, shoulder, etc.)." "A penetration of 18 inches is preferable."[17] "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."[18] Missed shots, grazing shots, or bullet failure are the problem. Only Full Metal Jacket (FMJ), tumbling rounds and Hollow Point rounds that Failed To Expand (FTE), penetrated to such a depth that could cause an overpenetration issue.

2. Reliability and Consistency: Reliability is a measurement of failure rate. Each of the 5 handgun bullet types is constructed to do something specific 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, turn sideways or in the case of the hollow points Fail To Expand (FTE) and jacket separation. "Handgun bullets (hollow points) expand in the human target only 60-70% of the time at best.

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

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

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."[19] 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 do cause dangerous under-performance and in hollow points can cause overpenetration, 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. They can exist between the weapon and target or be part of the target. Barriers can include bones, thick clothing, dry wall, plywood and other common everyday items. This is measured with three barrier categories: light domestic barriers (plywood, drywall, clothes and bone), heavy domestic barriers (hardwood 2x4's, auto glass and metal car doors) and armor products using the NIJ levels. We use light domestic barriers in our phase 3 and 5 and the results in comparison to the non-barrier phases give barrier results. Testing of ammunition on heavy domestic barriers yields information where we grade deflection, terminal performance and bullet properties after contact with the barriers. We do extensive testing with armor using products from multiple manufacturers and multiple levels of protection. 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. Bones are an exception to this rule due to their size and chance of hitting, but doors, plywood and glass will stop multiple bullets if they can stop one.

4. "Permanent Wound Cavity (PWC): The volume of the cavity is that tissue which is in direct contact with the projectile and is therefore destroyed."[20] "It is measured

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

[20] FBI's Firearms Training Unit at Quantico

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 (SMR) 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 create holes vastly larger than the bullet diameter. Actual measurement of the hole in the media is required. "Given adequate (and equal) penetration, a larger diameter bullet (wound area) will have an edge in wounding effectiveness. Any bullet which will not penetrate through vital organs from less-than-optimal angles is not acceptable. Of those that will penetrate, the edge is always with the bigger bullet."[21]

Unlike penetration depth, reliability of a round and barrier performance this characteristic can be increased with multiple shots. 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 frontal area change (Area = л x Radius squared). 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 there is a large amount of intentional fragmenting and 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 and can't be measured except 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 fragmenting rounds, solid metal rounds which create holes larger than their caliber and tumbling bullets that have holes that vary greatly at different depths.

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

"Temporary Cavity: The temporary cavity is caused by tissue being stretched away from the permanent cavity. 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. 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."[22] *High speed (>2,800 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 actually 2200 fps.[23] The real velocity (2000 or 2200) doesn't matter and is probably not a constant. What is important is that pistols 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 has a significant impact on a target and greatly increases the amount of damaged and destroyed tissue.*

Fluid transfer from the solid metal rounds is sending a jet of liquified tissue into adjacent tissue. It is not energy transfer! This will destroy some of the 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.

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

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

# HOLLOW POINT SUMMARY

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

Results from multiple tests have 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 major 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 calibers of hollow points velocities less than 800 fps resulted in larger failure to expand percentages in all 7 major 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. This happened with bonded hollow points as well. 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 types of ammunition tested increased velocity always produced better results, not true for hollow points.

1. Penetration. Most hollow points penetrated at least 12 inches in IWBA gel, but fail to reach 16 inches. Some exceeded 24 inches during failure to expand occurrences. In all cases increasing bullet weight increased penetration, while increasing velocity did many things and none of them reliably.

2. Reliability and Consistency. Unfortunately, of all 5 types of bullets tested hollow points recorded the second worst reliability and consistency. Hollow point bullets failed to function properly about 30% of the time. Reliability and consistency continue to degrade as barriers are added. 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. Failure to expand can cause the hollow point to behave as an FMJ with extreme over-penetration depths normally considered unsafe. Fragmentation occurs unintentionally by the accidental breaking apart of the projectile. Hollow points have the highest occurrence of accidental fragmentation. Two distinct characteristics increase accidental fragmentation with hollow points.

a. Velocity. Rounds traveling at over 1,200 fps have an alarmingly higher rate of accidental fragmentation. 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 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. “When fragmentation does occur, fragments are usually found within one centimeter (.39 inch) of the permanent cavity.”[24] For these reasons,

[24] DiMaio, V.J.M.: “Gunshot Wounds”, Elsevier Science Publishing Company, NY, NY

wounding effects secondary to any handgun caliber bullet fragmentation are considered inconsequential."[25]

3. Barrier Performance. Barriers greatly affected hollow points. Hollow points are neither barrier blind nor barrier fail. Results varied greatly from shot to shot. With simple barriers such as drywall and plywood:

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.
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 almost always larger than the FMJs, tumbling rounds and frangible rounds due to a good combination of expansion resulting in larger diameter wounds and deep penetration. Within a certain caliber and bullet weight the differences in PWC were minimal signifying that penetration, reliability and barrier performance are of greater concern.

Overall, hollow points generally don't penetrate as deeply as desired and are less reliable than the other bullet types. They don't go through barriers or get stopped by barriers consistently. Their overall wound cavity is smaller than the solid metal rounds.

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

## FULL METAL JACKET (FMJ) SUMMARY

FMJs are the second most used defensive rounds and are also the most used training ammunition.

1. Penetration. FMJs penetrate very deeply. FMJs routinely penetrate well past the 21-inch max desired depth or even completely through the IWBA calibrated gelatin blocks and all light domestic barriers that are used during testing. Overpenetration with this bullet type is probable and dangerous for defensive application.

2. Reliability and Consistency. Every round does almost exactly what it is supposed to do and does it every time. There are rarely problems with function on any FMJs. About the only failures that can occur would be tumbling which was witnessed almost never.

3. Barrier Performance. FMJs are almost completely barrier blind in regards to light domestic barriers. 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 barrier capability of all the hollow points and frangible rounds. Given that hollow points fail 25%-35% of the time and are unreliable versus barriers consider Full Metal Jacket rounds.

4. Permanent Wound Cavity. In each caliber tested the FMJ rounds produced the smallest Permanent Wound Cavity size compared to the other bullet types. The wound channel in actual tissue during testing was smaller than the diameter of the round. This has also been seen in medical forensic documentation in real-life shootings.

Overall, if extremely deep penetration, reliability/consistency and barrier performance are important while small diameter wounding is acceptable then FMJs are a logical choice. Overpenetration is a serious concern as a defensive round.

## SOLID METAL PROJECTILE SUMMARY

Solid metal bullets are non-expanding. Their designed destructive mechanism is contact tearing and fluid transfer. Since they are solid and don't expand about the only failure is tumbling which stops the designed fluid transfer. A tumbling round of this type will create a substantially smaller wound diameter and also less deep penetration than a functional projectile. As stated earlier some hollow points are made exclusively of copper but their design (expansion) remains the same and those rounds are discussed in the hollow point section.

These designs are non-deforming rounds designed to use a specific technology to create a larger wound cavity than FMJ or hollow point bullets. Tearing and hydraulic compression tissue redirection (fluid transfer) are the two mechanisms used to create larger wounds. Because gel is non-compressible and human tissue is compressible wound channels from these rounds are larger in gel tests than in tissue tests. This makes the use of animal tissue in testing required because gel is used not as a tissue simulant but rather a consistent media. With solid metal rounds due to their design use of compression, testing in a non-compressible liquid (gel) creates unrealistically large wound channels. If only gel was used then solid metal rounds would appear to be an order of magnitude better than all hollow points.

Tissue is liquified by the bullet shock wave and by impact. The radial flutes increase liquified tissue velocity because liquid is non-compressible described by the Venturi Effect using Bernoulli's Principle. The flutes constrict the fluid to increase velocity and direct the tissue outward to impact and destroy adjacent tissue not being contacted by the projectile itself, increasing wound diameter. With the increased velocity of the transfer fluid (castoff speed) more than three times higher than static, the fluid impacting the adjacent tissue is fast enough to tear that tissue. This is fluid transfer, not energy transfer. *Many testers wondered if vectoring high speed liquified tissue sideways into tissue would actually destroy that adjacent tissue that is not directly being impacted by the projectile. Remember that a hollow point opens the same way. Hollow points do not open because of friction, they open because tissue fills the hollow point cavity, gets compressed from the continued crushing of more material until it's a liquid (instantaneous) and then pushes outward, tearing and bending the metal petals. Once the petals are pushed outward the pressure is released and then friction takes over causing the continued opening to complete the expansion. If liquified tissue can create a pressure to the point of tearing and*

*bending metal (hollow point) then higher speed liquified tissue can certainly destroy tissue. For those who think this will only work in a non-compressible fluid like gel, it was confirmed that this technology works extremely well in actual animal tissue with or without barriers. In every tissue test and forensic report with these rounds the wound diameters far exceed the actual diameter of the projectile. Animal tissue tests confirmed that in over 200 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.*

There are two main characteristics to the solid metal rounds performance…. Velocity and specific design. The faster any solid metal round goes the larger the wound diameter. We tested the same 9mm projectile in standard pressure 9, 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 (pressure). 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, solid metal rounds always work better when faster.

1. Penetration. All solid copper rounds in all calibers tested penetrated 15 – 20 inches with and without barriers.

2. Reliability and Consistency. Every single shot did roughly the same thing. There were few recorded instances of tumbling, a 0% chance of failure to expand, and no chance to fragment. These were the most reliable and consistent rounds tested at over 95% reliability.

3. Barrier Performance. The solid copper 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. Solid metal barrier degradation was approximately 5% vs light domestic barriers.

4. Permanent Wound Cavity. In the realistic animal tissue tests these rounds produced the largest wound areas and with the incredible penetration depth exhibited in the gel tests they recorded the largest overall PWC in all calibers. Data from the IWBA gelatin tests show results with enormous wound diameters. The radial flutes work perfectly in fluid/gel. As noted, the PWC numbers are inflated in the gel tests due to non-compressible gel, but the penetration depths are more realistic to

compare. Calculated PWCs in all medias and forensic reports are the largest ever recorded in all calibers!

Overall, the solid copper rounds are very impressive if deep consistent penetration is desired. They exhibit great reliability and have the largest permanent wound cavity of any of the four bullet types.

# 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. Frangible rounds 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 testing 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 (accidental). Each fragment path must be included in the calculation of the PWC. 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. 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 frangible rounds do not qualify.

1. Penetration. Frangible rounds are not designed to penetrate deeply and they don't. None averaged anywhere close to 12 inches in IWBA calibrated ballistic gel.

2. Reliability and Consistency. All had extremely consistent numbers and reliably opened on every test. One gimmick round displayed erratic results.

3. Barrier Performance. Frangible rounds are supposed to be barrier fail rounds. All properly opened in contact with barriers.

4. Permanent Wound Cavity. Frangible rounds PWC size calculations are 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) the media, so measuring wound exit diameters was problematic. The measurements calculated were generally smaller than the hollow point rounds and much smaller than the solid metal rounds.

Overall, if minimal penetration or absolute barrier failure is desired than frangible rounds are designed for that task.

# TUMBLING ROUND SUMMARY

Tumbling bullets are designed to impact and immediately start to tumble. This will increase the wound size since the round is longer than its diameter and increase drag which will limit the excessive penetration depth exhibited in the FMJs. Unfortunately, tumbling only reliably occurs in high-speed rifle rounds, the 5.7 and the 4.6mm where the designed instability is very high. In traditional pistol calibers this is not the case and they don't tumble hardly ever.

1. Penetration. When the rounds did tumble the penetration results were very inconsistent. More than half the time the rounds failed to perform as designed and didn't tumble causing excessive penetration similar to the FMJs.

2. Reliability and Consistency. These rounds were the most unreliable and least consistent of any of the five bullet types.

3. Barrier Performance. Tumbling rounds are nearly barrier blind vs light domestic barriers equal to the FMJs.

4. Permanent Wound Cavity. The tumbling rounds could generally be considered equal to FMJs in regards to PWC. On the rare occurrences where they functioned as designed and actually tumbled their PWCs were larger.

Overall, these rounds fail more times than function as designed. They are extremely unreliable and normally act as FMJs.

## PENETRATION DEPTH GRADING CRITERIA SUMMARY

Penetration is the overall distance traveled by the bullet through the selected media or target and is considered the most important characteristic of projectile wounding.

The best penetration depths were observed by the solid metal rounds in all calibers and consistently penetrated between 15 – 20 inches with and without barriers. Hollow points penetrated the second best, but were unreliable and inconsistent. FMJs very reliably and consistently over-penetrated. Frangible rounds all under penetrated as designed. Tumbling rounds very unreliably over-penetrated.

## RELIABILITY AND CONSISTENCY GRADING CRITERIA SUMMARY

All involved agencies in recent tests stressed how important reliability and consistency are and demanded that they be addressed and reported. Many tests do not reference this critical benchmark.

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).

1. Hollow Points. They are designed to expand, stay linear (not tumble) and retain weight. Failure to do so, regardless of the cause, caused penetration depth and permanent wound cavity (PWC) size to be greatly affected. Of all five types of rounds tested hollow points recorded the second worst reliability. Hollow point bullets fail approximately 25-30% of the time. Reliability continued to be degraded as barriers were added. Failure factors include the caliber, velocity, target media, barriers and bullet design.

    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 velocity 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 and not tumble (stay linear). Failures are rarely noted since FMJs seldom fragment or deform enough to alter the results.

3. Solid Copper Rounds. Failure from these rounds comes from tumbling and not creating the designed tissue tearing. This was extremely rare in all of the tests. These rounds reliably and consistently perform as designed.

4. Frangible Rounds. These rounds open and fragment as designed with very little rate of failure.

5. Tumbling Rounds. These rounds had the highest failure rate and rarely tumbled.

Consistency was defined and graded as to whether the round's performance was persistent. A standard deviation for each shot tested was used. Large changes in the values showed rounds to perform differently from shot to shot which was deemed as low consistency. Obviously, failure rates were the largest cause of inconsistency but some rounds were inconsistent even while functioning. Generally speaking, hollow points, exhibited the lowest consistency. The FMJs and solid copper rounds were the most consistent.

Overall, reliability to function on target as designed cannot be overstated. Choosing a round with excellent characteristics really doesn't matter if it fails to function. Round reliability rates under 80-90% is a serious problem. Consistency is also important but less so then reliability. There were some rounds that were extremely reliable (nearly 100%) and very consistent in the solid metal and FMJ categories.

## 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 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 in both media (IWBA calibrated gelatin and animal tissue). Each media had tests accomplished with a light domestic barrier and without. Comparing those yielded a barrier performance metric, where the only differences were the addition of a single ¾ inch thick AA fir plywood panel IAW FBI / DoD protocols. Additional phase 6 testing to include heavy domestic barriers and armor is also accomplished but is not noted in this report.

Penetration and PWC degradation: Percent of penetration and PWC size lost from non-barrier shots to barrier shots.

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 measurable degradation in penetration or PWC. Barrier Blind.

3. Solid metal. Very minimal degradation on the order of 5% degradation in penetration and PWC regardless of caliber.

4. Frangible. Frangible rounds are supposed to be barrier fail rounds. All bullets performed as designed by functioning and opening due to contact with barriers.

5. Tumbling. Tumbling rounds were equal to the FMJs due to their inability to tumble reliably.

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. The solid metal rounds and all FMJs were barrier blind, while the frangible were barrier fail as designed. The hollow point results were erratic and it would be impossible to classify any hollow points as either barrier blind or barrier fail.

## 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 (Volume of Wound Index). 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 too shallow is virtually meaningless. Since the important organs are deep within the body this drives up the importance of penetration. Destroying a lot of skin and subcutaneous material does little to stop/incapacitate a human target.
2. Many rounds that create large PWC exhibit low reliability and consistency. Many of the hollow points that open extremely wide tend to do it inconsistently or accidentally fragment often.
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. That is why VWI is considered more valid because half of the calculation comes from light domestic barrier tests.

1. Hollow Points. The PWC of hollow points were some of the biggest seen along with the solid metal rounds. Caliber and weight had the largest bearing on hollow point PWCs with design being less important.

2. FMJ. The PWCs measured were the smallest of all five bullet types.

3. Solid Metal. The solid metal rounds produced the largest wound hole areas in tissue and with the deep penetration had the largest volumes. This was true in gel tests and animal tissue 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 the hollow points and solid metal rounds.

5. Tumbling. The PWC of the tumbling rounds were very similar to the FMJs.

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

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 this test came from multiple agencies to include the FBI, DHS, CBP, DoD, Marshalls, and multiple state DPS's and local police, sheriff and constables' offices, a local gun store 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 2 outdoor ranges. 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 and check all the data. 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 also Triple T Holsters.


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