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VOLUME 4 1999 NUMBER 1
INFORMATION FOR AUTHORS

The Wound Ballistics Review welcomes manuscripts, articles, short notes and letters to the editor that contribute to the science of wound ballistics. Publication preference will lean strongly toward pertinent papers with clear practical applications. We invite cogent reviews of articles, books, news items, etc. Our goal is to commend good documentation as well as to point out the errors in the wound ballistics literature. The Wound Ballistics Review especially requests our readers' help in submitting short reviews which correct errors noted in the literature.

The review of all manuscripts reporting original work will be open; the names of reviewers will be given to authors of rejected papers and will be made available upon request to anyone.

Articles are accepted only for exclusive publication in IWBA, and when published, the articles and illustrations become the property of IWBA.

If submitting a letter or review which refutes or points out errors in another work, please provide the address of the source (please include a copy of the article reviewed-these will be returned if requested).

In submitting original work, the manuscript and one copy are required; one set of high quality illustrations is required; black and white is preferred. Author's name must be clearly identified on the title page with addresses and telephone number. Manuscript must be double-spaced with ample margins (at least one inch on all sides) on standard (8 1/2" x 11") paper. NOTE: THE PREFERRED MANUSCRIPT FORM IS THE 3 1/2" (1.44 Meg or 720K) PC FLOPPY DISK WITH THE FILE AND A HARD COPY. Most major PC word processing files are acceptable but WordPerfect or Microsoft Word are preferred. (Please convert files to WordPerfect 5.1 or 6.0, or to Word for Windows 3.0-7.0.) PLEASE DO NOT PROVIDE COMPUTER TEXT WITH SPECIAL FONTS OR LAYOUTS: PLAIN: SIMPLE TEXT WITHOUT GRAPHICS OR MERGE FIELDS. Any graphs, tables, charts, etc. should be supplied as separate files and/or with a clean, high quality paper copy. Legends for all illustrations should be listed in order, double-spaced. An abstract of 150 words or less should precede the text.

References are to be numbered sequentially within the text and appear in the order cited at the conclusion of the article. Page numbers must be given in books, cited as references.

EXAMPLES:

Articles submitted for publication consideration should be sent directly to the Editor-in-Chief: Dr. Martin L. Fackler, 211 Star Lake Drive, Hawthorne, FL 32640
EDTORIAL

Dr. Martin Fackler

About This Issue

We are especially happy to present, in this issue, the article on “Suicide by Cop” by Shirley MacPherson, PhD, a mental health professional. This subject got national attention recently, when it was presented on one of the major TV news magazine programs (NBC’s Dateline, I believe) within the past few months. I think the perspective that Shirley presents in her authoritative and well written article is one that will provide some badly needed help to the law enforcement community.

In the past six months we have had several questions submitted by members that we felt warranted special attention. These questions, about the effects of rifle versus handgun bullets, about “shock waves” associated with bullet penetration, and about the efficacy of shots to the pelvic area, are asked frequently but rarely answered precisely. We felt that these topics deserved authoritative and comprehensive answers, so we put a lot of effort into attempting to furnish them. We hope we clarified these issues and provided a source to which others can refer in the future for clear answers to these questions when the subject come up again. We thank these members for providing the insightful and pertinent questions and hope others will notice their example and continue to give us the chance to clarify difficult issues. We like to think of our questions and comments section one of the most valuable parts of the Wound Ballistics Review.

The Briese bullet (testing described on pages 25-28) was probably invented because of the inconsistent performance of the 168 grain Sierra Matchking bullet, as pointed out previously in this journal (Vol 2, #3, 1995, pp. 8-12. No. 4, 1996, pp. 22-24. In these articles, it was also pointed out that this inconsistency could be very easily eliminated simply by enlarging the hole in the Matchking’s tip. But it is up to the law enforcement users to demand that this deficiency be fixed by those who sell the bullet. Sierra will make the Matchking with any size hole the buyer wants (personal communication with Kevin Thomas, Chief of Ballistics at Sierra, 1995). But so long as law enforcement continues to buy the cartridge loaded with Matchking bullets that have a hollow point hole in the .020 inch range, they will be stuck with a bullet that performs erratically – a disaster waiting to happen. It is about time that some of the large law enforcement purchasers specify to the bullet supplier that the 30 caliber Matchkings they purchase must have a hollow point hole of 0.60 to 0.70 inch. That should solve their inconsistent performance problem while still retaining the inherent accuracy of the Matchking bullet. We work hard in the IWBA to try to help the law enforcement community, but there is a point at which they have to take the initiative in applying the information supplied and help themselves.

Members who seek reliable information on ballistics should be sure to read the book review in this issue.

Feedback

We are extremely interested in any well documented shooting results involving handgun ammunition that has been rated against the IWBA Handgun Ammunition Specification. We are not interested in any “one shot stop” nonsense, but want to know how this ammunition expanded in actual use. We need to know what materials were penetrated prior to tissue contact, what part of the body was struck, whether bone was hit, and (if possible) the length of the wound track. Please contact the IWBA office if you have any such information.

The .224 BOZ

The November 1998 Guns and Ammo has a cover article on the .224 BOZ and the article shows that G&A thinks very highly of this development. While the G&A cover claims their report is an “International Exclusive”, members may recall a substantially less enthusiastic assessment reported six months earlier in the V393 Wound Ballistics Review.

Web Page

We have just begun to work on an internet web site for the IWBA. No details are available yet, but we expect to be able to introduce the web site with all the necessary information in the next issue.
Incapacitation Time

QUESTION

I was introduced to Dr. Fackler's studies by Bob Kong at a range instructor school I attended some time ago. Since then I have joined the IWBA and have a question, and believe your group can easily answer it...

QUESTIONS AND COMMENTS

1. “Does the rate at which blood loss from a non-CNS hit occurs affect the probable time to incapacitation?”

2. Would one expect the time to incapacitation to vary depending on each other and required (or deserved) one. That would presume that the questions were within the department. It’s tough when someone asks, hoping myself as a resident wound ballistics “expert” from perhaps a slightly different angle. separate answers. I realize they say the same thing, from perhaps a slightly different angle.

3. Is there a level/quantity of non-CNS tissue damage that can be expected to cause near-instantaneous incapacitation?

4. If increasing the amount of non-CNS tissue damage decreases probable time to incapacitation, is it via increased rate of blood loss or some other mechanism? I thought the idea behind the subject continuing to operate for several seconds was that the oxygen was already in the brain. That would seem to suggest it wouldn’t matter what happened to the rest of the circulatory system.

I don’t expect answers to these questions one-by-one. That would presume that the questions were independent of each other and required (or deserved) separate answers. I realize they say the same thing, from perhaps a slightly different angle.

Whatever light you can shed on this issue would be most appreciated. I’m trying to begin developing myself as a resident wound ballistics “expert” within the department. It’s tough when someone asks, “How come I heart-shot a deer, and he dropped in his tracks?” I’m comfortable saying handgun rounds can’t hit. It was, in fact, the result of a miss - the bullet had not hit the fellow but he obviously thought it had – not hit the fellow but he obviously thought it had -­-- and not simply declare unequivocally that it was an allergic reaction to the lidocaine used for the nerve block. It was not a result of a spreading of the infection into my entire circulation. But there had to be a reason for this sudden total incapacitation of a healthy young man. What was it? It was the physiological mechanism, with a psychological cause, known as neurogenic shock – more specifically the type of neurogenic shock called “Emotional fainting”. Strong emotions (such as fear) can cause widespread dilation of the body’s blood vessels and, as a result, blood pressure falls. These vessels are usually kept semi-constricted, but in Emotional Fainting, nerve impulses from the sympathetic nervous system can cause them to dilate completely. When this happens, the vascular capacity increases substantially and the blood available can no longer fill it. If the person is upright when this happens, gravity pulls the available blood back to the lower body, and the person falls, starring the brain and causing the incapacitation.

Neurogenic shock or Emotional Fainting is well documented and occurs probably much more often than is recognized. Ask Kevin Thomas, Chief of Ballistics at Sierra Bullets, about the shooting incident that occurred when he was a police officer. He had occasion to shoot and his opponent fell immediately. He thought this must certainly be the result of a CNS hit. It was, in fact, the result of a miss – the bullet had not hit the fellow but he obviously thought it had – and that thought caused his immediate collapse. Kevin published this incident, but I can no longer remember the reference. Anybody who has had occasion to review significant numbers of shooting incidents in detail has seen examples of this phenomenon – maybe in some cases it is not a miss but a graze or minor wound causing an unexplained major collapse.
There is no question in my mind that the effects of Emotional Fainting, or some gradation of psychologically caused incapacitation (the gamut from surrender to Emotional Fainting), are either totally or partially responsible for much more of the observed reaction from bullet hits than is recognized. The practical result of this misinterpretation of the causes of reactions to being shot is its overwhelming confounding effect on any attempt to compare the efficacy of various bullets by observing, recording, and comparing the reactions of those hit.

It seems likely that Emotional Fainting is more common in the scared-to-death petty criminal than in the seasoned and well-trained terrorist. If that is so, it appears to be a lucky break for law enforcement, who, in most of their gunfights will then be facing those susceptible to overreacting to being hit - or sometimes even to being missed. There is, however, a large degree of uncertainty about the type of person who might be more susceptible to the Emotional Fainting. That it occurs is certain, its physiology is clear: to whom it occurs, how much of their reaction might be due to it, and under what circumstances it is most likely to occur, however, is far from certain. It will probably help you a great deal, but it is unpredictable - don't count on it. You need to know about this factor, however, if you want to have a good, practical, and comprehensive understanding of wound ballistics.

2. "Would one expect the time to incapacitation to generally be shorter for a non-CNS chest shot from a .308 than for a similarly located shot from a .223 or .45 ACP?"

It is impossible to give an accurate answer without knowing what kind of bullets are being used in each caliber. For the past half century I have been reading about small arms and their effects. The great majority of the "experts" are strongly wedded to their ideas on what cartridge is best for a particular purpose. Their strongly held opinions, many based on wide experience, are often opposed by just as strongly held opinions of other well-qualified "experts" who prefer another cartridge. These experts generally overlook the single most important principle, the crux, of wound ballistics: the design and construction of the bullet is by far the most important element determining its wounding capacity. The cartridge or caliber is clearly of secondary significance.

To illustrate that principle I will answer this question in several ways: first, I will give the most logical answer, considering the question came from a law enforcement source. I will assume that the .308 bullet is a 168 grain Sierra Matchking (which I think is by far the most common bullet used in that cartridge by law enforcement), I will assume that the .223 is a nonfragmenting bullet such as the Federal Tactical round (which several sources tell me has been the unfortunate choice of many law enforcement groups), and I will assume that the .45 ACP bullet is a 230 grain hollow point which expands reliably and has a jacket that folds back and forms cutting edges which add to the tissue disruption and expanded bullet produces (such as either the Winchester SXT or the Remington Golden Saber - in this caliber, at least, most law enforcement groups seem to have made a valid bullet choice).

I would expect the time to incapacitation generally to be shorter for the .45 ACP, second for the .308 and longest for the nonfragmenting .223. Some might argue that I have chosen the most effective bullets available in the .45 ACP and compared them with bullets for the two other cartridges that are substantially substandard (in a judgment that law enforcement groups at argument is entirely correct. But my choices were made to reflect the irrational bullet choices currently being made by the majority of law enforcement groups. Are these the ones the ones I would choose to take the best advantage of the cartridges named? In the .45 ACP, yes; for the other two cartridges, a resounding No.

Now, I will answer the question assuming in all cartridges the most effective bullets available is used. These would be: in the .308, a bullet that fragments reliably, like 168 grain Sierra Matchking ordered from Sierra with a 0.060 inch or larger diameter hole in its tip. Please understand, this bullet is available - but not in small quantities - large departments must demand from their suppliers that they order these large-hole bullets from Sierra and load them rather than the ones with the tiny holes that are regularly supplied. Erratic performance with the current tiny-hole Matchkings (mostly they act like FMJs) is well-documented, as is the method of eliminating the problem by enlarging the hole. In the .223 cartridge, I have great difficulty identifying the most effective bullet. Every choice is a compromise. The military ball round would be fine if it weren't for the inherent variation in the distance the bullet penetrates before it yaws (then breaks and fragments) - about seven-in-ten times it yaws after four to six inches, but in the remainder it yaws sooner - or later - in its penetration. Many of the fragmenting .223s would be fine for precise placement at a specific well-chosen point in the human anatomy by a sniper using a rifle producing half-minute accuracy. But the inherent shallow penetration of these bullets would make them unacceptable for fast shooting when they might be required to perforate an arm before striking the torso. The best compromise would probably be one of the heavier .223s that fragments some but has a core that holds together for adequate penetration (the Winchester 64 grain soft point comes to mind). Please note, I am assuming that these bullets will be fired from a barrel with a minimum length of 20 inches.

We must remember that the .223 is a varmint cartridge, never intended for use against animals the size of human adults. Hence law enforcement groups are adopting it in ridiculously short barrel lengths (16, 14.5, and even 9.5 inches) which decrease significantly its already marginal performance. Bullets from a .223 will do the job reliably only when the bullet is placed with surgical precision - as it can be from a 24 inch heavy barrel on a bolt action scoped rifle. I'm afraid that if law enforcement groups continue to use the .223, with short barrels, as a spray-and-pray gun for entry purposes they will find out the hard way - by losing officers - that it is not up to what they are expecting of it. The cartridge just doesn't have the power to provide a safety margin - everything must be done exactly right for the little varmint round to give acceptable results on the human target.

OK, now let me answer the question assuming a reliably fragmenting .308 bullet, which can be made easily by enlarging the HP hole in the Sierra Matchking to at least 0.060 inch, one of the best available .223s, and the .45 ACP loaded with a 230 grain cutting action hollow point bullet. I would expect the time to incapacitation generally to be shorter for the .308 by a large margin. I would expect there to be no clear-cut difference between the .223 and the .45 ACP: the .223 has more spectacular successes - which would be counterbalanced by just as many spectacular failures - but I would expect the .45 to be the more reliable overall because of the large permanent hole made by its reliable expansion - with cutting edges on the expanded bullet, coupled with its reliable penetration to an adequate depth of 12 inches. With the potentially acceptable .223s shot from a short barrel, I would expect the time to incapacitation to be longer than that of the .45 ACP.

3. Is there a level/quantity of non-CNS tissue damage that can be expected to cause near-instantaneous incapacitation?

No, only direct or indirect CNS tissue damage can be expected to cause nearly instantaneous complete incapacitation. I think the question implies a hit in which the bullet does not actually strike the CNS. But let us not forget that indirect "CNS tissue damage" can also be produced by bullets that do not strike the CNS directly - by sudden violent motion transmitted to the bones of the spine, which cover and protect the spinal cord from the temporary cavity produced by a bullet, provided the cavity is large enough. I would expect a temporary cavity as large as the front-to-back diameter of the human chest (about ten inches; 14 inches side-to-side) might cause instantaneous incapacitation in many torso hits: but it is difficult to view this as "non-CNS" since the mechanism of incapacitation is, in fact, from CNS tissue damage. Such a temporary cavity would be large enough so that it could cause the spine to be moved violently and abruptly, causing the spinal cord to be struck by the wall of the spinal canal and causing a "concussion of the spinal cord" which affects the cord, transiently at least, as if it had been cut: it would cause immediate incapacitation of the muscles innervated by nerves that come from the spinal cord at or below the level of the concussion. This means that many torso hits would cause incapacitation of the muscles of the legs - but would be unlikely to incapacitate the muscles of the arms (which are innervated predominantly by nerves emerging from the spinal cord in the neck).

I recall an article in which a gun writer described shots into the torsoes of prairie dogs made with hollow point handgun bullets. He reported that some of these hits had literally blown these tiny animals in half. He used this to argue that the temporary cavity of the handgun was therefore of awesome power and could not be regarded as ineffective for shots in the human torso. This writer lacked a sense of perspective and proportionality: he overlooked the all-important...
scaling effect – which is little more than common sense. He was shooting these animals with bullets that caused temporary cavities more than twice the diameter of their torsos. Yes, if one scales up the prairie dog shots and shoots a human in the torso with a bullet that causes a temporary cavity of 36 inches, more than twice the diameter of the largest diameter of the human torso, it would certainly most likely cause instantaneous complete incapacitation: but the mechanism of this incapacitation would still be from CNS tissue damage – widespread cord concussion, maybe even accompanied by fractures of the spine and actual physical disruption of the cord. It seems to me, however, that this goes somewhat beyond the scope of our discussion since I am unaware of any of our fellow fired bullet that could produce such a temporary cavity.

4. If increasing the amount of non-CNS tissue damage decreases probable time to incapacitation, is it an increased rate of blood loss or some other mechanism? I thought the idea behind the subject continuing to operate for several seconds was that the oxygen was already in the brain. That wound seems to suggest it wouldn’t matter what happened to the rest of the circulatory system.

Yes, decreasing the non-CNS tissue damage time to incapacitation is via increased blood loss. Yes, the ten-second experiment after action blood stops coming to the brain occurs because of the oxygen already in the brain. Correct, it doesn’t matter what happens to the rest of the circulatory system in the ten seconds it takes the brain to use up the oxygen already there. Further explanations which bear on this question are included in some of the answers to the previous questions.

Although not in the form of a question, you also mentioned “Its tough when someone asks, ‘How come I heart-shot a deer, and he dropped in his tracks?”

After reading the answer to question three you should be able to answer that one. The shot might have been in the top part of the heart and made with a powerful enough bullet so that the temporary cavity was large enough that it caused the spine to be moved abruptly, causing the spinal cord to be impacted by the wall of the spinal canal and causing a “conclusion of the spinal cord” which affects the cord as if it had been cut. The paralysis resulting from “conclusion of the cord” might be transient—or it might be permanent. The shot in the deer also might have broken both front shoulders. By the way, comparisons of bullet effects on human sized animals, such as deer, are very useful in helping to understand bullet effects. It eliminates the Emotional Painting as a cause of incapacitation, leaving only the anatomic and physiological explanations. Pondering these comparisons brings up some interesting questions: if the .223 is an adequate cartridge for use by police on the human, why is it that so many state hunting laws prohibit its use for shooting deer?

As a further aid to comprehending wound ballistics, I suggest you study the damage patterns illustrated in some wound profiles and superimpose them anatomically correct diagrams of the human anatomy (available in an atlas of human anatomy — by Grant, Netter or Clemente) at various positions and angles—and make sure you get the scales right. In evaluating a shooting one should look over the variables—all of the variables. In how many cases are all of these variables known with certainty? Answer: damn few. This is the difficulty the layman has in trying to compare results from shootings: this is the reason gun writers so typically make fools of themselves when wandering into this area, which they do not understand. There is also an inescapable inherent variation in almost everything involving the human body—such as the time to incapacitation from non-CNS hits. That is why the biological sciences are called “inexact,” as opposed to the “exact” sciences, such as physics.

REFERENCES

Shock Wave

QUESTION
I would like to ask your assistance in a more or less running debate I have over the effect of waves and “shock waves” when a bullet hits a target.

In the discussion, I explained temporary and permanent cavitation effects when the bullet hits. My opponent (so to speak) mentioned that I had forgotten shot waves to which I replied that the shock wave he meant is actually a sonic wave. A shock wave occurs when the originator travels at a higher speed than the speed of the wave. Since the bullet is slower, it is not a shock wave. Also, this person mixes up the sonic wave with the wave effect caused by the cavitation (which is sometimes noticeable as gelatin blocks jumping up in game animals seen as a ripple going through the body).

However, I am at a bit of a loss (or losing ground) when the HESH-AT round comes up. A HESH round (high explosive squash head) is an antitank round which has an explosive charge which pans against the armor and then detonates. The “stress wave” that is caused by this then sets off chips of armor on the other side of it without creating a real hole. This is like the flakes of rust flying off a rusted steel plate when you hit it with a hammer on the other side. Since you can get this effect with a hammer, I would say we are talking about a sonic wave and not a shock wave. The term stress wave is very confusing here.

Can you explain all of this?
Maarten J. van Maanen

ANSWER
There are a couple of very specific technical usages of the term “shock,” but none are applicable to bullet penetration in tissue. A lot of people talk about “shock waves” in terminal ballistics without realizing that this terminology and concept are essentially meaningless in this application, and this practice has historically caused a lot of confusion for those who try to think about what they are talking about. The following comments on sound waves and shock waves attempt to clarify this without getting too technical.

Sound Waves
Pressure changes can easily be produced in fluids (“fluid” is used technically here, and includes all materials commonly called liquids or gases); almost any kind of agitation will create a pressure variation. The pressure movement through the fluid is called a pressure wave because the pressure at any location is a time varying parameter that can be visualized as analogous to the height of a wave on water. This wave modeling has three intrinsic parameters: velocity, frequency, and amplitude. The pressure wave velocity in any material is constrained to a specific value; all pressure waves (of interest in this context) in the material travel at this velocity. The pressure wave frequency and amplitude are unconstrained in the sense that they can assume any value of practical interest. The speeding organism in detecting pressure waves in air over a wide range of frequencies and amplitudes, and we call these waves “sounds” or “sound waves” or (if we want to sound impressive) “sonic waves”. Pressure waves with frequencies beyond our capability to detect are also “sound waves”; we are just “deaf” to them. Because we detect these pressure waves in air as sound, we call the unique velocity that these pressure waves travel in any material the speed of sound in that material. The frequency of the sonic wave is what musicians call pitch, longer wavelengths have a lower frequency and are “bas”, shorter wavelengths have higher frequencies and are “treble”. The amplitude of the sound wave is measured by how “loud” it sounds; greater pressure amplitudes sound “louder”. Extremely loud sounds can damage the delicate sensing mechanisms in the ear and can cause pain while doing this, but do not create incapacitating physiological trauma that persists after the wave passes.

Shock Waves in Air
The only correct use of the term “shock” in ballistics is in supersonic bullet flight in air (technically called a compressible fluid flow), where a shock is a separation between two different volumes where the air has different state properties (e.g., pressure, temperature, density). Aerodynamicists usually just use the term shock for this phenomenon, but in some contexts call this a shock wave; non-technical people invariably use the terminology shock wave in all technical contexts (and often apply the term to effects that are not shocks). The shock in front of a blunt nosed supersonic bullet is called a normal shock (the term “normal” is used technically here to mean perpen-
Our ears can detect these shocks as sounds; the “sonic boom” of a supersonic jet plane or the “crack” of a supersonic rifle bullet in air is the oblique shock wave passing the listener. This oblique shock travels at the speed of sound relative to the listener standing on the ground; this is a sound wave, and causes no more physiological trauma than any other sound wave having the same amplitude (loudness). The sensed loudness (pressure wave amplitude) is greater when the listener is close to the source. These shocks have nothing to do with bullet penetration in tissue, but simply illustrate that the layman’s presumption that “being hit with a shock wave” is always traumatic is simply not true.

**Waves in Tissue or Gelatin**

The general discussion of sound waves above applies to gelatin or tissue or water as well as in air, but the detailed dynamics are quite different because tissue and gelatin are very nearly incompressible. Fluid dynamics theory gives a truly incompressible fluid an infinite speed of sound; the speed of sound in nearly incompressible water at 70°F is about 4880 ft/s (and this is representative for most common liquids). The speed of sound in gelatin or tissue is about the same as in water because these materials are primarily water.

Nothing corresponding to the shock that can occur in compressible fluid flow exists for bullet penetration in tissue or gelatin or water because this “shock” is produced by compressibility effects. There is no transonic drag rise near the velocity of sound in tissue or gelatin because this effect is also a result of compressibility effects (the transonic drag rise is the increase in drag coefficient that occurs at velocities near the speed of sound in compressible fluids). This absence of “shock” and “transonic drag rise” is not a result of the typical bullet velocity being lower than sonic velocity in gelatin or tissue; tests have demonstrated this on special test projectiles driven near sonic velocities in gelatin. Thus, any “shock wave” effect due to bullet penetration in tissue is not just relatively inconsequential physiologically as it is in air; the “shock wave” is simply not there. This misunderstanding about the difference between bullet passage through air and through tissue or gelatin is very common, even among people with technical training who ought to know better. Use of the term “shock” in bullet penetration is common but erroneous, and it is done merely because it sounds technical or impressive or important. “The shock from being hit by a bullet” is actually much like “The shock from being called an idiot”; it is an expression of surprise and has nothing to do with physical effects or physiological trauma.

The wound ballistics effects attributed to a “shock wave from bullet penetration” by uninformed people actually are a result of the temporary cavity, a sonic wave, or imagination. I have also seen the term “hydrostatic shock” used to denote the effects of bullet penetration at high velocity; this is essentially meaningless even if the more correct adjective “hydrodynamic” is used. The phrase “physiological effects of temporary cavity formation” does not have the impressive ring of “hydrostatic shock” or “shock wave”, but does have the virtues of being precise and technically correct.

A very damaging pressure wave can be created in water with a powerful underwater explosion, but this is a sonic wave, not a shock wave, and has nothing to do with bullet impact effects. Bullet impact does produce a high frequency sonic wave in water, gelatin, or tissue that is not related to the gross movement of the medium caused by bullet passage (which is described below). The pressure wave is far too high, but the wavelength is so short that the total action time is only about 2 microseconds. As a result, the resulting soft tissue displacement is trivial and does not create wound trauma. From Reference 3: “The most quantification of the nondamaging effect of sonic waves is that such waves are now used to break up kidney stones without surgery and without damage to the surrounding soft tissue. Each of the 2000 sonic waves typically used to break up kidney stones is at least 5 times more intense than the sonic wave produced by bullet passage. The basic reason soft tissue is not damaged in this process is that the displacement caused by the sonic wave is very small and introduces only trivial strain in soft tissues. The small displacement causes much larger strain in the solid kidney stones; this is why the stone breakup occurs. Strain in soft tissues caused by the temporary cavity is vastly greater than strain caused by sonic waves under all conditions.”

**Temporary Cavity**

Bullet penetration in tissue or gelatin creates a high pressure at the bullet/gelatin interface; this pressure is large enough to create the deformation or fragmentation that occurs in bullets that are not constructed to withstand this pressure. Since the gelatin has high pressure on the side facing the bullet and low pressure on the other side, the gelatin is rapidly accelerated away from the bullet. This gross movement of the gelatin away from the bullet creates what we call the temporary cavity. This process is described in more detail in Reference 4; but in part: “This temporary cavity is produced because the bullet passage at high speed forces the gelatin laterally with enough velocity to temporarily create a hole much larger than the bullet.” This description is valid and has nothing to do with “sonic waves” or “shock waves”, and I think most people would have a much better idea of what is really happening if they thought about what was occurring instead of trying to describe this in terms of “sonic waves” or “shock waves”.

There is obviously a variation in pressure in the gelatin while the temporary cavity is going through the creation and collapse cycle; this can be called a pressure wave, but I don’t think this nomenclature provides much understanding of the actual process to most people. This “pressure wave” is not a sonic wave because the dominant effect is bulk movement of the gelatin or tissue that would continue expansion indefinitely if it were not halted by external forces (i.e., soft solid shear forces and gravity). It is true that the bullet penetration produces both the temporary cavity and the small sonic wave that does exist, but the sonic wave effects are too small to detect except with sophisticated instrumentation. The person you are having the discussion with is improperly describing the gelatin movement he sees as a result of a “sonic wave” and/or “shock wave” when it is really the temporary cavity generation and collapse.

**Armor Spall**

The process of armor side flaking you describe is technically called spallation or spalling, and this is a serious problem in armor design. Personnel behind plain sheet armor can easily be killed by spall without any penetration of the armor. The technical model of this spallation does involve a stress wave through the armor plate; in effect, this stress wave is a very rapid increase and decrease in the stress at any point in the armor. The effect of this stress wave is to “snap” pieces of armor off the back face. The most relevant simple physical model that readily comes to mind is the process of ejecting a particle stuck to your...
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Questions and Comments

fingertip by flicking your finger. This produces stress forces that the adhering particle interface can’t support, so the particle flies off. I am not surprised you find this confusing, but I suggest you just accept it unless you really want to get into heavy weapon armor design. The important thing for this discussion is to forget all about sonic waves and shock waves here as well because they aren’t useful in understanding the problem.

Summary

The bottom line in all of this is that I think the confusion goes away if you can just get the person you are having this discussion with to stop talking about “shock waves”. You are leaning too far over backwards in trying to get a definition of “shock wave” for him; you can easily show he is using this term without understanding by asking him to define exactly what he means by it.

Duncan MacPherson

References

2. MacPherson, Duncan, Bullet Penetration - Modeling the Dynamics and the Incapacitation Resulting from Wound Trauma, P. 104-106, Ballistic Publications, Box 772, El Segundo, CA, 1994
3. Ibid., P. 64
4. Ibid., P. 59

Kevlar Cap

QUESTION

I am a sergeant with the NYC Police Dept. assigned to the 45th Precinct in the Bronx patrol area. I have come across a piece of protective equipment called the Command Cap sold by Silent Partner Body Armor, Inc. This is a piece of level 2 Kevlar fitted into a baseball cap and provides coverage to the front of the forehead area.

Please forward any information regarding blunt trauma and head injuries as they relate to this piece of equipment. I have read of people being shot in the head and the bullet glancing off the skull with minimal injury. Does this cap make this more likely? Does it provide protection when hit with blunt objects?

Sgt. Edward Swarm

ANSWER

This kind of Kevlar cap does not provide the same kind of protection that body armor does because the skull still takes the force of the blow (unlike soft tissue lets resistive forces build up in the Kevlar). As a result, this cap provides essentially no protection against blunt trauma from a hard blow with a baton or baseball bat. This cap does provide a minimal cushioning effect which isn’t important for these blows; but could reduce the “seeing stars” effect when struck by a lighter object (e.g., an empty beer bottle). The same effect keeps the cap from providing the body armor level of effectiveness in stopping a bullet, so some bullets that are stopped by body armor will not be stopped by the cap when impact is near perpendicular. Some low power rounds (22LR, 25 auto, .32 auto) will still be stopped by the cap. The cap will cause bullets to glance off the skull rather than penetrate at somewhat higher angles of incidence.

This kind of Kevlar cap was more generally available in the past, but is not now produced by most body armor manufacturers. As a guess, this change is a result of a general recognition that the protection offered in very limited, and that the manufacturers have generally opted to not sell a product that could create unrealistic expectations in our current litigations society.

As with any equipment, the important thing is to understand its limitations and consider how these limitations relate to your particular requirements. In talking to Sgt. Swarm, I learned that the most common weapons threat faced in his jurisdiction is the low power handgun; the cap will be most effective against, so the cap would provide more protection for him than it would for others facing different threats.

Duncan MacPherson

Shots to the Pelvic Area

QUESTION

During September of this year one of my permanent staff range instructors attended a program, in pistol and shotgun techniques, sponsored by Bill Burroughs. As a result of that training, he is interested in obtaining additional information on the effectiveness of targeting certain areas of the body with pistol rounds.

Sgt. Edward Swarm

ANSWER

Mr. Burroughs advised that you may be able to assist in confirming or refuting her belief that there is validity in targeting the pelvic area. The theory being that due to certain autonomic responses the body undergoes during periods of stress the rounds fired by officers are likely to strike (low) the pelvic area, and that the human body is capable of suffering severe disability resulting from pistol wounds in that area.

Any assistance you can provide would be appreciated.

Mr. Michael Lenahan
OIC Firearms Training
Ontario Police College, Canada

ANSWER

I welcome the chance to refute the belief that the pelvic area is a reasonable target during a gunfight.

I can find no evidence or valid rationale for intentionally targeting the pelvic area in a gunfight. The reasons against, however, are many. They include:

- From the belt line to the top of the head, the areas most likely to rapidly incapacitate the person hit are concentrated in or near the midline. In the pelvic vis, however, the blood vessels are located to each side, having diverged from the midline, as the aorta and inferior vena cava divide at about the level of the navel. Additionally, the target that, when struck, is the most likely to cause rapid and resultant death is the spinal cord (located in the midline of the abdomen, thorax and neck), ends well above the navel and is not a target in the pelvis.

- The pelvic branches of the aorta and inferior vena cava are more difficult to hit than their parent vessels -- they are smaller targets, and they diverge laterally from the midline (getting farther from it as they descend). Even if hit, each carry far less blood than the larger vessels from which they originated. Thus, even if one of these branches in the pelvis is hit, incapacitation from blood loss must necessarily be slower than from a major vessel hit higher up in the torso.

- Other than soft tissue structures not essential to continuing the gunfight (loops of bowel, bladder) the most likely thing to be struck by shots to the pelvis would be bone. The ilium is a large flat bone that forms most of the back wall of the pelvis. The problem is that handgun bullets that hit it would not break the bone but only make a small hole in passing through it: this would do nothing to destroy bony support of the pelvic girdle. The pelvic girdle is essentially a circle: to disrupt its structure significantly would require breaking it in two places. Only one shot that disrupted the neck or upper portion of the shaft of the femur would be likely to disrupt bony support enough to cause the person hit to fall. This is a small and highly unlikely target: the aim point to hit it would be a mystery to those without medical training – and to most of those with medical training.

The “theory” stated in the question postulates that “certain autonomic responses the body undergoes during periods of stress” causes officers to shoot low, and that apparently this is good in a gunfight because such shots cause “severe disability.” I hope that the points presented above debunk the second part of the theory. As for the “autonomic responses” that cause officers to shoot low, I am unaware of anything in the anatomy or physiology of the autonomic nervous system that would even suggest such an occurrence. Most laymen do not understand the function of the autonomic nervous system. It is simply a system whose main function is to fine tune the glands and smooth muscles (those in the walls of organs and blood vessels) of the body. During times of stress such as perceived impending danger, the autonomic nervous system diverts blood from the intestines and digestive organs to the skeletal muscles – in the so-called “fight or flight” response. The effects of this response are constantly exaggerated by laymen who lack an adequate understanding of it – most notably by gun writers eager to impress their readers. Interestingly, the human body can get along quite well without major parts of the autonomic nervous system. During my professional life as a surgeon, myself and colleagues removed parts of thousands of vagus nerves (mostly in treating peptic ulcer disease) – thus depriving the patient of the major part of the parasympathetic half of the autonomic nervous system. We also removed many ganglia from the sympathetic half of the autonomic nervous system, in treating such things as profusely excess sweating and various problems caused by spasm of the arteries. I am unaware of any evidence that these operations produced any significant effect on the future capacity of these patients to react apro-

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Dear Dr. Fackler,

I have read with interest four IWBA articles (1, 2, 3, 4). What is really needed is not a "panacea", one must contemplate ALL the advantages, but a more appropriate rifle caliber for police. The comment "near hysterical stampede to the .223 by law enforcement groups" refers to the widespread adoption of the .223 without consideration of the severe limitations of this round for use on the human target, in the apparent belief that it is a panacea for the limitations of handguns in law enforcement. I believe that the efficient use of the .223 by law enforcement requires an appreciation of sound wound ballistics principles. In particular, the use of inappropriate short barrels, and inappropriate ammunition are common, and greatly reduce the already marginal effectiveness of the .223 in law enforcement.

Please see the answer to the question by Officer Wilcox (p 4-4) for clarification on my views on the marginal nature of the .223.

One of the objectives we are trying to achieve in the Wound Ballistics Review is to provide our law enforcement members with sound information so they can make valid recommendations on armament to their administrators. Law enforcement needs the best we can offer, and we need to make sure what we propose is actually the best. The inevitably unsatisfactory consequences of poorly selected .223 weapons and ammunition will not help the officer in the field either during the encounter or when he tries to get something else from his administrators.

Martin L. Fackler

REPLY

Dear Dr. Fackler,

It was my original intention for my 21 Dec 98, responses to your editorial to be of personal dispatch. However, by all means feel free to use it in the Journal if you so desire.

In addition, it certainly was not to my intention to challenge your wound ballistics expertise. I've attended several of your lectures and know better.

When you deliberately speak of the .223 as the "panacea", one must contemplate ALL the advantages, not just barrel length and bullet selection. With its superb delivery system and remarkable accuracy, even the shortest barrel AR with the worst performing bullet is better than any buckshot over 4 meters. We found it very important to play the "aa compared to what" scenario. As an example, when we were selecting a .223 cartridge, IWBA technical studies indicated the M855 had a slightly better wounding profile than the M193. The M193, however, is far more accurate than the M855. Decisions, decisions. Keep up the good work.

John Bedell, O.I.C.

Firearms Training Unit, Pembroke Pines Police

The .358 Winchester as a Police Rifle

I have read with interest four IWBA articles having to do with increasing the frontal area and weight retention of bullets which have passed through common barricades, such as car doors, plate glass, and more complex arrays such as aircraft windshields. (References 1, 2, 3, 4). What is really needed is a better bullet, but a more appropriate rifle caliber for police marksmen. If the engagement range of police marksmen is really as short as that reported by the FBI (about 70 yards), then a low velocity medium bore is probably indicated.

The .358 Winchester, 35 Whelen, and .358 Remington Magnum have never been very popular sporting cartridges and a suitable police load may not exist for any of them. Federal recently introduced a 225 grain Trophy Bonded for the .35 Whelen. Winchester offers a 200 grain Power Point. The Power Point uses a soft, thick, brass jacket (rather than copper), and is probably the best conventional expanding bullet line, offering premium performance at a Wallmart price. A 225 grain Power Point or Trophy Bonded .358 Winchester would probably be as reliable as the Nosler partition. A very satisfactory police load could be developed by using a 225 grain Nosler partition bullet in either cartridge case. It is possible to safely hand load a 225 grain Nosler at over 2500 fps in the small Winchester case with a compressed load of IMR 4895 powder. While this is the only powder listed which is capable of reaching this velocity, the Whelen and Remington can equal or exceed this velocity with several powder combinations.

The .35 caliber has an unexpended frontal area of 0.10 square inch compared to 0.504 for a .308 caliber, 0.089 square inch for the popular .338, and 0.110 square inch for the .375. Expanded frontal area of a .358 can range from .378 to .476 square inch at 2550 fps. I have had a lot of experience with the medium bores at close range killing American Buffalo with shots to the neck and spine. This shot placement gives the bullet only a few inches of tissue to expand in, and is unlikely to be replicated by a moose or a deer.

Despite their high energy and use of premium bullets, the .257 and .300 Weatherby Magnum would not kill a buffalo with one shot to the spine. Though the buffalo would go down quickly, they always needed a finishing shot. These high velocity small bore cartridges are very destructive on deer sized animals they were surprisingly ineffective on neck shots. The .338, .357, and .375 would kill buffalo with one shot, even when used with inferior bullets (like the inappropriate .308 or .338 Winchester Magnum and .504 muzzle loader) were poor killers, being much less effective than the .257 and .300 WM. There appears to be a complex relationship between frontal area and impact velocity.

What is significant to IWBA members is that the relatively low recoil 35 Whelen or .358 Remington loaded with the Nosler or bonded core Bitterroot bullets would kill as well as the high-energy .358 Winchester Magnum. Since so much velocity is lost passing through automobile and aircraft glass (180 - 634 fps as reported by Lt. Robertson), most rifle caliber's are going to have to depend more on frontal...
area and bullet mass than energy and bullet fragmentation to be effective. This suggests use of a medium bore like the .358 Winchester may be an ideal police cartridge.

Ammo makers may have to rename this unsan­
tum cartridge something like, "The .358 Police," to make it appealing. For shots within 300 yards, a prop­
ertly loaded .358 should equal or exceed the frontal area of the best 9mm pistol bullets, with more than twice the impact velocity. A .358 Remington extends this velocity threshold to 350 yards, and a .358 Norma Magnum to 400 yards.

I have been surprised that none of your authors have experimented with the .308 Nosler partition bul­
let as loaded by Federal. The copper partition will at­
least insure that the rear portion of the bullet gets through a barricade. The Nosler was the original pre­
mium hunting bullet, dating back to 1948, and is still equal to a 150 grain 30-06. In a typical 10 - 12
second and 3.3 lb seconds as energy with the mean­
ingless unit of lb ft/sec. This just is a nomenclature error because the recoil energy calculation is correct and in the correct units. Mannes' recoil calculation methodology assumes that the effective powder gas velocity is 1/4 times the muzzle velocity. This as­
sumed velocity is probably a little high for the loads under discussion, but any error is too small to signifi­
cantly affect the recoil numbers calculated by Andy.

Duncan MacPherson

Finally, I would like to suggest that when using a copper bullet like the Barnes X bullet, or a bonded core bullet with solid base or partition to halt expansion like the Trophy Bonded or Swift A Frame, that the lightest bullet available be used. The long, partially ex­
panded bullets are more prone to turn over and break up on a complex target array. The Nosler partition can also turn over, and expand from the base. A higher than normal rotational velocity is useful in keeping the bullet point forward, but it is even better to use a lightweight bonded bullet that has a short overall length. Since it is bonded, a bullet with greater SD is not needed.

The Trophy bonded with its solid base and the A Frame with its partition are both longer than desirable for a tactical bullet. The Bitterroot was the original bonded core bullet, being invented by Bill Steigers, of Lewiston, Idaho in 1965. It's tapered jacket which measures 0.065 inch thick at the base has never been duplicated by his many imitators. The Secret Service tested the 7mm and .308 Bitterroot in 1981. They were the only bullets tested to maintain structural integrity and accuracy after passing through the glass used in commercial skyscrapers. Unfortunately the Bitterroot will never be made in adequate numbers to be available to law enforcement agencies. And like all bonded bullets, they lack the match quality accuracy to inflate a marksman's ego.

I would urge any of your members to send one

of their .308 Winchester barrels to a gunsmith to be re­
barreled or re-bored to the .358 Winchester. Load it with a case full of 4895 and a 225 grain Nosler partition, and repeat any of the FBI's barricade tests. You won't be disappointed!

Andy Tillman
Retired Editor of the International Defense Review

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ume 2, no. 4 pg. 22-24, IWBA.
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6. Bullet Performance in the .375 H & H Magnum, by Andy Till­

Gun Retention, M1 Carbine vs .223

I've noticed a certain emphasis lately on the sad fact that about a sixth of police officers fatally shot are killed with their own guns, snatched by a bad guy re­
sisting arrest. This is a presented as a good reason for officers to use ammo which won't go through their own body armor.

We have here another case of a simple statistic that might turn into bad policy. If I'm close enough to grab an officer's weapon, I can probably tell if he's wearing armor. Current body armor might be called a good reason for officers to use ammo which won't go through your own body armor.

We have here another case of a simple statistic that might turn into bad policy. If I'm close enough to grab an officer's weapon, I can probably tell if he's wearing armor. Current body armor might be called a good reason for officers to use ammo which won't go through your own body armor.

Can any one out there tell us how many body armor "savers" were made against the officer's own armor? Can't we do it right now, at the expense of a lanyard loop and a couple of bootlaces? Must we wait for Colt, or someone else, to perfect some pistol that will only work for policemen?

It is to the great credit of the Journal when you assess the possible choices for "patrol car rifle". The ordinary officer these days is pretty sophisticated. He is educationally somewhat ahead of the common Army recruit, and there is no reason to think he can't be trusted to manage a good semi-auto rifle.

But what is assessed? Cut-down M16's and expensive foreign sub-machine guns, mostly. Hanging on my wall is a rather cheap weapon which could do most of the chores we expect of a patrol car rifle -- an M1 Carbine. We also note that the Ruger Mini-14 and Mini-30 are rarely considered. They don't cost $800 a copy, and they don't look like they fell off a flying sau­
cer that was trying to get back to civilization. In these designs, extractor, ejector, bolt face, locking lugs andcams, are all visible and open. They can be cleaned and lubed pretty well without taking the gun apart. Simple to be attached to the prowl car, not the patrolman.

The details of wounding effects so far discov­
ered show that in 5.56mm there isn't much to gain by varying bullet construction. We don't have much wigh­
gle room with a projectile of 45-60 grains. In 7.62X39mm, good police ammo design should be easier -- we can play with weights of 90-150 grains, and ve­
locities of 2000-3000 fps, and we ought to be able to find something reliable against people, not just wood­
chucks.

Anyhow, here's the $40. Talking to smart peo­ple is worth it.

Leon Day
Understanding the Law Enforcement Issues in Suicide by Cop

Shirley MacPherson, P.D.

Introduction

"Victim Precipitated Suicide" is a clinical term for the action of an individual who chooses to be killed by law enforcement officers as an alternative to a conventional suicide. The act is now commonly referred to as "Suicide By Cop", the term used herein.

Suicide by cop has existed for decades, but no hard data had been systematically compiled to support this category of officer-involved shooting until Richard H. Range Hutson, Research Director at Harvard Medical School, examined 425 fatal and non-fatal police shootings in Los Angeles County from 1987-1997 and found one in six were suicide by cop. The number would rise to one in five if ambiguous cases were included in the final accounting. Los Angeles County Sheriff's Department has reported that suicide by cop is now acknowledged by law enforcement, is now being acknowledged as a separate category from "criminal intent to commit assault on a police officer" and "justifiable homicide".

Suicide by cop has exploded, according to Hutson, and the hard data had been systematically compiled to support this category of officer-involved shooting until Richard Range Hutson, Research Director at Harvard Medical School, examined 425 fatal and non-fatal police shootings in Los Angeles County from 1980 to 1994. He concluded that ten per cent of fatal police shootings were suicide by cop. Dr. H. Range Hutson, Research Director at Harvard Medical School, examined 425 fatal and non-fatal police shootings in Los Angeles County from 1980 to 1994 and found one in six were suicide by cop. The number would rise to one in five if ambiguous cases were included in the final accounting. Los Angeles County Sheriff's Department has reported that suicide by cop cases have soared in 1997. Cases in which these shootings left individuals dead made up 27% of fatal officer-involved shootings during that year. Dr. Harvey Schlossberg, retired director of psychological services for the New York City Police Department, described suicide by cop as another form of euthanasia, similar in some respects to reaching out to Dr. Kevorkian. The principal difference here is that the pain is mental, not physical. Why the delay in recognizing this category of suicide?

1. It is difficult to accurately substantiate a suicide by cop, which is usually a judgment call, Anecdotal accounts by intimates of the victim, suicide notes penned by the victim, or records documenting previous suicide attempts can strongly indicate suicide by cop, but are not definitive evidence.

2. The bias of the courts reflects societal prejudices of communities in general which are influenced by religious, cultural and ethnic constraints on suicide. There exists a general reluctance to accept the premise that individuals can and do provoke law enforcement personnel into an escalated battle in order to be killed. Both courts and local communities in which the incidents occur have a tendency to interpret the law enforcement behavior as aggressive and punitive in these particular police shootings, denying the culpability of the true perpetrator, the suicidal individual.

3. Suicides by cop are less than 10% of overall suicides in the United States, and consequently have been overlooked by social scientists, the legal system, and others.

We can hope that as more studies document and substantiate suicide by cop cases, the reluctance on the part of the judicial system, communities and general public to accept the authenticity of this phenomenon will begin to evaporate.

Representative Suicide by Cop Shooting Scenario Outcomes

The following shooting scenarios represent the spectrum of perpetrator actions and outcomes in suicide by cop scenarios; these cases involved at least 40 minutes of dialogue before any shooting, and all these cases appear to have been planned as suicide by cop by the perpetrator. None of these cases involved shooting law enforcement deaths or injuries, although these have occurred in suicide by cop cases. In all of these cases there was dialogue with the perpetrator prior to any Vol 4, No. 1 shooting, although this does not always happen in cases that are at least arguably suicide by cop.

Scenario I

An ex-convict and parole violator, Thomas Belshie, on a suicide mission, failed to engage police officers in a suicide by cop in San Pedro, California, December, 1997. None of these cases include law enforcement with police Belshie brandished a weapon at officers, but did not fire. Special weapons team officers fired tear gas into his car, shot him with a non-lethal round and pulled him from his car. The officers involved adhered to departmental use of force policy in confrontational situations, with the result that there was no loss of life and no injuries to anyone.

Scenario II

William Griffin in 1981 had taken hostages in a bank in Rochester, New York. His only demand was that police execute him. Clinton Van Zandt, an FBI special agent commanded police and the FBI during the three and a half hour standoff with Griffin. Van Zandt refused to take Griffin's life although hostages taken by the gunmen were threatened. Griffin executed one of his hostages and then, only then, did Van Zandt allow the police to apprehend him. In this case, departmental use of force policy was either faulty or violated, with a resulting innocent hostage death in addition to the suicide of the symptom of the suicidal gunman was Van Zandt, who second-guessed the perpetrator and lost. He has lived with his decision and his nightmares since the event.

Scenario III

In July, 1997, Associate Press released a story about Henry Brown. He stood outside the Shelby, North Carolina police station, a .38 Rossi in one hand and a .357 magnum in the other. With 24 officers surrounding Brown, he shouted, "Do your job." One of Brown's pistols discharged, and a marksman killed Brown in response to his action; there were no injuries or other deaths. There is no way to know whether Brown's pistol discharge was accidental or intentional. After the fact analysis of the victim/perpetrator's actions and intentions is of no value to officer-involved shootings. The officers had the choice of either adhering to departmental use of force policy or risking another Griffin/Van Zandt case.

Scenario IV

The case of Michael P. Generakos of Costa Mesa, California, is illustrative of the mental pain evidenced by these suicidal victims. Generakos, a 45 year old unemployed teacher in Lakewood, California, believed he could call attention to his deaf son's educational needs by taking two administrators of the Orange County Board of Education as hostages in November, 1998. He also had mental anguish in losing custody of his two children. He was quoted as saying to intimates "I came here today to get myself killed because I don't have the guts to kill myself!". The Costa Mesa Police and SWAT TEAM went by the book. The departmental use of deadly force was employed in order to save the lives of two hostages. Strict adherence to established police policy in armed confrontational standoffs with a self-destructive subject resulted in one fatality (the victim/perpetrator) and no injuries. The investigation showed that Generakos actually had a relatively harmless pellet gun, but this was impossible to determine from the scene. The hostages themselves thought it was a firearm. This encounter required either shooting Generakos or violating departmental use of force policy with a decision to put the lives of the hostages at risk. The decision not to risk another Griffin/Van Zandt case was sound.

Public Response to Suicide by Cop

The public reaction to suicide by cop varies widely, with this variation between individuals being driven partly by their reaction to law enforcement in general. The general public's attitude toward law enforcement personnel is measuredly divided, with only a small segment of the population appreciating the difficulties of their work. The segment of the public that usually supports law enforcement generally sees no need for a revised use of force policy in response to suicide by cop. On the other hand, individuals who tend to consider law enforcement personnel as bullies interested primarily in trampling civil liberties and otherwise acting aggressively and oppressively tend to view incidents of suicide by cop as a validation of this philosophy. There is a real need for law enforcement to respond differently. A variant of this second group is the belief that law enforcement personnel are poorly trained and do not understand the psychological needs of the victims, but "shot first and ask questions later". On the other hand, individuals who have the skills of a mental health professional in order to prevent the death of such persons. The differences in interpretations between these two groups are remarkable; the former seeing a gun-slinging to kill people vs. the latter not hurting anyone or after the fact "every other thing"...
The Legal System Deals with Suicide by Cop

Although law enforcement has recognized suicide by cop over the years, the courts have not been supportive of this interpretation by participating police officers. In fact, judges in some cases have refused recognition of suicide by cop citing Daubert (lack accepted scientific basis for evidence). What happened in the Grimes/Van Zandt case is a classic scenario; law enforcement personnel historically have been faced with a hard choice of putting innocents at risk in an attempt to save the life of a homicidal/suicidal individual. The courts and the legal system in general are under extraordinary pressure from political leaders and special interest groups to accommodate this view. As a result, they tend to want the police to have a superhuman, intuitive sense that enables them to determine whether the perpetrator represents a Scenario II (killing a hostage) or a Scenario IV (no attempt to harm hostages) encounter. This determination has life or death consequences and must be appropriately reliable even though it sometimes must be made in seconds.

The considerable confusion and misunderstandings surrounding suicide by cop issues extend to legal status. As a case in point, an article on suicide by cop stated that the police position on this issue is becoming more difficult because "...the Supreme Court ruled that cities can be sued for inadequate police training that leads to death or injury - even when mentally ill or suicidal people threaten police officers with firearms. The decision came in a case brought by the wife of a suicidal man who manipulated Muskogee, Okla. police into killing him in 1994." This is an erroneous interpretation of the case and factually wrong in all important particulars. On March 2, 1998 the United States Supreme Court declined review of the Tenth Circuit Court of Appeals ruling on this case; they did not rule on the case, but merely let the Appeals Court ruling stand. The Appeals Court's ruling was not on the case itself, but was a ruling that the hearing court erred in issuing a summary judgment for the defense (the municipality sued). The hearing court's dismissal was in effect a statement that the police actions during the confrontation were proper; this increase has destroyed any claim that because the police tactics leading up to the shooting (which were not manipulated by the decedent) were egregiously bad by any reasonable standard. These poor tactics effectively forced the decedent's actions that led to the shooting, which by itself was not improper. This incident and the associated legal actions do not depend in any way on suicide by cop issues; the only relation to suicide by cop is a statement by the decedent that the police actions during the confrontation were proper; this increase has destroyed any claim that because the police tactics leading up to the shooting (which were not manipulated by the decedent) were egregiously bad by any reasonable standard. This case does not yet have a verdict of any kind, much less one that sets a standard for law enforcement conduct that requires the officer to determine the perpetrator's state of mind.

Mental Health Professionals Deal with Suicide by Cop

The suicide by cop phenomenon has placed increasing pressures on law enforcement officers to modify standard departmental use of force policies in dealing with emotionally disturbed individuals who display lethal threat and/or lethality. The decision has life or death consequences and must be appropriately reliable even though it sometimes must be made in seconds. The considerable confusion and misunderstandings surrounding suicide by cop issues extend to legal status. As a case in point, an article on suicide by cop stated that the police position on this issue is becoming more difficult because "...the Supreme Court ruled that cities can be sued for inadequate police training that leads to death or injury - even when mentally ill or suicidal people threaten police officers with firearms. The decision came in a case brought by the wife of a suicidal man who manipulated Muskogee, Okla. police into killing him in 1994." This is an erroneous interpretation of the case and factually wrong in all important particulars. On March 2, 1998 the United States Supreme Court declined review of the Tenth Circuit Court of Appeals ruling on this case; they did not rule on the case, but merely let the Appeals Court ruling stand. The Appeals Court's ruling was not on the case itself, but was a ruling that the hearing court erred in issuing a summary judgment for the defense (the municipality sued). The hearing court's dismissal was in effect a statement that the police actions during the confrontation were proper; this increase has destroyed any claim that because the police tactics leading up to the shooting (which were not manipulated by the decedent) were egregiously bad by any reasonable standard. These poor tactics effectively forced the decedent's actions that led to the shooting, which by itself was not improper. This incident and the associated legal actions do not depend in any way on suicide by cop issues; the only relation to suicide by cop is a statement by the decedent that the police actions during the confrontation were proper; this increase has destroyed any claim that because the police tactics leading up to the shooting (which were not manipulated by the decedent) were egregiously bad by any reasonable standard. This case does not yet have a verdict of any kind, much less one that sets a standard for law enforcement conduct that requires the officer to determine the perpetrator's state of mind.

Dealing with the Reality of Suicide by Cop

Reference 6 includes an analysis of 240 shooting cases to assign the likelihood of suicide, and grouped them into five categories: Probable suicide - 4% possible suicide - 12% Indeterminate - 67% Suicide unlikely - 5% no suicide motive - 9% The striking fact about this analysis is the large fraction of the cases that are indeterminate in after-the-fact-analysis even though this analysis is not done in a stressful environment or under time pressure, and can include information that was not available to the officers during the confrontation. This inability to come to conclusion after the encounter is over illustrates better than any other argument why any attempt to identify suicide by cop during a confrontation is doomed as a general strategy. Note that a better understanding of suicide by cop might sometimes help crisis negotiators in their task of preventing the confrontation and not react until an incident without considering this possibility. Note also that even these crisis negotiators cannot predict with certainty what a perpetrator may do during any given incident.

In effect, a segment of the public and even some mental health professionals are asking the officer in the field to assess the threat in a situation based on what he subjectively believes to be the best evidence of this suspect and not what he sees as the threat posed to society at that moment. Putting responsibility on the officer to do a psychological analysis and to base decisions on this psychological analysis requires him to modify departmental use of force policy (presumably thoughtfully chosen and precisely delineated) on the spur of the moment. This approach is irrational and illogical and inevitably places the officer and others in jeopardy; note that Van Zandt was absolutely correct that a suicide by cop was being attempted, but his lack of proper action still got an innocent killed. Most law enforcement personnel understand this problem very well; the rest of society also needs to understand the practical realities of this problem.

Legal systems and the police agencies should have unambiguous, well thought out use of force policies that respond to the threat observed, and that do not attempt to utilize on-the-spot psychoanalysis. The responsibility of the field officer is to adhere to this use of force policy, not attempt to do more, no less, at all times under all provocations. The responsibility of the rest of society is to support the officer when he or she has the mental discipline to accomplish this difficult task.

References
3. Bennett V. Murphy, Civil Action 94-214, US Federal Court, Western District of Pennsylvania
12 GAUGE 00 BUCKSHOT AMMUNITION TEST

George Bredsten
Lead Instructor, Firearms Division, Steve Bryant
Inspector, U.S. Marshals Service, Dan Fair
lead Inspector, U.S. Marshals Service, Eddie Brundage
Arms, Firearms Division, Billie Savell
Arms, Firearms Division, all at Federal Law Enforcement Training Center, Glycno, GA

Abstract
The U.S. Marshal's Service has been interested in finding a replacement for the authorized Remington, 12 gauge 2 3/4" 00BK, 4DR. EQ. 12 Pellets (Index Number: SP12SMAG), provided the replacement load would produce a smaller dispersion (pattern), penetrate approximately the same and if possible develop less recoil. While the shotguns used by the U.S. Marshal's Service are exclusively Remington, Model 870's, the barrel length and choke configuration can vary; i.e., 14" Cylinder Bore (CB) to 20" Improved Cylinder (IC), with the current preference the 14" Modified Choke (MC) barrel.

A request was submitted by the U.S. Marshal's Service to the Federal Law Enforcement Training Center, Firearms Division to conduct tests to determine which, if any, 00 buckshot loads (available for testing) would meet the above requirements. These tests were conducted over a period of several months to determine the dispersion, penetration and velocity values. Barrel lengths of 20" IC, 14" MC and 14" CB were used to determine dispersion values at fifteen (15) and twenty-five (25) yards. The 14" MC barrel length was used to determine penetration values at fifteen (15) yards and velocity values at five (5) feet.

The results of this test tend to substantiate the FBI's general view (FBI Close Quarter Combat Shot­

Editorial Note:
This article abstracts the primary results and the conclusions in a detailed (about 85 pages) report of the same title describing the buckshot test program implemented by the authors. This study used 10 shot samples, and so is more extensive and reliable than the typical testing that uses fewer rounds. The full report contains details of each test shot and statistical analysis of test shots, and should be in the files of any law enforcement agency that uses buckshot. Space limitations preclude our publishing the whole report, but law enforcement agencies can order a copy of the complete report from: George Bredsten FAD - Bldg 221 Federal Law Enforcement Training Center Glycno, GA 31524

A Mean Dispersion Values
The differences between the mean dispersion (pattern diameter) values of each type of tested shotgun ammunition (10 shots each type) were quite varied.

15 Yard Pattern Diameter

Index Number
Minimum Maximum Mean*

RR12BK-00 05.375" 10.75" 08.3"
SPL12-00BK 05.625" 10.5" 08.5"
LE132 00 08.75" 12.75" 10.9"
RR12-00BK 08.625" 12.625" 10.9"
SP12SMAG 12.25" 15.625" 14.1"

*Mean values rounded to nearest 1/10 inch.

B Mean Penetration Values
As described under Test Protocol, C.2.d. of this test, the two types of tested ammunition which produced the smallest mean pattern diameters were to be tested for penetration by firing five shots of each load into calibrated 10% Ordnance Gelatin at fifteen (15) yards. The dimensions of this circular test medium were 17-1/4" diameter by >19" in depth (thickness) and a separate test medium sample was used for each test shot.

The difference between the mean penetration values of the two types of tested shotgun ammunition was insignificant.

Index Number
Penetration Minimum Maximum Mean*

RR12BK-00 13.1" 19" 16.73" SPL12-00BK 14.9" 19" 16.83"

C Mean Velocity Values
The differences between the mean velocity values of each type tested shotgun ammunition (10 shots each type - 14" Modified Choke Barrel) vary from insignificant to significant.

Index Number Velocity (feet p/second)

LE132 00 1003.6 1053.9 1020.6
RR12-00BK 1062.6 1120.3 1094.3
RR12BK-00 1068.7 151.2 1110.38
SP12SMAG 1097.5 1152.1 1118.96
SPL12-00BK 1148.4 1254.1 1188.24

D Recoil
Using an individual mean pellet weight of 5.1 grains, a shotgun weight of seven and one-half pounds, the mean velocity values of the tested loads, the following recoil values are listed in ascending order.

Index Number
Shotgun Weight Recoil Foot Pounds

RR12BK-00 7.5 lbs 10.4 ft lbs
LE132 00 7.5 lbs 10.8 ft lbs
RR12-00BK 7.5 lbs 12.4 ft lbs
SPL12-00BK 7.5 lbs 14.8 ft lbs
SP12SMAG 7.5 lbs 22.3 ft lbs

* Loads which produced the smallest mean pattern diameters.

Summary
1. Dispersion (Core/PATTERN)

a. 15 YARDS Comparing the pattern performance of the five loads from each of the barrels tested disclosed all five loads fired from the 20" IC barrel had a sufficient quantity (3+) of 00 buckshot pellets impact within the eight inch core. Four of the five loads fired from the 14" MC barrel had a sufficient quantity (3+) of 00 buckshot pellets impact within the eight inch core. Three of the five loads fired from the 14" CB barrel had a sufficient quantity (3+) of 00 buckshot impact within the eight inch core.
b. 25 YARDS Comparing the pattern performance of the five loads from each of the barrels tested disclosed...
none of the five loads fired from the 20" IC barrel had a sufficient quantity (3+) of 00 buckshot pellets impact within the eight inch core. One out of five loads fired from the 14" MC barrel had a sufficient quantity (3+) of 00 buckshot pellets impact within the eight inch core. One out of five loads fired from the 14" CB barrel had a sufficient quantity (3+) of 00 buckshot pellets impact within the eight inch core.

Distance 

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<tr>
<td></td>
<td>14&quot; MC</td>
<td>7.5 lbs</td>
</tr>
<tr>
<td></td>
<td>14&quot; CB</td>
<td>7.5 lbs</td>
</tr>
</tbody>
</table>

Conclusion

1. The results of this test disclosed several important 00 buckshot performance characteristics. First: The quantity 00 buckshot per load, i.e., 8, 9, or 12 was not by itself a critical factor in determining how many 00 buckshot pellets did or did not impact within the eight inch core. Second: Whether or not there was a significant deformation of the 00 buckshot pellets was not by itself a critical factor in determining how much penetration was or was not achieved. Of the two tested loads disclosed no significant differences in the depth of penetration achieved. Third: There was no meaningful difference in either the mean pattern size or the mean penetration attributable to velocity differences alone. Fourth: Generally, the 00 buckshot load gave a better pattern from the 20" IC barrel than from either the 14" MC or 14" CB barrels. The one notable exception was Index Number: RR12BK8-00 which produced significantly superior patterning (especially within the eight inch core area) when fired from the 14" MC and 14" CB barrels. Fifth: The load, RR12BK8-00 developed significantly less recoil than the load, SPL12-00BK.

2. A standard for penetration established by the FBI and accepted by many law enforcement agencies requires a minimum penetration of 12-inches and a maximum penetration of 18-inches in calibrated 10% ordnance gelatin. Projectile penetration less than 12-inches is considered inadequate to marginal and projectile penetration more than 18-inches is considered excessive and might result in projectile perforation of a human thorax.

3. When the two loads which produced the smallest mean dispersions (patterns) were tested at 15 yards for penetration in calibrated 10% ordnance gelatin, the difference in mean penetration was less than one (1%) percent. Both tested loads produced mean penetration values of approximately seventeen (17") inches. When the elasticity of the skin is also considered, the risk of excessively (00) buckshot perforation 00 buckshot pellet penetration is minimal.

4. Four of five 00 buckshot loads tested produced mean velocity values within 10% of each other. The one exception had a mean velocity about 16% higher than the load with the slowest mean velocity. The total pellet energy impacting the core at 15 yards will be about 987-ft lbs for RR12BK8-00 and about 803 foot pounds for SPL12-00BK.

Abstract:

Purpose: To establish the .308 Winchester 168 grain Briese Controlled Disintegrater ammunition wound profile.

Method: 10% ordnance gelatin, gelatin covered with heavy clothing, and gelatin embedded with swine ribs, was shot at 25 and 100 metres with 168 grain Briese ammunition in calibre .308 Winchester. Skinned black bear skulls backed with 10% ordnance gelatin blocks were also shot at the same distances.

Results: The bullets had consistent and core fragmentation in all the test events with penetration depths between 8% and 10% of the bullet diameter.

Conclusion: This bullet may have a practical application in a specialized operational use when over-penetration is unacceptable.

Introduction:

The wound profile method for measuring the damage caused by penetrating projectiles was developed at the Wound Ballistics Laboratory of the Lettermen Army Institute of Research in 1982. Its purpose was to clarify the interaction of penetrating projectiles with body soft tissues and establish a quantitative, predictive model for human wounds. This method was based upon shooting projectiles into 10% ordnance gelatin at 45° and recording the projectiles penetration depth, its yaw pattern, and its deformation (including fragmentation and the size and location of the temporary cavity it produced). The two mechanisms of wounding as discussed and recorded by Dr. Fackler in his Wound Profile, are those created by the permanent cavity, (which is the "bullet hole") produced by the projectile crushing the tissue it strikes) and the temporary cavity (which shows the approximate extent to which the walls of this hole were stretched a few milliseconds after bullet passage). MacPherson in his book Bullet Penetration - Modeling the Dynamics and the Incapacitation Resulting from Wound Trauma states "The maximum volume of the temporary cavity represents stored strain energy in the tissues of the target. The creation of wound trauma as a result of this strain energy storage is entirely dependent on whether the tissues have been stressed beyond their elastic limit." The large temporary cavities created by high velocity rifle bullets can create significant wound trauma in man sized or smaller animals.....

Discussing hand gun ammunition, MacPherson states "The strain produced by these small cavities is below the elastic limit, in most tissue, and so there is usually little or no tissue damage.......

Fackler, Surinach, Malinowski and Bowen recognized the magnitude of the effects of fragmenting bullets on tissue disruption in their research entitled Bullet Fragmentation: A Major Cause of Tissue Disruption when they stated "Tissue weakened by fragment passage may be split by a stretch that would otherwise be absorbed by the tissue’s elasticity." MacPherson also comments on the importance of bullet fragmentation at high velocities. "High velocity bullet fragmentation can lead to severe trauma in the temporary cavity: this is unusual in high velocity rifle bullet impact, but is rare in typical handgun cartridges (because velocities are lower and a bullet designed to break up will have inadequate penetration)."

The depth of penetration of the projectile prior to the bullet disruption and maximum temporary cavity formation must also be noted when determining the wounding potential of ammunitions. Recognizing the importance of establishing a quantitative model for human wounds, the wound profile as developed by...
Fackler was established for the Briese Disintegrater ammunition in caliber .308 Winchester by firing into 10% ordnance gelatin, gelatin covered in heavy clothing and gelatin with imbedded swine ribs. The distance before bullet deformation, the size of fissures created by the temporary cavity, the overall depth of penetration and an examination of the fragmentation of the ammunition was recorded.

The ammunition was tested following established RCMP methodology, with some variation. Skinned black bear skulls backed with 10% ordnance gelatin were also introduced as an additional test.

**Methods and Materials:**

All tests were conducted with a Winchester Model 70 action, incorporating a 24 inch McMillan barrel in caliber .308 Winchester. The serial number was 867842. The ammunition tested was the Briese Disintegrater ammunition, lot 1012V. The bullet that is loaded into the caliber .308 Winchester Briese controlled disintegrater cartridge is a match grade 168 grain boat tail of frangible design. It is a "multiple lateral lobe core" consisting of four long cores which interlock laterally designed to separate immediately after impact. Five rounds were chronographed with an Electronic Counters Division of MV Ordnance Industries Model 4040 Chronograph at an instrumental distance of 20 feet.

Dr. M. Fackler’s recipe for manufacturing 10% ordnance gelatin as outlined by Post and Thompson was followed. Only variations of previous RCMP methodology will be discussed. Test events were conducted at 25 and 100 meters. Three rounds in each test event were recorded. Calibration of all gelatin blocks was conducted using an Archer Model 87 pneumatic air rifle, serial number E3291, firing a copper coated BB. Fissures created by the temporary cavity were measured by placing transparent overlays over the gelatin block after it had been cut to the depth of the permanent cavity.

In the black bear skull tests, the cranial bone thickness, width of the skull, and the bullet fragment penetration depth into the adjacent ordnance gelatin were recorded.

**Results:**

![Result Diagram](image)

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**Tests at 100 metres**

**Shot Type: Bare Gelatin**

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<td>Corrected Penetration (cm)</td>
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</table>

**Penetration Tests Through Black Bear Skulls Into 10% Ordnance Gelatin Directly Behind Skull**

- Distance – metres: 25 - 100
- Skull Width – inches: 8 - 6
- Cranial Bone Thickness – inch: 0.14 - 0.11 - 0.12 - 0.19
- Penetration Depth (bullet jacket fragments only) – inches: 2.75 - 4.0
- Width of Temporary Cavity – inches: 0.54 - 2.75
- Bullet Fragment Weight Recovered in Gelatin – grains: 32.3 - 28.0

**Discussion:**

Depth of penetration prior to bullet deformation was similar for all tests at both distances. Neither ribs or cloth had an appreciable affect on depth of penetration of the fragmenting projectile. The total depth of penetration of the fragmenting projectile through the combined skull and ordnance gelatin was equivalent to penetration depths recorded in the other three test events. The single lobed temporary cavity was heavily laden with small lead alloy core fragments. The jacket fragments achieved the greatest depth of penetration. In two tests fired through heavy clothing at 25 meters and two tests fired through heavy clothing at 100 meters bullet fragments penetrated beyond the temporary cavity to a maximum distance of one inch. Impact with the skinned bear skulls resulted in the complete removal of the brain through the top of
the cranium. Skull damage was extensive, the skull fragmenting along suture lines, with total removal at the top of the cranium as well as the bullet exit. There was no appreciable deviation from the bullet path through the skull into the gelatin.

In further test shots unrelated to this original research project, two black bear skulls were shot at a distance of 20 metres using the same ammunition. Cardboard witness panels were placed two feet from the back of the skulls to examine the forward spatter of blood often associated with firearm injuries. The test data was intended to independently verify performance in gelatin in addition assessing the skull impact performance. This bullet is not now used by LAPD SWAT because the only available loading exhibited unsatisfactory functional reliability (bullets would occasionally pull from the cases).

Duncan MacPherson

Conclusion:
The bullets in all test events offered complete and consistent fragmentation. This bullet may have a practical application in a specialized operational use, when overpenetration is unacceptable (i.e. non-barrier II and consistent fragmentation. This bullet may have a small fragmenting along suture lines, with total removal at the back of the skulls to examine the forward spatter of blood often associated with firearm injuries. The research project, two black bear skulls were shot at a distance of 20 metres using the same ammunition. Cardboard witness panels were placed two feet from the back of the skulls to examine the forward spatter of blood often associated with firearm injuries. The test data was intended to independently verify performance in gelatin in addition assessing the skull impact performance. This bullet is not now used by LAPD SWAT because the only available loading exhibited unsatisfactory functional reliability (bullets would occasionally pull from the cases).

Duncan MacPherson

One can’t have a bullet that will never perforate the human target, and yet always penetrate deeply enough to disrupt major blood vessels in the human torso, especially if it has to perforate an arm prior to striking the torso. This lesson was learned by the FBI in the 1986 "Miami shootout" at the cost of two dead and five wounded agents. It is the reason that informed law enforcement groups now specify a 12 inch minimum penetration depth for their handgun bullets. For the same reason, this 12 inch minimum penetration depth also applies to the effective trauma volume of rifle bullets used in torso shots. Bullet fragmentation acts synergistically with the large temporary cavity produced by a 168 grain bullet at velocities above 2500 ft/sec to produce much more tissue disruption than a handgun bullet causes. However, this increased tissue disruption needs to be at an appropriate depth to ensure effectiveness on torso shots. This penetration depth is not required on head shots, where almost any .308 bullet is adequate. Snipers always talk about head shots, but there are an inordinate number of torso shots in my own forensic work and in cases reported to me by others.

Not all fragmenting .308 bullets have the temporary cavity located at the same depth. The Briese bullet and other similar designs that have a core that is a conglomeration of lead particles rather than cast or swaged lead tend to open up rapidly and have the temporary cavity located at an inadequate depth for torso shots. The Briese bullet was probably invented because of the inconsistent performance of the 168 grain Sierra Matchking bullet, as pointed out previously in this journal (Vol 2 # 2, 1995, pp. 8-12, and Vol 2 # 4, 1996, pp. 22-24). This subject is discussed in the editorial on page 3.

Duncan MacPherson

Vol. 4, No. 1

Note: At one time the Briese bullet was deployed by LAPD SWAT for head shot scenarios, and these tests were intended to independently verify performance in gelatin in addition assessing the skull impact performance. This bullet is not now used by LAPD SWAT because the only available loading exhibited unsatisfactory functional reliability (bullets would occasionally pull from the cases).

Duncan MacPherson

Editorial Note

The Briese bullet was probably invented because of the inconsistent performance of the 168 grain Sierra Matchking bullet, as pointed out previously in this journal (Vol 2 # 2, 1995, pp. 8-12, and Vol 2 # 4, 1996, pp. 22-24). This subject is discussed in the editorial on page 3.

Duncan MacPherson

Vol. 4, No. 1

Reference

1 The IWB Handgun Ammunition Specification Package, Wound Ballistics Review, Volume 3 #3, 22-27
THE LIMITATIONS OF WATER-FILLED CARDBOARD CARTONS IN PREDICTING BULLET PENETRATION

Gus Cotey, Jr.

Abstract

Purpose: To determine whether rows of water-filled cardboard milk and juice cartons employed as a test medium will accurately predict the calibred gelatin penetration results of projectiles with substantially lower impact speeds than those of typical modern small arms impacts.

Method: A total of 18 test shots of Linitotype alloy, 680-inch diameter, 428.9-grain (27.792-gram) spheres were propelled from a 12 gauge shotgun at recorded speeds of 93 feet per second (fps) to 1476 fps into single file rows of water-filled, 2-quart cartons. One of the carton rows had four 1-gallon cartons placed before the 2-quart ones to determine if this would affect overall penetration. Gelatin penetration was predicted by dividing actual carton row penetration (A) by 1.5.

Results: The lower the velocity, the greater extent to which the A/1.5 calculation overestimated gelatin penetration. Also, the disparity between actual carton row penetration (A) and gelatin penetration per MacPherson's model (M), tended to increase as impact velocity increased. This increase in A – M values was possibly related to the severity of carton burst effects as impact speeds increased. However, the placement of four 1-gallon cartons in front of a row of 2-quart ones had apparently no effect on overall carton row penetration at 1086 fps.

Conclusion: At very low velocities shots into carton rows will yield exaggerated predictions of gelatin penetration, especially with high sectional density, minimally disruptive projectiles. The lower a missile's sectional density and the more disruptive its shape, the lower the impact speed at which A/1.5 begins to approach accurate gelatin penetration prediction.

Introduction

The current state of the art soft tissue simulant is 10% Type 250A ordnance gelatin at a nominal temperature of 4°C (39.2°F), and calibrated to a BB penetration depth of 8.5 cm (3.35 inches) at 590 fps. With this medium it is possible to accurately predict penetration depths, expansion, fragmentation, temporary cavitation, and fragment pattern morphology for a wide variety of projectiles at practically all velocity levels. With the recent development of an analytical model and corresponding calibration correction procedures, it is now possible to measure penetration with heretofore unheard of accuracy. Unfortunately, not everyone interested in validating valid wall ballistics data has the facilities to properly prepare and use gelatin.

One method of testing bullets in the absence of gelatin is to use water-filled, 2-quart (1.89 liter), cardboard milk and juice cartons assembled in a single-file row, firmly pressed against each other as a testing medium. Previous experimentation has indicated that penetration for typical modern small arms projectiles at normally encountered impact speeds in water-filled, 2-quart carton rows is generally approximately 1.5 times what would be expected in calibrated gelatin.

Purpose

This series of experimental test shots was performed in order to determine whether or not missile penetration in single-file rows of 2-quart cardboard cartons would continue to be approximately 1.5 times what it would have been in calibrated gelatin as impact velocities decreased well below those normally encountered with modern small arms.

Method

The test media used in this experiment were single-file rows of water-filled, 2-quart milk and juice cartons made of polyethylene-treated bleached sulphite cardboard. The cartons were assembled on an 8-foot long, 2 x 6-inch board with 2 parallel pencil lines spaced 3.75 inches apart running along it lengthwise, which were used as guides to insure that the carton row was straight (a 2-qt. carton's cross section measured 3.75 x 3.75 inches). For one test shot at 1086 fps, four 1-gallon cartons were set up in front of the 2-quart carton row. These had 5 9/16 x 5 9/16-inch cross sections and a combined row length of 22.25 inches, or .25 inches short of the length of a row of 6 2-quart cartons. Prior to being shot the test cartons were carefully trim the sprues, blending them down to and buffered, with the first carton to receive the shot being designated as #1. Before pressing the cartons together, those equipped with threaded caps had these caps loosened and the threads lightly tightened when the pressing process was completed.

The test weapon was a Browning A-5 auto-loading 12 gauge shotgun with a 24-inch "Buck Special" improved cylinder choke bored barrel equipped with rifle sights. Test projectiles were .680-inch (17.28 mm) average diameter spheres cast of Linitotype (an alloy of 86% lead, 11% antimony, and 3% tin) used to make type for certain printing applications) with an average weight of 428.9 grams (27.792 grams). Each test was taken from scrapped typewriter pieces, rather than from virgin ingots. Plastic shotcups protected the test spheres from contact with the weapon's bore.

The spheres were cast using a Lyman-IDEAL #678.R.B. single-cavity iron mould. After the balls were cast, a 4-inch fine cut Nicholson file was used to carefully trim the sprues, blending them down to match the rest of the spheres' rounded profiles. Diameter measurements were taken with a Starrett No. 230 .680-inch analog micrometer with .0001-inch resolution. Projectile weight was determined after filing via a Lyman-Ohaus D5 balance-type scale with .1-grain resolution. The spheres' weights ranged from 428.7 to 429.2 grams.

Projectile velocities were measured with an Oehler Model 33 Chronotach chronograph. Skyscreen spacing was 4 feet, with the fastest screen from the test weapon's muzzle being approximately 8 inches from the first carton in the row about to be shot.

A sphere will present the same profile to the test medium as it penetrates regardless of whether or not it rotates on its axis, making this missile shape virtually yaw free and inclined to travel in relatively straight trajectories therein. The hardness of Linitotype alloy is adequate to prevent substantial deformation in valid tissue simulants at the 1500 fps maximum impact speeds anticipated for these tests. With 453 to .454-inch Linitotype spheres shot in gelatin, Duncan MacPherson noted the first visible signs of metal yielding occurred at about 1600 fps.

Results

All test shots overestimated calibrated gelatin results per MacPherson's model. The most accurate estimation of calibrated gelatin penetration came from shot #18 at 1476 fps, which predicted gelatin results to within 5.2%. The least accurate estimation came from shot #1 at 93 fps, which was over 10.7 times what MacPherson's model predicted. Generally, the lower the impact velocity, the greater the extent to which the test shot's calibration errors overestimated the penetration that would have occurred in gelatin.

Table 1 contains the carton penetration results for 18 shots into carton rows. The recorded velocity for each shot expressed in feet per second (fps) is listed along with the number of the recovery carton ("Rec. CTN") and the number of the carton row ("Row No."). The test weapon's muzzle being approximately 8 inches from the first carton in the row about to be shot.

A sphere will present the same profile to the test medium as it penetrates regardless of whether or not it rotates on its axis, making this missile shape virtually yaw free and inclined to travel in relatively straight trajectories therein. The hardness of Linitotype alloy is adequate to prevent substantial deformation in valid tissue simulants at the 1500 fps maximum impact speeds anticipated for these tests. With 453 to .454-inch Linitotype spheres shot in gelatin, Duncan MacPherson noted the first visible signs of metal yielding occurred at about 1600 fps.

"A" is the actual penetration based on the combined 3.75-inch widths of all cartons penetrated, plus the width of the recovery carton. Where 2-quart cartons are concerned one would simply multiply the recovery carton number by 3.75 inches to arrive at "A".

"C" refers to Cotey penetration calculation based on A/1.5. "M" is the penetration depth calculated via the model developed by Duncan MacPherson and described in his book, Bullet Penetration, listed in the references. The "M" calculations were done via computer courtesy of Duncan MacPherson. A - M readings were calculated to determine whether or not there would be a constant difference between these 2 variables after a certain velocity.
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Table 2

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Diagram of water-filled, 2-quart carton row penetration test results for 18 shots with .5804-inch, 428.9-grain spheres at velocities ranging from 93 f/s to 1476 f/s. "Rec. CTN" is the number of the recovery carton. "DENT" refers to the magnitude of the dent in the far wall of the recovery carton, with dent magnitudes classified as follows:

N: None Evident
S: Slight, barely discernible from outside, more easily discerned from inside of carton.
M: Moderate, easily observable from exterior without any cracks completely through wall.
CS: Carton wall split through.
PR: Projectile penetrated row.

* Almost a CSA.
** Almost entered carton #12.
*** Ball found on ground only 20 feet away, so it is assumed that it would have stayed in carton #13 if another carton were backing it.
**** Ball first penetrated 4 1-gallon cartons, then made it into the 13th carton of the 2-quart carton row behind the gallon ones.

Water-filled, 2-quart carton row penetration test results for 18 shots with .5804-inch, 428.9-grain spheres at velocities ranging from 93 f/s to 1476 f/s. "Rec. CTN" is the number of the recovery carton. "DENT" refers to the magnitude of the dent in the far wall of the recovery carton, with dent magnitudes classified as follows:

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Discussion

It would appear that a major factor determining the impact speed at which actual 2-carton row penetration divided by 1.5 (C" in Fig. 1) equals cali­
tron penetration occurs after shot #15. In cases where there were 2 velocities for a given depth, both speeds were averaged and the aver­
figures.

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COMPARISON OF THE TERMINAL PERFORMANCE OF .22 LONG RIFLE HOLLOW POINT BULLETS


Abstract

Purpose - To describe, with the help of a tissue simulant, the performance, fragmentation process and behavior of common .22 LR hollow-point loads found on the market.

Method - Thirteen hollow-point .22 Long Rifle bullets were fired into ordnance gelatin tissue simulant. Shots were taken at different distances to carry out research.

Results - The 180 % or greater reduction in velocity due to the shortened barrel caused a marked reduction in the expansion and fragmentation of the bullets tested.

Conclusion - The penetration depths, expansion, and fragmentation patterns of the bullet tested should give the forensic scientist a standard of comparison to assist in identifying the bullet type in a given shooting.

Introduction

Today in France, there are still many shootings involving .22 Long Rifle bullets. Although their wounding potential is less than that of most larger caliber bullets, they are the cause of a large number of deaths. There are many misconceptions in France regarding bullets effects due, in fact, to a paucity of the type of research reported in this paper. In our lab, .22 rimfire represents 13 % of cases. It is, however, with the 12 Gauge shotgun, one of the calibers most involved in crimes.

Regarding the "wounding potential" of this rimfire cartridges in France there are major problems. This situation is due to lack of information, knowledge and time to carry out research.

Though it is known that distance produces performance variations, and velocity, bullet drops or paths can be calculated with a ballistic software, the questions of bullet shape, weight, design, jacket thickness and hollow-point depth are almost never mentioned in ballistic case reports. These numerous parameters have a decisive impact on the winding process, and they are not always taken into account, which presents a proper understanding of the wounding process.

Appearing in 1887 and developed by J. Stevens Arms & Tools Company1, the first hollow-point bullets were introduced to the market in 1930 by Remington1. CCI-Stinger, Winchester X-Pediter and Yellow Jacket bullets followed the Remington bullets.

In France we have "experts" who believe that .22 hollow-point bullets are not powerful enough to cause a serious wound, and who have a limited knowledge of the wounding potential of .22 caliber rimfire bullets. Serious consequences for those wounded by these bullets, and miscarriages of justice in the forensic cases arising from such shootings, can be expected because of this lack of knowledge.

Method

As the use of standard US Kind & Knox 250 gelatin powder would have been difficult, we therefore decided to switch to a French manufacturer. The powder used in the mixture had to be tested in order to check its ability to be an efficient substitute to the original K&K powder.

The powder comes from the French manufacturer "WEISCHARDT INTERNATIONAL": this product is delivered in 25 kg (55lbs) bags.

Prior to the tests, we tried to reproduce the standard gelatin preparation and we checked the linear relationship between penetration and velocities. We used an air rifle and .177 inch (.45 mm) steel copper-plated BBs. Results of this test are shown on Graph One.

We also reproduced well-known wound profiles with our mix. We then used Weischard's powder as an efficient substitute in the original mixture.

<table>
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<tr>
<th>Load</th>
<th>Weight</th>
<th>Bullet Shape</th>
<th>Frontal Area (mm²)</th>
<th>Hollow-Point Depth (mm)</th>
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<tr>
<td>X-Pediter</td>
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<td>Round nose, copper plated</td>
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<td>1.4**</td>
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<td>22 Mag SJHP</td>
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<td>2.1</td>
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<td>Stinger</td>
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<td>1.4 *</td>
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<td>Minimag (HP)</td>
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<td>Flat nose, copper plated</td>
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<td>Lapua hollow point</td>
<td>2.35 - 36</td>
<td>Semi-pointed, hollow point</td>
<td>2.60</td>
<td>6.2</td>
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</tbody>
</table>

* Pentagonal hole
** Elliptic hole

In the following table, we present the results of our research.
With the help of Duncan Mac Pherson’s general procedures for gelatin, we reached the calibration standard (8.5 cm penetration at 590 ft/s) with a 11 % (by weight) mix of gelatin, which is in fact very close to the Kind & Knox ordnance gelatin ratio.

Gelatin was added in the water at 8 °C and about 13 grams of Thymol were added to avoid bacterial growth. We added this chemical product to delay bacteria development. The mix was put in a cold chamber at 4 °C. After, the gelatin mixture was heated slowly in a "Labovolt" double boiler to ensure that heating was progressive and regular.

The heating process was stopped after all the gelatin had dissolved. Particular care was given to avoid inhomogenous gel parts from being submerged. Temperature when the mixture was converted into liquid was around 35 °C (95 °F) and heating was stopped before reaching 40 °C (104 °F).

After being poured into 40cm x 20cm x 36cm moulds, the blocks were stored again in the cold chamber and left uncovered for a period of 48 hours. After this protocol, final dimensions were 20cm x 15cm x 36 cm (8 x 6 x 14 inches). Block weight was 13.50 kg (27 lbs), sufficiently heavy and large to avoid movement during the shooting process.

After being used throughout the tests and after being cut into pieces, the blocks were reheated in order to be used again. We remelted the gelatin no more than three times, in this way for the entire study 500 kg (1100 lbs) was produced.

We decided to use only bare gelatin in our tests, as we wanted in our study to determine the effects of .22 LR non-jacketed bullets fired into gelatin and to study their behaviors. Frequently the jacket plays a key role in controlling expansion in usual hollow-point bullets. For .22 Long Rifle hollow-point, a thin copper plating is applied to some bullets and other were conventional lead bullets.

Prior to testing, shooting range and gelatin block temperatures were recorded with a "Comark" thermometer to ensure that firing was effected with the correct temperature and to avoid viscosity being changed during shooting time.

Calibration was obtained by firing two standard .177 inch (4.5 mm) copper-plated BBs into the block, the air rifle being a Daisy Air Pump "Powerline 856" N°0796 04269. The BBs velocity and penetration were both recovered bullets to show differences or similarities with the failed bullet behavior.

Two different weapons were used during the shooting (see Fig 1), a German, single-shot action revolver, a "RECK-12" n°35996 and a Russian bolt action rifle "TOZ 17-01" N°RN13233. The German single-action revolver had a 15.1 cm (6 inch) barrel, and the Russian rifle had a 50 cm (19.7 inch) barrel. Both weapon types are found easily in France and are available to the common citizen.

The ammunition tested in the study came from various manufacturers. Test loads presented various shapes, bullet hollow-point designs and weights (see Table One, Fig 3). Selection was based upon several criteria. These bullets are commonly involved in criminal activities or gunshot cases, due to their widespread availability on the market.

Two types of tests were done:

Test I: 5 rounds of each bullet were fired with the TOZ 17-01 with a 50 cm (19.7 inch) barrel.

Test II: 5 rounds of each bullet were fired with the RECK-12 with a 15.1 cm (6 inch) barrel.

During the shooting process we tried to avoid temporary cavity radial fissure crossing between shots and maintained a typical shooting pattern (Fig 2). Velocities presented in data charts are impact velocities. In both events, if a shot velocity was not recorded by the chronograph, a subsequent shot was fired on the same block, and the failed bullet behavior was eliminated from the data presented but kept for subsequent checking.

After each shooting session, impact velocity, penetration, and bullet configurations were recorded. Measurements of wound cavities were made, with their maximum seize and position, to allow wound profiles to be established. After the gelatin was cut to be analyzed, the bullets were recovered.

Bullet measurements were done with a Mitutoyo "Digimatic" precision caliper: the bullet measurements being minimum and maximum expansion diameter, and remaining length. Largest and smallest diameters of the distorted bullet were averaged. Remaining weight was given by a Metler PM-400 scale.

Each gelatin block was photographed to help conduct bullet behavior analysis. Pictures were taken with all recovered bullets to show differences or similarities with all bullets fired throughout the study.
Figure 4
Fragments mostly encountered during the study. Fragments are from small to entire hollow point detached from the bullet (from the left to the right) CCI Minimag, Rem-Yellow Jacket, Lapua-HP, Rem-Yellow Jacket.

Figure 5
Base view of Lead Hollow point plugged in the hollow base, (from the left to the right) two Swartklip-Blitzer and two CCI-Stinger.

Figure 6
Sideview of Lead Hollow point plugged in the hollow base, (from the left to the right) two Swartklip-Blitzer and two CCI-Stinger.

Figure 7
Three different core-hollow point separation (left) separation coming from both side of the hollow point, (middle) break-up of a side, lead part tears and separate the rest of the hollow-point lead from the core (right) separation in one piece of the hollow point wall.

Figure 8
Most common bullets remains after the fragmentation (from the left to the right) Lapua HP, Swartklip Blitzer, Win X-pediter, Remington Yellow Jacket, Fiocchi HP.

Figure 9
Bullet impacting gelatin block with a yaw angle (shots done at 3 meters with the Reck S.A.R) no intermediate target was in front of the block. (Left) Remington High Vel (right) CCI Stinger.

Figure 10
Asymmetric expansion encountered during the experiment. Bullet were fired with a Reck handgun, (From the left to the right) Swartklip-Blitzer, Lapua-HP (Largest asymmetric diameter recovered), Swartklip-HP, and Eley Subsonic HP.

Figure 11
Regular expansion and soft edges (from the left to the right) RWS-low Noise with TOZ, CCI-Minimag with RECK, Remington High Vel-HP with TOZ, and RWS High-Vel fired with a TOZ.
Lowest and highest expanded diameters encountered during experiment and effects on penetration.

Two particular wound profiles for highest and lowest impact velocity recorded.

**Figure 12**

**Figure 13**

Wound profiles were created to allow bullet behaviors to be presented (see Fig-12, Fig-13). These simplified wound profiles were established with measurements taken from cut sections. Each shot was analyzed with this method. Lacking an X-ray equipment, we used front and side close-up pictures to help plotting fragments on profile diagrams.

**Results**

The results are shown in Figures 2, 4-13, Tables One and Two, and Graphs One and Two.

**Discussion**

**Velocity variation**

Ammunition fired with the German RECK revolver had an average velocity between 225 and 394 m/s (835 to 1290 fps). Those fired with the Russian TOZ rifle were between 306 and 500 m/s (1005 to 1660 fps). There was a difference of at least 60 m/s (197 fps) between same bullets fired with the two barrels. Being one of the numerous parameters of the wounding process, impact velocity seems to play a role in these lead bullet behaviors. Using this velocity variation associated with a ballistic software allowed distance variation for these barrel differences to be estimated. A CCI-Minimag shot with a TOZ rifle reaches the RECK's velocity at a distance of about 60 meters (Graph Two). This variation can be used in a distant shot case analysis.

**Fragmentation**

Fragmentation represented a value of between 30% to 70% in most cases. Fragmentation often occurred with light loads (Remington Yellow Jacket, Swartklip-Blitzer, Fiocchi-HP, CCI-Minimag, CCI-Stinger) with the 19.7 inch barrel. Only four loads did not retain their integrity with the short barrel (6 inch). With the TOZ rifle, only two loads retained their weight (Rem-High Vel and RWS Subsonic Low noise). Three other loads (Eley-Subsonic, Swartklip-Blitzer and HP) showed a weak weight loss even fired with the TOZ (a bullet over five had fragmented).

The velocity generally found to be necessary for fragmentation according to the experiment was 335-365 m/s (1100-1200 fps) for loads between 33 to 37 grains. Above 1200 fps fragmentation over 30% (Table Two). Various fragment sizes were found: Fig-4 shows these different types of fragments. It appeared during bullet measurements that Winchester X-Pediter Bullets have a pre-cut mark applied on the nose to lead to produce regular small fragments. Depending on the impact velocity, small square-like fragments were noted during the shooting experiments with the TOZ rifle.

At least three different bullets fragmenting processes were distinguished during the experiment (Fig-7).

The first process comes from an entire side of the bullet, with the hollow-point remaining is entire and crushed when detached (thin HP walls). This process induces a single large fragment.

The second process comes from a breakup of a part of the hollow-point wall. A strip-like detached lead part progressively tears the entire hollow-point lead. In this specific process, lead already separated under the pressure of the drag forces withdraws itself towards the rear of the bullet and strikes the base of the bullet. Few bullets were recovered with the hollow-point wall plugged in the base. Generally velocity impact is lightly slower than full hollow-point fragmentation. This process induces typical bullet remains (Fig-5, Fig-6).

Marks created by the lead striking the base can damage several lands or groove marks. It appears less easy to evaluate the characteristics of these rifling marks. Bullets fragmenting over 45% by weight have been shown to produce such distortions.

The last process takes place when the expanded diameter increases substantially to over 10 mm (0.40 inch) rapidly. The drag forces generated by this rapid expansion create a weakness inside the bullet. Expanded diameters separated from the bullet core and recovered in one piece are inside out. The inside hollow-point face is now outside. In fact, the weakest side at the border of the hollow-point base breaks first. Lead break-ups ensue from both sides and communicate together resulting in a large break-up. The result is a separation of the entire hollow-point.

Fragmentation patterns are mostly reduced, often erratic with loads between 33 and 37 grains. Few fragments are pushed outside the permanent cavity during the flight path. These fragments are embedded 0.5 to 2.0 cm from the center of the permanent cavity within the temporary cavity. The biggest fragments create their own permanent and temporary cavity. An interesting finding also is the releasing of lead components at the end of the flight this having occurred in many cases (Fig-13).

After bullet fragmentation, small remaining flattened cylinders were recovered at the end of bullet's
path (Fig-8). It was established that when they are smaller than 40 mm, they do not remain stable and go sideways. These small cylinders at all times, are slightly distorted (Fig-8).

After separation, hollow-point fragments stopped close to the end of the bullet (around 0.5 to 4 cm from the base). Some hollow-point lead parts remained attached (often by a thin link) to the bullet’s core (Fig-6).

Expansion
The expanded diameters of recovered bullets were variable, depending on the bullets fired. All types of expansion have been obtained, showing the same features with soft edges (Fig-11).

Many subsonic leads expand reliably with a barrel longer than 6 inch. When bullets yawed before impacting the gelatin blocks (3 shots out of 130), the hollow-point was flattened and curved away from the point of contact.

Asymmetrical expansion occurred before regular expansion, velocity threshold for semi-pointed hollow-point expansion have been obtained, showing the same features with a smaller diameter (Fig-12). A deeper diameter (Fig-12) was flattened and curved away from the point of contact.

Penetration
Attenion was given here to defining bullet behavior which might prove useful to a pathologist or to a ballistic technician when confronted with a wounded ballistic case.

During these experiments penetration was between 11 cm (4.33 inch) to 30.6 cm (12 inch). Generally most of 22 fired lay between 17 cm to 30 cm (6.69 to 10.8 inches). Penetration here depended from the bullet’s expansion, weight and fragmentation (Fig-12).

Maximum average expansion diameter found is 10.37 mm (.40 in) with the Lapua-HP fired with the handgun. Individually, Fiscochi-HP, and Yellow Jacket, have the largest diameter recovered. In such cases, cartridges were fired with the handgun. For these two bullets, expansion diameters were regular when recovered on account of their high fragmentation rate, but often a core and hollow-point wall weakness was noted, which compromise penetration and favored separation. They have quite similar penetration (11 to 13 cm).

Bullet weight
Retained weights for non-fragmenting bullets were different regarding nominal weight. A difference of 3 to 8% between the theoretical weight and fired bullets was shown during our experiments. Reaching a theoretical 100% retained weight was written when no fragmentation occurred in spite of a lighter weight. Generally bullets rated lower than announced weight by manufacturer. For example, over the ten Remington High-Vel fired, at least four came from distinct bullet case’s molds (distinct letter marks on the bottom of the bullet base).

Remaining bullet length
During our experiment, various lengths were noted. Table Two gives remaining length measurements. The smallest recorded measurement is 2.37 mm (0.09 inch) for a CCI-Stinger fired with TOZ rifle. For this round, extremely shortened, the bullet remained flattened at weight loss. The largest length is 11.39 mm (.44 inch) for an unexpanded bullet a RWS-Low Noise round fired with the Rem S.A.R (single action revolver).

TABLE TWO

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<th>Load</th>
<th>Lab</th>
<th>Lrl</th>
<th>Vel</th>
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<th>Rl</th>
<th>%</th>
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<th>Pen</th>
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 Vel- velocity (m/s and ft/s) 
 ED-average expanded diameter (mm/inches) 
 Pen-average penetration (cm/inches) 
 RW- average weight (grains / grams) 
 RL- average length (mm) 
 % average retained weight
Conclusion

Having a smaller wounding potential than larger calibers, .22 LR HP bullets have various performances. Unjacketed bullets produce behaviors including limited or deeper penetrations depending on the remaining velocity and fragmentation. Behavior were also strongly related to bullet construction. Nose shape, hollow-point cavity depth and depth weight together play a key role in .22 LR upset. Few bullets were able to reach 12 inches. Lighter bullets at higher velocities had a shallower penetration and a high fragmentation rate.

For forensics scientists, it is necessary to seek out information about load behaviors and performance encountered during a case examination. It is also useful to the check ballistics case theory. This can only be accomplished through bullet behavior research. After having acquired a solid knowledge of forensic and ballistic elements provided by experts, attorneys will be able to make more informed decisions in gunshot wound cases.

Acknowledgments:

I would like to thank all people who helped the author with this study: especially, Dr. M.L. Fackler, Mr. L. Haag, Dr. Eric Baccard, and Mr. Tcherkassow.

References

2. Ibid., p 290
4. Ibid., pp 133-135

BOOK REVIEW Duncan MacPherson

Rifle Accuracy Facts

Vaughn, Harold R. Precision Shooting, Inc. 222 McKeel St., Manchester, CT 06040

soft cover $34.95, hard cover, $39.95 +$3.50 S&H 290 pages, many photos, figures, and graphs

A book review in V3#3 of the Wound Ballistics Review and a comment on this review in V3#4 brought up the issue of a good book describing exterior ballistics for the general reader. I said I didn’t know of one then, and Rifle Accuracy Facts is not devoted to this subject, but will fill this purpose for many readers. With this as an introduction, we will go back to a standard review format.

Harold R. Vaughn is an engineer whose distinguished technical career was spent at Sandia National Laboratories in flight dynamics and aerodynamics. He retired in 1986, and devoted his considerable technical skills to an orderly analysis and test program to understand and demonstrate what factors contribute to making rifles shoot more accurately. I called Mr. Vaughn to discuss some technical details not relevant here, and we had an interesting discussion about small arms and technology. We both deplore the fact that modern engineering capabilities and techniques are so little used by those interested in small arms. There is little hope that this situation will be rectified anytime soon by the firearms and ammunition manufacturers, who are forced to be very bottom line oriented in this very competitive market. The amount of money required to run a laboratory that could revolutionize understanding of a variety of small arms features is relatively modest, but there is little hope for anything like this anytime soon. The few government facilities that might fund this work do not have staff with the required technical skills, and there is no obvious other source for the money. As a result, the primary source of advanced understanding is entitled individuals who are willing to devote their own resources and efforts to this end for the satisfaction of accomplishment. That is what Mr. Vaughn has done in the area of rifle accuracy, and fortunately, he has not only done this well, but has written it up well in Rifle Accuracy Facts.

Readers should be under no illusions; Rifle Accuracy Facts is not light reading, and not for anyone who thinks Guns and Ammo is a technical publication. Rifle Accuracy Facts is a superb book; most attentive readers will understand almost all the material in the main text. On the other hand, almost all readers will find that they have little or no interest in most of the appendix material (about 20% of the total) even though this will be invaluable to readers who wish to do sophisticated experimentation on their own or who are interested in detailed equations. The bulk of Rifle Accuracy Facts is a detailed description of Mr. Vaughn’s experimentation in making rifles shoot more accurately. This work is a true technical advance in understanding this issue, and the description of this work is interesting in its own right. Anyone seriously interested in rifle accuracy should own this book.

Anyone who wants a solid understanding of either interior or exterior ballistics should get this book even if they are not interested in rifle accuracy. The descriptions of interior and exterior ballistics (one chapter each) are both precise and understandable without forcing the reader to follow the details in a lot of equations. The important equations are there for readers who want them, but can be skipped without losing comprehension for readers not technically oriented. Each of these chapters could be “puffed up” to longer length and some readers might prefer this, but the information is efficiently imparted in the chapters as written and I personally prefer this approach.

Perhaps the best summary of the contents of Rifle Accuracy Facts is the chapter description given on the contents page of the book:

1. Introduction: Contains data on the accuracy to be expected from different types of rifles and backround information on why and how this work was done.
2. Internal Ballistics: Methods of measuring chamber pressure are discussed and the complete in-
ternal ballistics of a representative cartridge (.270 Winchester) are measured experimentally for use in later chapters. Such things as bullet engraving force, different powders, and cartridge case failure are discussed.

3. Chamber and Throat Design: Methods of machining chambers and throats and their effects on accuracy are discussed. Various types of rifling and barrel problems are analyzed.

4. Barrel Vibration: Detailed measurements and theoretical calculations of barrel vibration are presented along with methods of reducing barrel vibration. The effect of barrel vibration is measured on sporters, bench rest, and rifle guns.

5. Scope Sight Problems: Scope sight and scope mount problems are investigated and some solutions to these problems are found.

6. Barrel-Receiver Threaded Joint Motion: It was experimentally determined that the barrel-receiver threaded joint moves as a result of the shock from firing. A simple solution to the problem is described.

7. Muzzle blast: The effect of bullet in-bore cant and muzzle blast on dispersion were determined experimentally and theoretically. Methods of reducing dispersion from this source are presented.

8. Bullet Core Problems: Bullet core slippage due to the spin up torque is measured and found to be a problem. Other bullet problems are analyzed.

9. Bullet Imbalance: The static and dynamic imbalance of bullets is measured and the effect of imbalance on dispersion is evaluated theoretically and experimentally. The causes of bullet imbalance are discussed.

10. External Ballistics: The detailed motion of the bullet after leaving the muzzle is shown and the effect of this motion for a given initial disturbance is evaluated. The effect of wind, gyroscopic stability factor, and ballistic coefficient on the bullet’s trajectory are shown in detail. Chronograph development and use are discussed. Wind gauges and their use are covered.

11. Other Problems: Miscellaneous Problems, such as bore cleaning, bullet coating, drift free bullet design, case neck tension, and shooting techniques are discussed.

Appendices: Accelerometer design, barrel vibration computer equations, bullet balancer device design, six degree of freedom computer equations, tunnel range construction, rail guns, shadowgraph testing.

As the chapter descriptions indicate, most of the material in Rifle Accuracy Facts is related to rifles, not handguns. However, those interested in handgun interior and exterior ballistics should not despair. The material in chapters 2 and 10 uses rifle bullets as examples, but the principles also apply to handgun bullets.

Reviews are supposed to describe the book’s shortcomings, but I found only two small faults, neither important to most readers for different reasons. There is a typographical error in the equations for F1 and F2 on page 187 (exponent ½ on wrong bracket), but this will be recognized by most people attempting to use this equation and is of no importance to anyone else. The second topic is in the Chapter 11 discussion of “moly coated” bullets (the relatively recent technique of coating bullets with molybdenum disulfide and cearuna wax). Vaughn has done testing of some claims relative to the effects of moly coating bullets and has very interesting comments on several issues, but is essentially neutral on the effects of extended barrel life because he hasn’t proved this. This is a good example of how careful Vaughn is in making claims, a stance that many others in ballistics would do well to emulate. The careful distinction Vaughn makes throughout the book between what he has demonstrated and his speculations is laudable and very evident here. However, in this instance the advantages of properly moly coated bullets in extending barrel life have been established beyond reasonable dispute by many others, and Vaughn’s “could be true” is unnecessarily weak even though he hasn’t personally verified this. Again, readers who care will know this, and it doesn’t matter for the others.

Rifle Accuracy Facts is going to be recognized as a classic in years to come, you will be glad you got it.

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