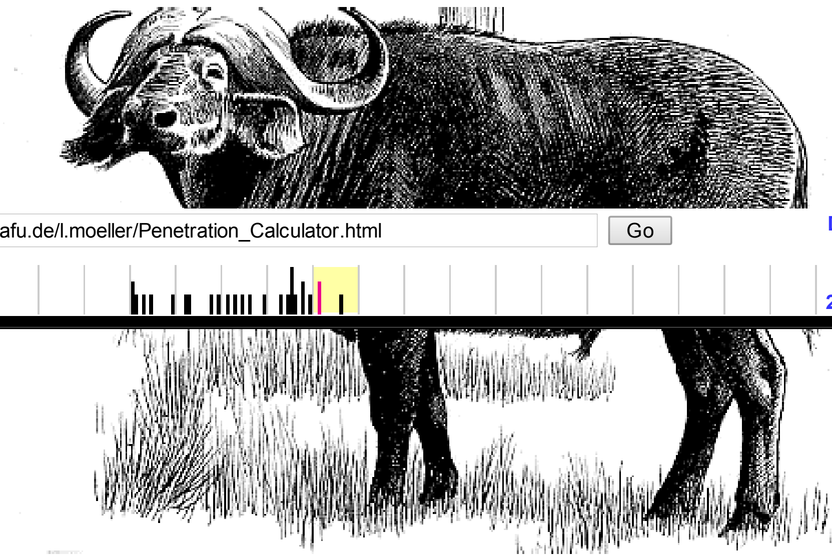
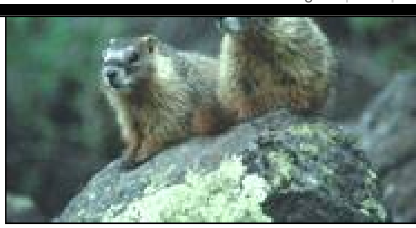
Bullet penetration

1st Issue





[Graphical Penetration Calculator](#) [Poncelet Penetration Calculator](#)

[Stanley Adams Penetration Calculator](#)

2nd Issue

If animals are hunted, one needs to know, whether the bullet penetrates into the life, means, whether it reaches deep enough to kill. Here i develop a simple Resistance model to foresay the Bullet flesh penetration.

To do so, I assume

1. Within two Calibres lenght Penetration blast soft semijacketed Bullets their Tip off, loosing some Weight. If any Bullet crimps towards a Mushroom shape, the Bow crimps within this short Depth. At high Speeds the Bullet looses Splinters. Those Splinters also leave the Bullet within this short Way. For the further Travel on, the Bullet then keeps its Shape.
2. After passing through the Target, Bullets will only leave the Target through the Skin, if the Bullet still moves with certain Speed (about 30 m/s). Else the elastic Skin captures the Bullet.
3. Flesh Pullstrength is assumed 40 Kp/cm^2.
4. As long as soft Bullets penetrate only boneless Flesh, they mushroom always alike. Small calibred Bullets (between 6 and 8 mm) mushroom 2,2 to 2,6 mm on each Side

   Example: 6 mm Hornady V-Max mushrooms from 6,17 mm diameter up to 10,5 mm diameter. Bigger Bullets mushroom wider.
5. Soft tipped jacketed Leadbullets form upon Impact always a lense shaped Bow. If the Jacket rips off, the soft Jacket Rim rounds with about 1,5 mm Radius. Thicker Jackets round to larger Radius.

At any Bulletspeed the Flesh pull strenght remains constant. The resulting Shearforce has to be accounted by the Sheardrag = Area * Pullstrength.

Bulletdrag = Sheredrag + Pressueredrag.

Hydrodynamic Pressuredrag is such

> v := velocity [m/s]
> m := mass [g]
> p := jam pressure [Kp / cm²]
> F := force [Kp]
> a := acceleration [m/s²]
> rho := Flesh density [g/cm³]
> Cd := drag coefficient []
> A := area [cm²]
> t := time Zeit
> x := Penetraion way [cm]

The Brakeforce is F = p*a.
The Jampressure is F = A * ½ * rho * v² in SI-Units
To account for the Non SI Units we apply factor 1/100 and hence write F = A * ½ * rho * v²/100.

As the above Jampressure only presses right in the Bowcenter, levels towards the side off, we use a Dragcoefficient C_d to describe the working Force as F = F* C_d

From above experience backed Assumptions, mainly from the same shaped Bow, follows, all impact flattened Bullet resist in Meat with the same Dragcoefficient. The fabricated Differences (Spitzer, Roundnose Flatnose) flatten always towards the same Bow. Duncan McPherson researched those Dragcoefficients and states several C_d's: Cylindre 0.83, roundnose 0.57, Cone 0.52. As he unfortunately states no Value for the typical flattened Bullet bow, I assume C_d Bow 0.7, which corresponds well with Experience.

> Read: Duncan MacPherson´s book "Bullet Penetration": Modeling the Dynamics and the Incapacitation Resulting From Wound Trauma, published by and obtainable from: Ballistic Publications, Dept. NH, Box 772, El Segundo, CA 90245. $39.95 + ship, states further Calculations for Bullet penetration. Look here!

Sum Force along the Way

When we know initial Speed V_0 Mass and Force at all Waypoints, we can integrate the Forceintegral over the Way to yield the final Penetration. Beeing too lazy or dumb or modern to integrate analyticaly, i let the Computer solve numericaly Step by Step in Javascript by the following Alghorithm. The analytical solution did Poncelet

> Hint: Before you calculate Penetration, cognize exterior ballistic Speedloss. So mix Target V_0 Speed at X_0 not with Muzzlevalues. We strictly, only look at the Target.

Forceintegral over the Way :

- The Bullet meets the Target with V_0 Speed at X_0 Way.
- The accompanying Jam pressure p_s = ½ * rho*v² develops (fully in the Frontcenter).
- 1^{st} Calculation: Over a very short Way we assume the Speed v = s/t and force constant.
- Within this infinitisemal short distance we calculate from mass and Brakeforce the resulteing Acceleration against the Speed by a = F/m.
- 2^{nd} Calculation: Above Decelleration yields resulting

  Bulletspeed $v_1 = v_0 - a*t = v_0 - F/m*s/v_0$ at the Stepend x_1.
- Loop 1^{st} and 2^{nd} Calculation until the Bullet stops or the Sow ends.

Save this File http://home.snafu.de/l.moeller/Penetration_Calculator.html on your Disk to calculate off line

Penetration Calculator `1st Issue`

v := Speed [m/s] to hit the Target

m := Mass [g]

k := Calibre [mm]

mc := Crimp [mm] radially at each side, use 0 when no Crimp occurs

wl := Mass loss [g], use 0 when no Weight is lost

jd := Bulletlength [cm]. Within this lenght, the Weight is lost.

rho := Target Density [g/cm³] 1 for Meat, 2 for Bone

ps := Flesh Pull Strenght [kp/cm²] 40 kp / cm², much higher for Bone

C_d := Drag coefficient [] Choose C_d ○ Cylinder 0,83; ◉ Lensebow 0,7; ○ Roundnose 0,57; ○ 45°Cone 0,52.

X := Calculationdepth [cm].

default | clear | calculate

A := Bulletsurface � [cm²] results after Bullet crimps towards a Mushroom shape

p := Jampressure [bar] in Bow middle

F := Force [kp] on hole Bullet

a := Decelleration [m/s²]

t := Time since Impact [sec]

x := Penetration [cm] If you calculate stepwise, this x-result must be added to the previous.

Lutz,

Its not a typo. Your analysis is too simplistic. The most significant thing that you neglected is, that the deformation of the bullet and the penetration of the target do not terminate at the same time. The deformation of the bullet terminates very quickly after it enters the target (animal). However, there is another aspect, that is very important and that is the material characteristics of the bullet as compared with the target. The densities differ by a factor of 10 and the flow stresses by at least that much. Since, according to von Mises rule, the stress is equivalent to the deformation energy per unit volume, a different quantity of energy can be involved in the deformation of the bullet than in the deformation of the target, even though both experience the same instantaneous pressure.

Hope this clarifies the situation,

If I understand your first argument, that the bullet stops "working" in a few centimeters of penetration while the target continues "working" for the full distance, then yes, that is it exactly.

The first phase of penetration is one in which the dynamic pressure acting on the bullet and the target is greater than the flow stress of either material, so both deform. This is called the *hydrodynamic phase*, because the bullet behaves like a fluid. They do not deform to the same extent, however; each deforms in accordance with its material properties (density & strength).

When the velocity is reduced to the point, that the dynamic pressure is equal to the flow stress of the bullet, then the bullet ceases to deform, but continues to penetrate because the flow stress of the target is still much lower than the dynamic pressure. This is called the non-hydrodynamic or *rigid body phase*, because the bullet acts as a rigid, non-deforming body. Solids behave in this way at all velocities (or they are supposed to). The penetration ceases when the dynamic pressure is equal to the flow stress of the target.

Von Mises rule is a mechanical explanation of elastic and plastic deformation by solids. One of the consequences of the relation is, that it becomes clear, that stress is also expressed as deformation energy per unit of volume. If the flow stress of a material is high, then a greater quantity of energy per unit of volume is required to deform it. Think of it as an energy sponge which can absorb more energy than the target material. So, with deforming bullets (as opposed to solids) a significant amount of the impact energy is spent on the bullet, not the target. At each instant, different amounts of energy are being consumed in the deformation of the bullet and the target. Although these systems are joined by an interface having a peak dynamic pressure, they are treated as independent systems.

I quoted the fraction of 20% to 40% from another source. I have not calculated this. It would not be a simple calculation, but I have been giving it some thought. If I can find a way of doing it without too much effort, I will let you know. There may be a way to extract that information from my hydrocode analyses, otherwise it would require performing a finite element analysis and integrating the deformation energies at each step. That's more work (I fear) that I had originally intended to put into my penetration model, but there may be a quicker method.

MacPherson seems to be using a modified form of the aerodynamic flight equations to solve the penetration problem. This is crude and not strictly correct but probably reasonably accurate for bullets, that either do not deform or which deform almost instantaneously upon impact (e.g., pistol bullets, which is I believe the primary subject of his research).

Get a reference source on hydrodynamic penetration. I highly recommend any of the papers published by Prof. Manfred Held of Messerschmitt-Bölkow-Blohm (sorry, can't make umlauts). These pertain to the penetration of steel by shaped charge jets, but the mechanics are the same for the hydrodynamic phase of penetration.

You can also adapt the Tate equations. These will be found in any good reference on ballistic penetration.

I was guessing that the flow stress of muscle would be roughly 10 MPa. It may well be 4 MPa as MacPherson suggests.

Have fun! :)
Hal

From: "Lutz Möller" <l.moeller@snafu.de> To: "Harald Ledbetter"<ulfhere@mindspring.com> Cc: "'Chris Bekker'" <chris@vouzi-isp.co.za>; "Gerard Schultz" <gscustom@intekom.co.za> Sent: Wednesday, March 13, 2002 5:48 PM Subject: Penetration

Hallo Gentleman,
Careful Penetration understanding, combined with equally profound knowledge of Bullet material constants like lead, Copper or Brass would lead to certain Recommendations which Bullets should be used on certain Targets, whether small or large, soft or big, to put the „Best Bullet" question to some Rest. Each Bullet has its own Merits on certain Targets, but misses them on quite different Targets. To choose the right Bullet with appropriate Speed for the given Target it the Art.
Sincerely
Lutz Möller

Thanks Lutz,
It looks useful and may settle some arguments. The biggest problem with Chris Bekker and the guys who support his theories is, that they do not understand the mechanism of a flat fronted cylinder that penetrates in tissue at speeds over 2700 fps. They do not grasp the fact that there is such a thing as different shape factors to take into account and that there are dramatic variations with these shape factors at higher speeds. At the Aim Shooters show two weeks ago I had some long discussions with people who have been involved with reloading for many years but have no ballistics background and it is a very difficult concept for someone with no technical background to grasp. They look at the mushroomed bullet and then at the cylinder shape and shake their heads and walk away. Time will tell and educate, I hope.
Regards Gerard

From: Dr Robertson**To:>** Chris Bekker 03 April 2002 11:42 **Subject:** Reply from Kevin re Penetration vs Lethality

Hi Chris,
While important, penetration is not the be all nor end all of a bullet's terminal performance - period. You need enough so that the bullet will get to where intended - but not too much so that it exits and wastes all its energy somewhere else. In my opinion,

No.1 in importance is shot placement. I've made this very clear in my book, 'The Perfect Shot' No animal will survive for more than a few minutes with the top of its heart or the big 'plumbing' which is situated there ruptured, together with its lungs (which surround that area) punctured, collapsing and filling with blood.

No. 2 is calibre. There is just no getting away from the fact that 'bigger is better'. This equates to more hitting 'punch', greater hydrostatic shock release and a larger permanent wound channel size. The bigger the hole, the more rapid the onset of the inevitable - period (provided the hole is in the right place that is)

No. 3 is bullet construction/type/weight/sectional density. Appropriately heavy expanding bullets being the ones of choice for most situations simply because of the better wound channels they create. In this day and age, solids are in reality only needed for elephants and awkward angle 'backing shots'. All the rest can be taken with the 'right' expanding bullets like the Barnes X bullet for buffalo. Lion & leopard are different. They require a more fragile bullet for greater 'shock' release, as to easily 'switch off' the felines highly tuned nervous system

Forth would come penetration, but it must be realized that all these factors are interrelated and must be considered collectively. Penetration is but one piece in the whole confusing puzzle. It serves no purpose in my book to compare different calibre's on penetration alone, especially as all the solids compared will shoot right through a bull buff from the side-on position. Another important factor is 'shootablity' for want of a better word. The 9,3 works so well because it is 'shooter friendly' as well as being 'adequate' ballistically. This all equates once again to shot placement and we're back where we started !!

Hope this makes some sense to you.

Keep in touch.
Kevin

Chris,

you wrote:

> The benefit of using the heavier bullet, even though at a lower velocity, that mushrooms to a smaller diameter, is clearly demonstrated.
>
> It is also interesting to see the variance in penetration depth between wet paper and flesh - evidently penetration is not so deep in flesh than in a Wetpack as it is generally denser. (Density differ between skin, muzzle and lungs for example)

Penetration, that is not „Power" or „Lethality", just a Prerequisition for a Bullets Ability to puncture or rupture a vital Organ (Central Nerve, Spine, Heart, Aorta, Lung, Liver …) in a big Bodies Depth after being braked by Skin (thick in cases) Flesh, Bones, Lung , … can be predicted. The real Hitpoint is much more important than anything else. A Big wound in a Leg somewhere will let the poor Animal flee for a long time an maybe even never be found by the Shooter, while a Neckshot in the Spine will ground anything in its Tracks.

In between is the interesting Field.

Your Observation, that bullet expansion helps to produce large Wound, needed in large Game more, than in small will lessen Penetration. Longer Bullets in the same Caliber and Material penetrate (with same expansion) always deeper then shorter (lighter) ones. The Fact you shoot shorter = lighter Bullets from the same Cartridge usually faster that longer = heavier ones, exacerbates the Expansion with the shorter, lighter = faster Bullets, again lessening the Penetration.

The natural Evolution from Experience was to shoot baling fast small short soft Bullets into Varmints very successfully, while you almost never will be able to kill a Hog with a .220 Swift, that already in the Skin blasts into Pieces, maybe never see any Flesh, less any vital Organ. To do so would be to torture the poor Pig, not to hunt responsibly.

The Speed plays in natural Material (Animals off Flesh and Bone) a minor Role (different with armor, Tanks and such) as the smallest penetrating Velocity is a given with all Bullets from Huntrifles.

I would not be so concerned about erratic results from Wetpapertests, as the Target varies greatly. Scientific Researchers take Great care to produce AND calibrate a Ballistic Gelatine. Unless that is done, Results are mere anecdotal.

Bullettest

> The only real easy test one can do is to vertically fire Bullets through a Chronograph into deep Water. Shoot into a Barrel in a Ditch with some Sand on the Bottom an a fine Net to capture the Bullet leftovers. The Barrel will most like likely rupture, so the Barrel shall not keep the Water in, but the Sand out. Some Clay around the Barrel will keep the Water. You gain knowledge about expansion and retained weight, quite close to shooting on Flesh. The experimental Conditions are easily comparable, as water changes its density in all its liquid State over Temperature only a little Bit. The Penetration in Water cannot guide you, as the slow Part is completely different as in Flesh as Water gives no Shear Force but Flesh and much more Bone, does.

So to realistically compare Bullets with each other

1. first shot them in Water to know Expansion and retained weight,
2. Feed a Penetration Calculator with the obtained Data, to know Penetration
3. Judge from the to be shot Animal whether the vital Organs may be reached from any Angle, including Bones
4. Judge wether the Resulting Wound seems appropriate for the size (please no Needle Sticks into Elefants Hearts)

Then shoot and hit as planned (the most important Part of all.

After saying all this it's obvious, that there is no single Value or Number may give a Hint on the Suitability of a specific Bullet, less Cartridge (where the Bullet is unknown) to hunt a specific Animal with a specific Shot. Only to understand the Animals Anatomy, know the Bullets ability (from Water test and Calculation) and good Marksmanship will improve the first shot Lethality of an unknown Bullet.

To believe differently is hopelessly naive.

Sincerely

Lutz Möller

Von: Ulfhere [mailto:ulfhere@mindspring.com] Gesendet: Mittwoch, 31. Juli 2002 06:50 An: Lutz Möller

Lutz,

Regarding the illustration, I would have thought that the assumptions were clear. The text states that the assumed termination velocity was 1900 fps. That is arbitrary. It could be any number of values, depending on design. The remaining KE is simply 1/2 the retained mass multiplied by the remaining velocity squared. This is simple math. I created a series of curves corresponding to different retained masses and plotted the hydrodynamic penetration phase energy as a function of these different masses (as a fraction of original mass) from 3000 fps to 2000 fps, assuming a constant 1900 fps termination velocity (selected so that I could have a chart that went all the way to 2000 fps impact velocity). It is important to remember that some of this energy is used by the target and some by the bullet. Both deform. At the end of this phase only the target continues to deform.

By "pull strength" I think you are translating "tensile strength". It is important to use yield strength or flow stress, and not ultimate tensile strength. I am not familiar with the units, except N/mm2, which is MPa, but these values look about right. The correct equation governing the critical velocity (vcr) for termination of the hydrodynamic phase is given by:

vcr = [2 (sp - st) / pt] ^ 1/2, where:

sp is the flow stress of the projectile (N/m2, or kg/m-s2)
st is the flow stress of the target material (N/m2, or kg/m-s2)
pt is the density of the target material (kg/m3)

If all variables are expressed in kg, m and s, then the resulting units will be m/s.

Hal,

I understand you equal the Stagnation Pressure 1/ rho v^2 to the Yield stress sigma. If I got the Units right, I get above Values. So I understand you Model.

But this (from Duncan Mc Pherson*) puzzles me:

According to the Calculation, Lead should, when shot into Water, flow from 300 m/s on, So that's about 1.37 times faster. But it only meaningfully expands from 417 m/s onward. It seems the Matter can withstand short Loads much better than long ones.

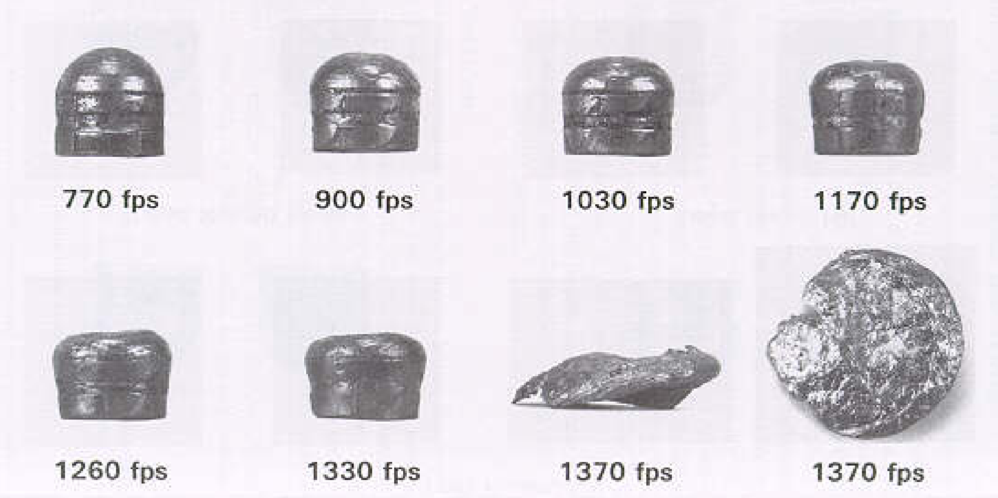
Would you have Constants for Lead, Copper and Brass that give better Results?

Sincerely
Lutz

Lutz,

What you have just discovered is the complexity (one aspect) that makes simple penetration equations too simple to ever be very satisfying. The difference between static yield strength values and real world behavior is due to strain rate dependent behavior in metals. Some metals are momentarily strengthened, others are work hardened. There are strength models that account for this over prescribed regimes of conditions, such as the Johnson-Cook model, the Steinberg-Guinan-Lund model, the Zerilli-Armstrong model and many others. They are all based on experiments conducted with Hopkinson Bar apparatus or similar arrangements to measure tensile strength and strain as a function of very high strain rates (more than 1e3). You might try searching for high strain rate strength models in the literature of material strength. All of these models were originally presented in papers or articles to journals. The difficulty you will have, I fear, is that you must calculate the strain rate at each integral step of the penetration, and doing that properly may require finite element methods and at least a 2-D analysis. But don't let that discourage you. Anything can be solved, even if it requires a homemade 2-D finite element code.

Figure 7-4
Cast Bullet Expansion Tests



235 m/s	274 m/s	314 m/s	357 m/s
384 m/s	405 m/s	417 m/s	417 m/

Regards,
Hal

* **Duncan MacPherson Bullet Penetration**: Modeling the Dynamics and the Incapacitation Resulting From Wound Trauma. ISBN 0-9643577-0-4 El Segundo, CA, 1994, Ballistic Publications, $39.95 Ballistic Publications, Dept NH, Box 772, El Segundo, CA 90245.

Stanley Adams Calculator

Von: Stanley Adams [mailto:sadams16m@hotmail.com] Gesendet: Montag, 11. August 2003 23:56 An: l.moeller@snafu.de Betreff: Software

There's a "Stopping Power v1.50" terminal ballistics program at www.geocities.com/sadams16/ The McTraj there has RA4, GL and GS drag models.

sadams16@juno.com

Hallo Stanley,

long time no hear. I hope you are well.

Kind Regards
Lutz Möller

Stanley M. Adams <sadams16@juno.com> Basic Penetration Calculator 9.0 ZIP

Hunt Bullet Selection
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