2007 Study Update, Part 4

Extreme FOC: Penetration Enhancing a 54# Longbow

By
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In prior testing, Extreme FOC arrows from both the 70# and 82# bow encountered the off-side rib penetration-barrier and/or the limit of measurable-penetration. Throughout all test sequences they demonstrated substantial increases in penetration over both normal and high FOC arrows, but penetration barriers left accurate *quantification* of Extreme FOC's effect vague. Accurate quantification required lower impact-force testing.

Prior to the 2007 testing-trip, a lighter draw-weight bow; scaling 54#@27"; was borrowed from a friend. Dimensionally-matched normal and Extreme FOC arrow-sets were developed for it, just in case testing with the 70# bow also failed to provide a clear-cut answer regarding the degree of penetration gain Extreme FOC could provide.

This bow is an older straight-end longbow, having performance typical of such bows. In addition to the arrows for FOC testing, one set of perfectly tuned arrows, approximating arrows typically used from such a bow, was also developed. Their purpose was to serve as a "baseline". Across the chronograph, this placid bow cast these 520.7 grain 'baseline' arrows at a staid 156 feet per second.

Test with this bow established the degree of Extreme FOC's effect on penetration, and conclusively demonstrated the remarkable penetration gains that can be achieved through enhancing your arrow's penetration potential. In its wake this humble bow has left intense implications for those who hunt big game with lighter draw weight bows.

Establishing a Base Line for the 54# Bow

No prior buffalo testing had been done with this bow. To permit comparison of the performance gain possible over a typical 'customarily used' arrow, it was necessary to first establish a performance baseline.

Baseline "Customarily Used" Arrow Setup for the 54# Bow: Parallel cedar shaft footed with purple heart, 11/32" (0.344") diameter; Zwickey Eskimo broadhead, double-bevel, and with the tip modified to a Tanto profile, finished weight 123 grains; Total arrow mass: 520.7 grains; FOC 10.3%; Impact Momentum: 0.351 Slug-Ft/Sec; Impact Kinetic Energy: 26.71 ft. lbs.; Shaft 9.47% smaller than the broadhead's ferrule. (All *impact* momentum and kinetic energy values, in all Study references, are for the 20 yard test-distance used.)

The Zwickey Eskimo was selected for use on this baseline setup because of its mechanical advantage (MA). The Eskimo has nearly the best MA among 'commonly used' broadheads, being far better than any multi-blade; much better than the majority of single blade broadheads; and slightly better than its closest rivals - the Magnus II and 125 grain Eclipse. The Ace Standard has a very slightly higher MA than the Eskimo, but was not used because of its poorer heavy-bone penetration performance (See *Part 7; 2007 Updates*).

With a footed shaft having a 'slick' finish, quality broadhead of relatively high MA, Tanto tip, honed and stropped double-bevel edges, normal FOC, favorable shaft-to-ferrule ratio, a mass-weight commonly used for bows of this draw force, and tuned for perfect flight; it is appropriate to think of this baseline group as representing the very "top end" among "commonly used arrows" for such a bow.

The performance of this 'baseline set' represents the best you can expect from most any 'common arrow' setup for a bow of this draw-weight and efficiency, short of incorporating the penetration maximizing features: higher broadhead MA, single-bevel edges, tapered shaft, higher mass (above the heavy bone threshold), Teflon™ broadhead coating and, of course, Extreme FOC.

The Baseline Group Outcomes: Six back of the shoulder shots were taken on large, trophy size male buffalo; at a broadside shooting angle, from 20 yards. One shot hit into a preexisting entrance hole from another shot, invalidating it. It gave 7.875" of penetration. Among the remaining five shots, none penetrated the entrance rib. They showed penetrations of: 5.0"; 5.25"; 5.375"; 6.125" and 6.875", for an average penetration of 5.75". None of the arrows suffered structural damage.

No one should be surprised by the performance shown. With low impact-force and arrow mass below the heavy bone threshold, performance against the ½" thick rib bone was about as expected. It is well worth considering the number and location of bones of ½", or greater thickness that are found in lighter-built, more commonly hunted, big game.

On a true heavy-bone impact, this baseline gives a good indication of what the "likely outcome" will be with this 54@ bow and any "commonly used" arrow setup. As you read through the performance of the test arrows that follow, keep these "top-end common arrow" outcomes in mind.

Testing and Evaluating Penetration-Enhancing Factors

Existing buffalo test-data contains several hundred shots with both the 70# and 82# bow. It was not only possible to set up baseline and 'like arrow' comparisons with the lighter bow, but also derive comparative analysis against database average-outcomes for 'commonly used' normal and high FOC arrows from each of these heavier bows.

Great effort was placed into developing each arrow setup for the light draw-weight testing. Extreme FOC arrows; having mass above the heavy bone threshold and showing perfect bare-shaft flight; were developed first, then normal FOC arrows with *precisely matching* mass and external dimensions (excepting a 0.433" difference in shaft length) were developed. Obtaining perfect bare-shaft flight from a normal FOC arrow; while maintaining *precisely* matching arrow profile and mass; required extensive trial-and-error juggling of the weight-distribution.

Another Look at Single-Bevel vs. Double-Bevel Broadheads

This light draw-weight test series also provided an excellent opportunity to take yet another look at the single-bevel vs. double-bevel broadhead issue. All required was to mount the 189 grain Pro Big Game on a portion of the 54# bow's normal-FOC arrow-group, and a 190 grain Grizzly on the balance.

The 189 grain Pro Big Game has astonishingly close dimensions to the 190 grain Grizzly (when the Grizzly's tip is modified to a COI design and the edge-angle changed to the 25 degrees I routinely use). They form a ready-made test set. Both have COI Tanto tips and straight-taper cutting edges. Each has equally long, smoothly tapering ferrules, with a smooth fade-in of ferrule into blade face. Ferrule diameter differs by only two-thousandths (0.002) of an inch; being 0.400" on the Grizzly and 0.402" on the Pro Big game. Total edge-bevel angle on each is 25 degrees; with the Grizzly (as tested) having a $25^0/0^0$ single-bevel and the Pro Big Game having a $12.5^0/12.5^0$ double-bevel. Cut width differs by only six thousandths (0.006) of an inch, with the Grizzly having the wider cut. Mechanical advantage (MA) is near identical; 2.75 and 2.71. The accompanying photos show their similarity.

The 190 grain Grizzly (L) and 189 grain Pro Big Game
(Shown on short shaft sections, permitting foam-block mounting for the picture)

Ferrule profiles: 190 Gr. Grizzly (L) and 189 gr. Pro Big Game

From the package, the 190 grain Grizzly weighs well over 200 grains, before sharpening and tip modification. Earlier production models of the 190 Grizzly employed a different brazing material, and these weight around 213 grains from the package. Current production models average 203 grains. For these test, the earlier, heavier Grizzly broadheads were used, and each was taken down as *precisely as possible* to 190 grains.

Similar detail was paid to the Pro Big Game heads, as well as every other component, for each and every arrow used throughout these test series. Even the fletching for each arrow was matched in weight prior to being attached to the shaft.

Final adjustment of weight variance for each finished arrow was made with *tiny* droplets of glue applied at the fletching's trailing edges. Except for the degree of FOC, arrow match is as precise as I could achieve. Weight tolerance for every finished arrow in Test Sets 1, 2 and 3 was held to *within plus or minus 0.50 grains*.

Arrow setup for test Sets 1 & 2 (the 54# bow's normal FOC arrows with differing broadhead edge designs) was:

Set 1; the 54# bow's double-bevel broadheads; normal FOC: Total mass, 723 grains; Pro Big Game 189 gr. (25 degree double-bevel edge, with COI Tanto tip); Cabela's 45-60 shaft; aluminum insert; hollow aluminum broadhead adaptor, weighted with JB Weld; snap-in nock weighted with JB Weld; and one piece of 2.7 mm diameter weed eater line. FOC was 10.3%. Impact Momentum, 0.421 Slug-Ft/Sec.; Impact Kinetic Energy, 27.55 ft. lbs.

Note the 3.1% increase in impact kinetic energy and 19.9% increase in impact momentum (at 20 yards) the extra 200 grains of arrow mass makes over the 54# bow's top-end 'commonly used' arrow; the 'baseline group'. This is a result of higher arrow mass and increased bow efficiency with the heavier arrows.

Set 2; the 54# bow's single-bevel broadheads; normal FOC: Total mass, 724 grains; Grizzly 190 gr. (25 degree single-bevel, with COI Tanto tip); Cabela's 45-60 shaft; aluminum insert; hollow aluminum broadhead adaptor, weighted with JB Weld; snap-in nock weighted with JB Weld; one piece of 2.7 mm diameter weed eater line. FOC, 10.3%. Impact Momentum, 0.421 Slug-Ft/Sec.; Impact Kinetic Energy, 27.58 ft. lbs.

Obtaining an exact match in both flight quality and total mass, while keeping shaft length as near identical as possible between the normal FOC comparison groups (Sets 1 & 2) and the Extreme FOC arrows (Set 3, below) required weighting the hollow aluminum broadhead adaptors and nocks. A measured amount of powdered steel ("Atomized Steel" from Brownell's Inc.) was mixed into the JB Weld, for additional weight. Once the JB Weld had cured, the fill-material was carefully ground down with a Dremel™ tool until the weight of each nock and each adaptor was identical.

Test-Shot Conditions

All shots, for both the 'baseline group' and all test sets, were on freshly-culled, very large, trophy-class buffalo bulls. Each was taken from a range-finder verified distance of 20 yards. All were from a broadside shooting angle. All were taken less than 30 minutes after animal collapse. Each group's shots (including the 'baseline' set) were divided among the buffalo used for testing, maintaining as much uniformity as possible. Because of the pronounced overlapping rib structure on mature buffalo every back-of-the-shoulder shot must penetrate bone.

Bevel Test Results

Set 1 (Normal FOC; Double-Bevel)) Outcomes: A total of seven shots were taken with Set 1. All impacted back of the shoulder. There were shaft-cracks on three of the shots, with each failing to penetrate the entrance-rib. Their average penetration was 5.96". The 4 structurally-intact shots penetrated the entrance-side rib, and gave outcome penetrations of: 8.5"; 8.875"; 9.125" and 10.125", for an average penetration of 9.16".

Note the increased heavy-bone penetration rate and average penetration increase over the 54# bow's "baseline" group; the "top-end common arrows". Bone penetration rate for Set 1's *structurally-intact* arrows is 100%, and their average penetration shows a 59.3% increase. Both the bone-breaching rate and the increased penetration are a result of greater arrow momentum and higher broadhead MA. The degree (percentage) of penetration increase shown by Set 1's heavier, normal FOC arrows is over *19 times* the 3.1% impact kinetic energy increase over the 'baseline group'. It is also almost *3 times* the impact momentum increase. Why?

(1) The Pro Big Game's 49.7% greater mechanical advantage over the "baseline group's" Eskimo is using the arrow's total available force more efficiently. More efficient use of available force means a greater *time* of impulse; the arrow keeps penetrating *longer*.

(2) Set 1's arrows are 39% heavier than those in the 'baseline group'. The contribution arrow mass makes to momentum has more effect on the *time* of impulse than does arrow momentum derived from increased velocity. This is because arrow mass remains constant throughout penetration, whereas velocity decreases exponentially during penetration.

This is one more example *implying* that it is momentum's *impulse of force* formula that determines outcome tissue penetration: the momentum *multiplied* by the time period over which the momentum acts. Increasing momentum, and/or the efficiency with which arrow momentum is used, results in a percentage of tissue-penetration increase greater than the percentage of momentum/efficiency increase made.

Set 2 (Normal FOC; Single-Bevel) Outcomes: A total of six shots were taken with Set 2. All impacted back of the shoulder. The shaft cracked on one, and its penetration was 7.5". The 5 structurally-intact shots had outcome penetrations of: 9.5"; 10"; 10"; 10.5" and 12.5", for an average penetration of 10.5".

Here the average penetration increase over the 54# bow's baseline top-end "common arrows" is 82.6%. Against baseline arrows, this represents an additional 23.3% increase over that shown by Set 1 (the double-bevel Pro Big Game), and is solely a result of the single-bevel advantage. This is *indicative* that the single-bevel broadheads are using less arrow force in breaching the bone, conserving force that can be applied to increasing penetration.

The Edge-Bevel Effect: Comparing Apples to Apples

Between Sets 1 and 2's normal FOC arrows; *for all arrows not suffering structural failure*; the single-bevel Grizzly averaged 14.6% more penetration than the double-bevel Pro Big Game. Four of the five hits with the single-bevel Grizzly show 10" or more penetration; exceeding or essentially equaling the double-beveled Pro Big Game's *single best* penetrating shot. The single-bevel's worst-penetrating shot exceeds the double-bevel's *average* penetration.

Using arrows that are virtually identical, and at equal impact force, the consistency of outcomes is *demonstrative* that the single-bevel broadheads are using less arrow force in breaching the bone, conserving force that can be applied to increasing penetration.

The Single-Bevel Advantage

Matched-set bevel testing on normal FOC arrows has now involved numerous single-blade broadhead profiles, tested at several impact levels; using three longbows and a compound. In every test-series the single-bevel broadheads have unfailingly demonstrated a *marked* bone-breaching advantage, resulting in a higher frequency of bone-penetration and/or greater average outcome penetration. Among these tests, the average single-bevel penetration-increase ranged from the 14.6% difference shown by the 54# bow with very high MA heads to 58% for some wide-cut, low MA broadheads; which were tested with the 70# and 82# longbows and the compound.

In bone-penetration rate (*frequency)*, low MA broadheads benefit more from having a single-bevel edge than do broadheads having high MA, and this is a major reason they show a greater *degree* (percentage) of penetration increase. *Do not* misinterpret the *degree* of benefit as meaning low MA single-bevel broadheads penetrate heavy-bone better than high MA broadheads; single or double-beveled. The high degree of single-bevel benefit merely indicates that low MA broadheads have greater room for improvement, because their initial bone-penetration rate is much lower. Having high broadhead MA shows a penetration benefit on all hits, and especially on bone hits.

Before we look at the performance of the 54# bow's Extreme FOC arrows (Set 3), let's take time to further discuss some of the factors highlighted by Sets 1 and 2, and the Baseline group.

The Importance of High Broadhead MA

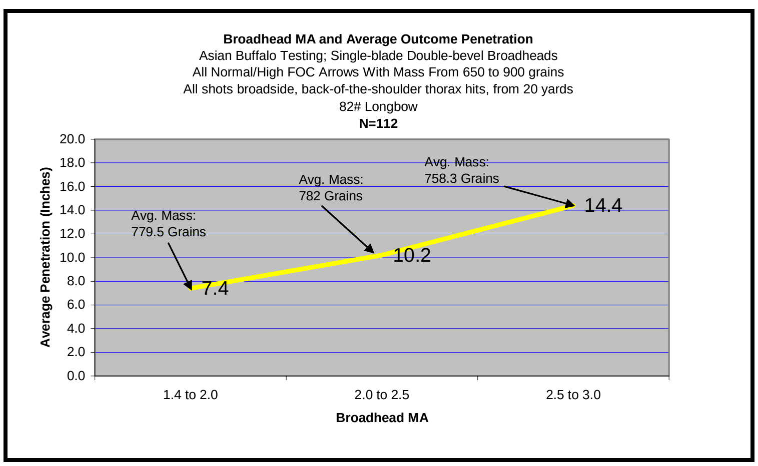
Broadhead mechanical advantage is an important penetration factor. How significant a factor is it? Let's take a look at the cumulative buffalo data.

First, lets delineate our data set: (1) All *adult* buffalo (male and female); (2) all broadside shots impacting the thorax, back of the shoulder; (3) from a 20 yard distance; (4) for all structurally-secure normal and high FOC arrows; (5) having a favorable ferrule-diameter to shaft-diameter ratio; (6) single-blade, double-bevel broadheads; (7) total arrow mass above the heavy bone threshold (650 grains) and below 900 grains (the 'super-heavy' arrows); and (8) from *only* the 82# longbow.

From this "MA-effect" data set, let's also eliminate some specific single-blade, double-bevel broadheads/types: (1) the Eclipse, because its Teflon™ coating gives it a demonstrated penetration advantage *after the bone is breached* (over that shown by broadheads of comparable MA) and, (2) those broadheads having data-verified features which markedly retard heavy-bone penetration (such as open-ring ferrules and/or radical blade profiles). Elimination of these yields more uniformity of broadhead characteristics in the data set we're using to evaluate broadhead MA's effect.

It must be remembered that this still leaves many broadheads with both excellent and poor ferrule-profiles in each set. However, the two lower MA groups shown contain a fairly balanced ratio between favorable and poor ferrule profiles, while the highest MA group has fewer less-than-optimum ferrule profiles. This would skew penetration of the highest MA group slightly upward.

For this data set, the following graph reflects the effect a broadhead's MA has on outcome penetration. Note that the average arrow mass for each group is very similar: 779.5 grains for the lowest MA group; 782 grains for the mid-level MA group; and 758.5 grains for the group having the highest MA broadheads. The lower arrow mass of the highest MA group would tend to skew their results downward, somewhat offsetting the advantage they have in the percentage of heads having favorable ferrule profiles.



The trend shown is as one should expect. It is, however, an interesting feature that the ratio of penetration increase shown is *roughly* proportional to the increase in broadhead MA ratio. Since each group has similar arrow-parameters (excepting broadhead MA), near-equal average arrow mass, and all are from the same bow, at the same distance, the average impact force would also be near-equal. The difference in penetration should, indeed, roughly reflect the different efficiency each broadhead-set applies the near-equal arrow force.

As noted above, the highest MA group's preponderance of excellent ferrule-profiles should skew their penetration upwards, and the outcome reflects this.

NOTE: Some folks seem to misinterpret the "Heavy Bone Threshold" to mean that only arrows of this mass or greater *ever* penetrate heavy bone, or that *any* arrow above this mass *always* penetrates heavy bone. This is incorrect.

The Heavy Bone Threshold is merely a point of arrow mass where the data indicates an *abrupt and marked increase* in the *frequency* of heavy bone penetration. It is present for all broadheads tested, of all types, and is consistently *near* a mass of 650 grains; ranging from approximately 625 grains for the high MA single-bevel broadheads, to approximately 675 grains for some low MA broadheads.

Above 'threshold value' the *probability* of heavy bone penetration abruptly increases for *all* broadheads tested. However, the increased frequency *is not* equal in either *degree* or *amount* for all broadheads. Some jump from virtually zero to 10 or 12 percent, while other might jump from 20 or 30 percent to 65 or 70 percent. In all but extremely massive heavy bone, and when arrow-integrity remains intact, the best overall-design broadheads show frequency jumps from 85 or 90 percent to a full 100% frequency. Broadhead type, bevel type, tip type, main blade profile, broadhead MA and ferrule profile are all *strong influencing* factors.

For fresh in situ bone, the Heavy Bone Threshold is a definite and persistent, thoroughly repeatable entity. Testing into both 'old bone' and extricated fresh bone proved equivocal, showing poor correlation to in situ results. It is *suspected* that changes in composition influences 'old bone' results, and absence of supple support from cushioning collateral tissues influences extricated-bone results. Irrespective or cause, these media do not yield outcomes consistent with that shown by fresh, in situ bone.

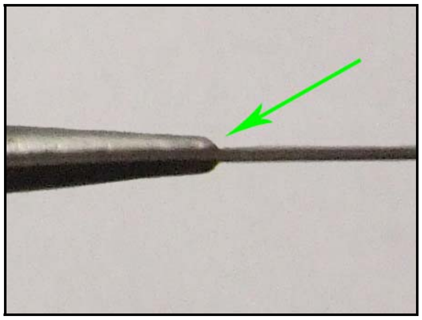
For a given broadhead, the Heavy Bone Threshold shows little change throughout a fairly wide range of impact forces. It is *theorized* that this is because the Heavy Bone Threshold represents a *time* of impulse which acts ('pushes') sufficiently *long* (time wise) to exceed the structural limits of a heavy bone's supporting matrix; more so than the level of 'raw force' applied. A loose analogy might be: *how* an armor piercing round applies the impact force it carries is far more important in penetrating a tank's armor than is the level of raw force it carries.

Another Look at Broadhead MA's Effect

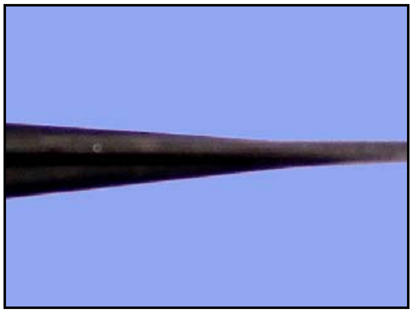
We can also look at the effect of high broadhead MA among other data sets. Among current Asian buffalo test-data, for *all thorax-impact shots (all size buffalo)* at shooting angles of 40 degrees or less, where broadhead-skip was not present, with all bows tested: *With normal/high FOC arrows, when arrow mass was above the heavy bone threshold and structural integrity was maintained*, data shows a 100% penetration-rate on buffalo ribs for *all* broadheads having a MA of 2.6 or greater. Regardless of the bevel-type, or arrow impact force, high broadhead MA showed a marked advantage. Among those in testing, all broadheads with a MA of 2.6 or greater would be single-blade heads, relatively long and of modest width. No multiblade or wide-cut broadhead currently available has a MA this high.

Other Broadhead Factors to Consider

It's important to note that most of the higher MA broadheads being used in the current study series have ferrule designs *with long tapers which fade very smoothly into the blade*. Both smooth ferrule taper and a smooth transition of the ferrule into the blade face are important penetration factors. The Howard Hill broadhead's blade has a very high MA and a smoothly tapering ferrule, but its ferrule terminates abruptly, creating a 'bump' rather than a smooth transition from blade-face to ferrule. During extensive prior testing it demonstrated a marked tendency to hang up in heavy bone, right where the ferrule's taper abruptly ends.

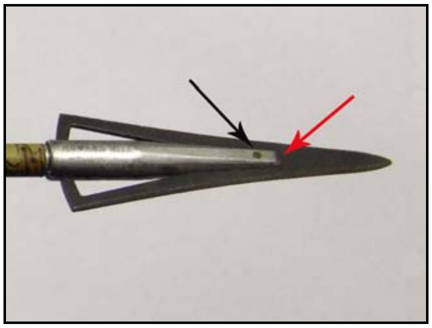


Abrupt ferrule termination often halts penetration in bone. Ferrule taper should fade smoothly into the blade. Irregular surface along the broadhead/arrow profile, whether 'bump, lump, ridge or hole', increases resistance during penetration.



Smooth ferrule fade-in lowers peak resistance force during penetration and increases the MA of the ferrule's wedge-effect.

Most high MA broadheads in the current Study are ones that have demonstrated great structural strength, an important design feature. The Hill broadhead also shows a problem here, especially on angular impacts. On forceful angular impacts its ferrule tends to break where the retaining rivet passes through.



Broadhead strength is an important design feature. Even with excellent blade MA, the Howard Hill Broadhead tends to fracture the ferrule where the retaining rivet (black arrow) passes through. This is more common on angular bone impacts, and there's little doubt that the abrupt ferrule fade-in (red arrow) is a contributing factor to this tendency.

The above comments are not meant to denigrate the Howard Hill broadhead. Their only purpose is to make you aware that broadhead design factors other than MA also need to be considered when you make your choice of broadhead; when desiring to maximize your arrow's performance. Even with these undesirable features, overall performance of the Howard Hill broadhead is better than many lower MA broadheads that *do* have these two desirable features. However, getting the most performance possible from your arrows requires that each and every arrow component perform to the maximum. The smallest of factors has the potentially to make the difference between a successful hit and one that fails.

Single-Bevel's Effect on High MA broadheads:

Among the cumulative data for this same 2.6 or greater MA group (all size buffalo; all thorax-impact shots; all 'above threshold' normal/high FOC arrows; at shooting angles of 40 degrees or less; *with all bows tested;* where structural integrity was maintained; and broadhead-skip was not present), single-bevel broadheads show an average (mathematical mean) penetration increase of 32.98% over the double-beveled heads; 15.87" vs. 11.938". The median penetration (the mid-point measurement for the group's shots; where half show more penetration and half less) shows a 44.8% penetration increase; 15.750" vs. 10.875".

Regardless of whether the median or mean 'likely outcome' is used as the gauge, the 'average difference' a single-bevel made on these thick-chest animals equates to the difference between a single or a double-lung hit. For heavy-bone shoulder hits on mid-size, lighter big game, that 'average difference' equates to the difference between having an exit wound and not having one. Will it make that amount of difference on every single shot? Of course not, but *'on the average'* it will make that much difference; it becomes *"the likely outcome"* on any given hit.

Once the bone is breached, final outcome penetration depends on how much 'useful force' the arrow has left, and how efficiently it uses that remaining force. The *demonstrated* penetration difference *indicates* that single-bevel broadheads are: (1) able to penetrate the bone using less of their available force and/or; (2) open the bone to a wider degree, reducing resistance on the shaft as the arrow penetrates.

The Directly Comparable Single-Bevel Testing

In *every* matched-set test series, single-bevel versions have shown a significant penetration increase over *identical-profile* double-bevel broadheads. Correlation is 100%. This overwhelmingly *data-verified* single-bevel advantage holds for both straight and convex profiles broadheads, whether of short-wide or long-narrow configuration. Data *indicates* that single-bevels are, without question, a major factor in increasing your arrow's bone-penetration potential. That's in addition to their other lethality-enhancing characteristics (See *Why Single-Bevel Broadheads*).

Arrow Rotation and Single Bevels

When using single-bevel broadheads, it's important to match fletching-induced arrow rotation to that caused by the broadhead's bevel. Use only right-wing fletching with a right-hand single-bevel broadhead, such as the Grizzly. Failure to do so results in a *loss* of penetration-potential (See 2005 Update, Part 1).

If you mix arrow rotation and bevel induced rotation, all tests *indicate* the average penetration will be somewhat *less* than that shown by a double-beveled broadhead having otherwise equal features and MA. This *demonstrates* that mixing rotation squanders significant amounts of 'useful arrow force', especially on heavy bone hits; and that matching rotation enhances the arrow's available 'useful force'. It is counter productive to mix the direction of rotation, and the 'likely outcome' is that penetration will be somewhat *less* than had you used a double-beveled broadhead *of equal mechanical advantage*.

When right single-bevel broadheads are used with screw-in broadhead adaptors, adaptor and insert should be secured to prevent broadhead rotation unscrewing the adaptor. LocTite™ works well. As a practical matter, on hunting arrows I secure *all* screw attachments with LocTite™; regardless of broadhead or bevel type.

Recent bevel-testing has been attempted with both a concave profile two-blade and a three-blade broadhead. That data is included in a later Update.

Now let's return to the 54# longbow and see how its Extreme FOC penetration-enhanced arrow's performance stacks up against the baseline group, and the matching normal and high FOC arrows; sets 1 and 2.

Testing the 54# bow with Extreme FOC Arrows

Set 3; the 54# bow's Extreme FOC Arrows: The Extreme FOC arrow setup used for the 54# bow was: Total mass, 724 grains; Grizzly 190 gr. (25 degree single bevel, with COI Tanto tip); Cabela's 45-60 shafts; steel insert; Steel broadhead adaptor. Arrow FOC, 25.7%. Impact Momentum was 0.421 Slug-Ft/Second; Impact Kinetic Energy, 27.58 foot pounds.

Set 3's external arrow dimensions and total mass *precisely* match those of Set 2 in all aspects except degree of FOC, and the 0.433" difference in shaft length. They differ from Set 1 – those with the double-beveled Pro Big Game – by the difference in shaft length, one grain of mass and the broadhead differences; bevel-type and a 0.04 MA difference.

Set 3 Outcomes; the 54# bow's Extreme FOC arrows: A total of 8 shots were taken. Two were intentional scapular-impact shots, and six were *aimed* back of the shoulder. On one scapular hit the shaft cracked back of the insert, with the shot stopping on the bone. Penetration was 5.625". The other hit impacted high on the scapular-flat, and came within one millimeter of the entire broadhead passing through the bone, stopping against the underlying rib. This shot gave 9.75" penetration.

Among *intended* back of the shoulder shots, one resulted in a low shoulder hit. It missed all shoulder bone, passing through the on-side rib to give a heart hit; with 10.5" of penetration. The remaining five shots, all impacting the thorax back of the shoulder, averaged 14.625" of penetration, with a range of 12.25" to 16.625".

The somewhat lower penetration of the inadvertent shoulder shot is likely a result of the poor finger-release I made on this particular shot, which also caused me to pull the shot some 10" low-left … just as *could happen* on any hunting shot. With lower draw-weight bows, a 'hesitant release' has plagued me all my life, and results from a congenital bone deformity in my right hand, which makes voluntary straightening of my distal and ring fingers near-impossible.

The inability to fully extend my ring finger makes it difficult for me to get a clean release, and shooting any light-draw bow well is problematical. That's a big reason I prefer to use bows with longer length, greater limb mass and higher holding-weight. They have less finger-pinch; are capable of literally ripping the string from my fingers; and the high-mass limbs help correct any 'poor release' string torque long before the arrow clears the string. I simply get fewer 'bad outcome' releases with them, shooting more consistently.

Though arrow Sets 2 and 3 are dimensionally equal and have equal impact force, when Extreme FOC is added to the other penetration-enhancing factors the average outcome-penetration shows a 154% increase over the baseline 'top-end common arrows'. A 154% *increase* means they yielded just over two and a half times as much average penetration. This *additional*

71.4% penetration-boost (compared to that shown by Set 2, the matching normal FOC single-bevel arrows) over the baseline 'common arrows' is solely the result of combining Extreme FOC effect with the penetration enhancing features of Set 2's arrows.

Set 1, 2 and 3 Comparison: FOC's Penetration Effect

For all back of the shoulder hits with structurally-intact arrows, the Extreme FOC arrows (Set 3) show an average penetration gain of 59.7% over the double-bevel 189 gr. Pro Big Game (Set 1); and 39.3% over the normal FOC 190 Grizzly (Set 2). The lowest-penetrating back-of-the-shoulder hit in Set 3 (the Extreme FOC arrows) essentially equals the best penetrating hit shown in either Set 1 or 2 (the normal FOC groups); 12.25" vs. 12.5". Even Set 3's poor-release shoulder hit equaled the average penetration shown by Set 2's matching normal FOC arrows.

Extreme FOC's Effect on Other Penetration-Enhancing Factors

An interesting feature is the *greater increase in penetration a single-bevel broadhead shows when it's on an Extreme FOC arrow.* The Extreme FOC arrows (Set 3) show a 39.3% gain over their like-arrow comparison group (Set 2). In the Set 1 vs. Set 2 comparison, the singe-bevel showed a 14.6% penetration gain over its matching double-bevel comparison group. Adding these; 39.3% plus 14.6%; implies that the penetration difference between Sets 1 and 3 should be 53.9%. The actual outcome difference was 59.7%; an additional gain of 5.8%.

Taken alone the bevel-provided penetration difference shown by these Extreme FOC arrows would be of no significance, because of sample size. However, such additional gains have been consistently manifest in all test series; *every single time* the degree of effect is compared between dimensionally-matching normal/high FOC arrows and Extreme FOC arrows - 100% concurrency.

The other penetration-enhancing factors also unfailingly show greater penetration gain with Extreme FOC arrows; over that they show when comparison-tested on matching normal or high FOC shafts. This is the strongest evidence of all that *impulse of force* (the arrow's momentum *multiplied* by the time period over which it is applied) dictates outcome penetration. Kinetic energy can not be used either mathematically or logically to explain such outcomes. Momentum's impulse of force formula both forecasts and explains this outcome.

Performance Comparison: The Cumulative Extreme FOC Arrow Test

In addition to their 'normal testing', Extreme FOC data now contains five 'focal study' test sets; comprised of 92 directly comparable 'matched-set' shots. Each test-set consisted of precisely identical or virtually identical arrow setups, differing significantly only in the amount of FOC. All arrows in each test-set; both normal/high FOC and Extreme FOC; had closely matched features, external dimensions and flight quality.

The greatest dimensional deviation among any of the test-sets was with the below-the-heavy-bone-threshold arrows, which had a 23 grain variance in mass; with the Extreme FOC arrows being the lighter. The next greatest variance between test-sets was 7.5 grains of mass; with the Extreme FOC arrows again being the lighter of the two. This final series (with the 54# longbow) contained *precisely* matching dimensions, save the very small shaft-length difference and amount of FOC.

In every test series; throughout all normal and focal testing; Extreme FOC arrows have *consistently demonstrated* a marked penetration increase over their 'like arrow' normal or high FOC setup, for *all* comparable shots. The overwhelming consistency and magnitude of outcomes is *conclusive*: In tissues, where all other arrow dimensions were equal, Extreme FOC arrows conserve arrow-force, usefully applying it to penetration. This allows them to far out-penetrate arrows having normal or high FOC. This conserved force can only result from a reduction in resistance during penetration, implying a lower shaft-drag factor. The most logical explanation for this lower drag is a result of reduced shaft flex (See *Prologue, 2007 Updates*).

The consistency of outcomes offers *conclusive evidence* that Extreme FOC, in and of itself, conserves arrow force during penetration. Their conserved force is also what permits each of the other penetration-enhancing features to show an additional penetration gain.

Quantifying Extreme FOC's Penetration Effect

The 54# bow's Extreme FOC arrows show gains of 59.7% over the double-beveled Pro Big Game and 39.3% over the *precisely matched* Set 2 arrows. In this test series not only did the arrows match, all penetration-measurement constraints were absent. The outcomes correlate favorable with the earlier test.

Examine the (infamously misused) text in 2005 Update, Part 2. There, Extreme FOC's penetration gain ranged from 19% for high-mass arrows (where both normal and Extreme FOC arrows were impeded by measurement constraints) to 62% for arrows in the lower-mass groups (where only Extreme FOC penetration-measurement was impeded). The reason lower-mass arrows *should (and do)* show a greater *degree* of gain from Extreme FOC will be explained in Part 5, as we progress through the data.

For the 54# bow neither speculation nor estimation is required. Results are clear-cut, and absent of measurement-confining features. With the other penetration-maximizing features equally present on both arrows, the Extreme FOC effect equated to a penetration-gain of nearly 40%.

This amount of Extreme FOC gain represents the *absolute minimum* average penetration increase you can expect for bows in the mid-50# range. And, as shown by the 54# bow's baseline group, the gain will be *enormously* higher when compared to even top-end 'common arrows' lacking the other penetration-enhancing factors; giving approximately two and a half times as much tissue penetration on heavy-bone impact hits.

Perhaps a better way to think of this is: Once you've done everything you can to maximize the penetration potential of a normal/high FOC arrow, data *indicates* you can increase *its already enhanced penetration* by another 40% to 60% by simply changing its weight distribution to Extreme FOC; as long as you maintain perfect arrow flight and keep external arrow dimensions the same.

Considerations

As you contemplate the above penetration benefits, consider that their greatest *degree* (percentage) of benefit will be to those shooting lower draw-weight bows and arrows of lower mass (but not the greatest *amount of benefit* – the *actual inches* of penetration gained). What Extreme FOC provides the light-draw shooter is an arrow option giving average outcome penetration equaling that of a substantially higher draw-weight bow, even *when the heavier-draw shooter is using a perfectly tuned normal/high FOC arrow of equal dimensions.*

Words of caution

(1) It must be stressed: This performance gain was shown when both arrows had perfect flight. Obtaining this improvement *requires* that you tune your Extreme FOC arrow for perfect flight. Merely changing your arrow to Extreme FOC, while disregarding arrow flight, ***will not*** give you these benefits.

(2) In the 54# bow's testing, all the penetration-enhanced arrows were above the heavy bone threshold. To date, Extreme FOC has shown no effect on the heavy bone threshold, though its effect *is* manifest once a bone is breached. When the hit involves *heavy bone,* don't expect Extreme FOC alone to compensate for a lack of arrow mass and/or momentum … or a poor bone-performance broadhead choice. However, even at low arrow mass you *can* expect Extreme FOC to substantially boost your arrow's penetration *whenever a bone is successfully breached*.

Tip: Whether you use normal, high or extreme FOC arrows, *the lighter your bow's draw-weight and the lower your arrow mass, the greater the DEGREE of bone-penetration benefit you'll derive from using both as much broadhead MA as possible and single-bevel edges.* At low levels of impact force and/or arrow mass, their use won't guarantee your arrow is going to get through even moderately heavy bone; but what it *will do* is significantly *improve the odds* of your arrow getting through. Getting maximum penetration-potential from your arrow is a package deal, requiring a combination of *all* the penetration-enhancing factors.

More to Mull Over

Think back to outcomes between Sets 2 and 3. What the Extreme FOC advantage implies is that (with perfect arrow flight from each) the average tissue-penetration gain provided *merely by changing the arrow's weight distribution to Extreme FOC* would equate to 14" rather than 10"; or 28" rather than 20". Think of the implications on chest hits on thick-bodied animals, or any long-angle hit. Consider what that much implied 'extra available penetration-force' *might mean* on a badly placed shoulder or spine hit.

Now let's make a similar comparison against those top-end 'common arrows'. They represent the best performance you can expect when your arrows don't incorporate the penetration-enhancing factors shown in Sets 1 or 2. If you're currently using arrows lacking Set 2's penetration-enhancing factors, think about the implications if you apply both them AND Extreme FOC; two and a half times as much penetration potential. It means, on the average, you can expect 12-½" of penetration instead of 5"; or 25" instead of 10" – depending on the nature of the hit made. Moreover, look at what you'll gain in bone-penetration capability. That's clearly shown in the test results.

Now ponder what the penetration-potential difference is if the 'common arrows' you're currently using don't even have the penetration-enhancing features of the baseline 'top end common arrows'! Regardless of whether it's on a deer, elk, pig, bear or moose; should you make a heavy bone hit, or one at a long quartering angle, which arrow would you *prefer* to be using? Which do you think gives you the *best chance* of successfully recovering that animal?

A 'bad hit' can also be one into all soft tissues having low vascularity, such as a gut hit. Depending on animal angle, extra penetration ability frequently carries the arrow deeply enough to encounter areas of higher vascularity; into (or through) thorax or hip. However, it may also pass through only the gut cavity.

There are many who maintain that multiblade broadheads offer a tremendous advantage on gut-only hits; cutting far more intestinal capillaries, resulting in greater hemorrhaging. However, there are two factors unique to single-bevel broadheads that make this questionable. The major factor is their tendency to create 'starburst' cuts in the highly mobile intestinal tissues (See *Why Single-Bevel Broadheads*).

A lesser, but still significant factor is that single-bevel rotation results in a longer 'primary cut pathway'. This is because the blade edge's cut is a spiral, rather than a straight-line through the tissues; ergo, its pathway is longer in length than the linear depth of the wound channel.

It is suspected that the single most important factor in successful recovery of any purely gut-hit animal is how you manage the follow-up. Regardless of the amount or nature of lacerations, hemorrhaging from a gut hit will be far slower than from hits into areas with larger average blood vessel size. Allow lots and lots of time before follow-up.

From both personal kills, for which there is hard data, and those of friends and clients, it has been my experience that: (1) when undisturbed and the hit was a pass-through, very few gut-hit woodlands-dwelling animals every travel more than 160 yards before bedding down; and many stop within 40 to 60 yards. (2) Un-pursued, open-country dwellers generally travel until they reach the first suitable cover. (3) Herd animals usually try to follow the herd until they become too uncomfortable to carry on. However, once the hit animal does stop, if undisturbed the herd frequently remains in the vicinity of the downed animal – and that can help you locate the animal's whereabouts.

For whatever it is worth, on gut-only hits I allow a minimum of 8 hours before follow-up, and prefer 12 or more; depending on the situation. Though the number of 'gut-only' hits in the kill-records is not great, to date the recovery-rate is 100%.

The performance of the penetration-enhanced Extreme FOC arrows used in the 54# bow's testing could still be boosted somewhat, to the level I like to refer to as "fully penetration maximized". How? By adding the few penetration-enhancing factors not present in Set 3; even higher broadhead MA (such as with the Modified Grizzly, which has a MA above 3.0), a smoother broadhead finish (Teflon™ coating), and a tapered shaft.

Before we compare the 54# bow's penetration-enhanced Extreme FOC arrows against the 'commonly used' normal and high FOC arrows from the heavier bows, let's pause to look at another feature these light-bow tests highlighted; the one most critical to arrow performance – structural integrity.

Structural Failure: Affect and Effect

Separating structural failure's event-sequence is difficult. Which is affect and which effect? Does structural-failure result from failure to penetrate the bone or does structural-failure cause the bone-penetration failure? The two outcomes show extremely high concurrency; 86.2% for carbon shafts.

Study data provides a strong clue. Among all hardwood, double-shaft and Internally Footed (IF) data, no arrow has a mass below the heavy bone threshold.

Data was isolated among these arrows to include (all): (1) shots from reasonable shooting angles (broadside, to plus or minus 25 degrees); (2) impacting bone; (3) having a favorable ferrule-diameter to shaft-diameter ratio and; (4) tipped with *any* of the 'best performing' broadheads.

The resulting data was subdivided into two groups: (a) those having rib-only impact and, (b) those showing multiple or extremely-heavy bone impact.

The rib-only data revealed that it was *only* when structural-failure was present; a bent, broken or damaged broadhead, insert, adaptor or shaft;

that *any* of these arrows failed to penetrate a buffalo's rib. Correlation was 100%.

Even some 1000-plus grain double-shaft arrows having the best-performing broadhead (Modified Grizzly) showed failures to penetrate buffalo entrance-ribs when structural failure of insert, adaptor of shaft was present. This particular setup produced thorax-traversing hits on *every* shot where the arrow remained structurally-intact.

Among multiple and extremely-heavy bone hits, though numerous occurrences of arrows being stopped by bone are present, the high-durability arrows usually maintained structural integrity. However, among the scapular hits, every shot that *did* penetrate both scapular-flat and underlying rib had maintained structural integrity. No arrow showing *any degree* of structural failure did so. On multiple bone or massively thick bone hits, penetration of the structurally-intact arrows became purely a matter of impact force vs. resistance force(s).

These outcomes *indicated* that when arrow mass and impact-force was clearly sufficient: (1) Structurally-intact arrows penetrated the rib every time. (2) Only when structural-failure occurred did *any* fail to penetrate the rib. (3) Even arrows which, undamaged, consistently provided thorax-traversing hits failed to penetrate the entrance-rib when structural failure occurred. (4) On strongly-built arrows, scapula/multiple-bone stops did not always cause structural-failure. (5) On scapula/multiple bone-hits, only structurally intact arrows penetrated the bone(s). (6) Each scapula/multiple bone hit that did show a structural failure resulted in a failure to penetrate.

An additional indicator is provided if we examine the shots for all Extreme FOC arrows employing 'best broadheads' and *not having an Internal Footing*. Among them, none with mass-weight above the heavy-bone threshold failed to penetrate the entrance rib *except when a structural-failure occurred*.

For these 'best broadhead' tipped arrows, in every instance where impact force and arrow mass was clearly sufficient for bone penetration, structural failure in the arrow system and bone-penetration failure was coexistent. This data is *indicative* that structural-failure of the arrow initiates a bone-penetration failure. Structural integrity of the entire arrow system is ***the** absolutely essential requirement* for consistently reliable penetration; even when impact force is sufficient, arrow flight perfect, and the other penetration-enhancing factors present.

Arrow Integrity Implications from the 54# bow's testing

The three test series with the 54# bow provide classic examples of what becomes of arrow penetration when structural failure occurs. Every structural-failure on the above-the-heavy-bone-threshold arrows in Sets 1, 2 and 3 halted penetration.

Bone-penetration causes a rapid and forceful spike in resistance. During such collisions the weakest item suffers the most damage; be that broadhead, insert, adaptor, shaft or bone. In each case where these above-threshold arrows remained structurally-secure it was the bone which suffered most.

Now examine the shaft damage-rates shown between Set 1 (the double-beveled normal FOC group) and Sets 2 and 3 (single-beveled). The arrows are as close to identical as possible, and have virtually identical broadhead MA. Set 1's double-bevel broadheads show a shaft damage rate of 42.9% (3 of 7 shots). Set 2 (the normal FOC single-bevels) shows a damage rate of 16.7% (1 of 6). Set 3 (the Extreme FOC single-bevels) has a damage rate of 12.5% (1 of 8).

In these three sets, sample size is small, and Set 3's steel insert and adaptor lends strength. What does looking at the larger data set (all shots with 'normal' carbon shafts) show?

As reported in Part 2, the *overall* heavy bone impact damage-rate for normal carbon shafts (excluding the Internally Footed ones, but including those with both single and double-beveled broadheads, and adaptors/inserts of all types) is 31.8 per hundred shots. However, when only the non-IF carbon shafts having single-bevel broadheads are considered the data shows an overall impact-damage rate of only 5.1 per hundred shots. That's still 59% higher than the damage rate for hardwood shafts using *any broadhead*, but it's far better than the 893.8% (that's correct; eight hundred ninety three point eight percent) damage-rate difference between the overall 'normal carbon' damage rate and that shown by hardwood shafts!

This marked difference in damage rates among normal (non-footed) carbon shafts graphically illustrates the extreme magnitude of the disparity in peak resistance-force encountered, during heavy-bone breaching, between single-bevel and double-bevel broadheads. It clearly implies that single-bevel broadheads encounter a much lower peak resistance force during bone breaching; a result of their ability to split bone, rather than having to force their way through bone.

Lower peak resistance means a lower level of stress is placed on the entire arrow system. It also means less of the arrow's useful force is expended when penetrating a bone. Is it any wonder that single-bevel broadheads uniformly show more outcome penetration on heavy-bone hits than matching double-bevel broadheads?

It is fully expected that use of an Internal Footing (IF) will significantly reduce the carbon shaft damage. For Extreme FOC arrows having single-bevel broadheads and steel or brass adaptors/inserts, it is expected the IF-shaft damage rate will be near zero; as they demonstrated in initial testing with the 82# bow.

The IF may well represent the most significant 'hardware advancement' to come from the Study. All testing has indicated that the Study-developed version *did* make carbon shafts as durable on hard-bone impacts as the best hardwood shafts.

The Study-developed IF information, construction details and test data was passed to a shaft manufacturer some months ago. A commercially produced IF is in the works, and the Study expects to be testing a factory-produced prototype shortly.

If field testing goes well, it is likely a commercially-produced IF will be available very soon. Its design differs from some of the Study's prototypes. They incorporate computer-modeling derived features that design-engineers suggest will best redistribute the flexional forces, when using the specific composite material under consideration; one which will allow financially-viable fabrication. The outcome-performance must be tested before I can comment on the level of performance of these prototypes.

It is the Study's desire for IF's to become easily available to all, opening the door to *reliably* obtaining Extreme FOC's benefits on *every hit*. The Study is in favor of *any and all* equipment developments that provide effective equipment choices to the bowhunter, and will assist wherever possible.

I would like to reiterate that the IF specifics were passed freely to the shaft manufacturer without compensation *of any nature*. Neither I nor the Study is financially connected, in any fashion, to any aspect of the archery or bowhunting industry, and intend to remain so. (I've heard strong hints that a particular broadhead under development might be "named after", but should that happen, rest assured that I and the Study will not, in any manner, be a financial beneficiary of its usage … and will undoubtedly test it more harshly than other broadheads too! So, if someone out there *is* planning to tag my name on one, you're welcome to do so … but it had better be a darned good broadhead. Fair warning!)

Either the Study or I have been referenced in advertising by a number of companies. Some have requested permission to do so; others have not. Such linkages do not imply Study endorsement of a specific product(s). So long as commercial linkage to the product(s) is limited to *factual and contextual* representations of Study results, conclusions, comments or observations, *and their use remains uncompensated*, I have no objection to such usage. It merely assists in the dissemination of Study information to the bowhunting community at large.

Now let's move on to what, I suspect, will be the data of most interest to those who hunt with bows of lighter draw weight; how the 54# bow's penetration enhanced arrows compare with 'commonly used' arrows from the heavier bows.

Going Head-to-Head with the Heavier Bows

A perspective into the performance achieved by the 54# bow's penetration-enhanced arrows is gained by examining database records. Let's consider comparable shots from both the 70# and 82# bow, when those are used with 'common' arrows.

First, let's set comparison parameters. These are: (1) all broadside shots on both large and trophy size male buffalo; (2) from twenty yards; (3) impacting back of the shoulder, with rib only impacts, and (4) where the arrow suffered no structural damage. We'll also eliminate the 70# and 82# bows' Extreme FOC arrows (against which we'll compare later, in Part 5), all multiblade broadheads, and the 'specialty arrows'; those with extreme mass.

The 54# Bow's *Normal FOC* Arrows vs. 70# Bow's 'Common Arrows'

IMPORTANT NOTE: All test arrows, from each bow used, were tuned. Differences in quality of arrow flight IS NOT a factor in the following results; for any of the data. The need to maintain perfect flight among all test arrows is the biggest reason doing such testing is, more or less, a full-time avocation. Tuning takes time!

The 70# longbow has been used for many focal, broadhead punishment, tip-design and edge-bevel testing; sometimes done at closer test distance. It has, however, also been used for 'normal testing', and for these data may be compared.

For 'all single blades', average arrow mass is 763.25 grains and average penetration is 9.25". For all shots having the same broadhead (190 gr. Grizzly), average arrow mass is 725.0 grains. Average penetration is 10.75". Note the 16.2% penetration increase when the 190 Grizzly's higher MA and single-bevel advantage is factored in, even though average arrow mass is lower and both arrow-sets contain innumerable other variables. *This shows how high MA and/or single-bevel's effect on outcome penetration* *overshadows the influence of the maelstrom of random variables, indicating its high level of importance.*

First, note that the average penetration from both groups of arrows from the 70# bow far exceeds that shown by the 54# bow's "baseline", top-end 'commonly used' arrows; by 60.7% for the 'all single blades' group, and 87% for the '190 Grizzly' group. Next, remember that these shots all have heavy bone impact, and the penetration difference between the 54# bow's 'baseline group' and 70#'s arrow-groups would be less on 'all soft-tissue' hits; where the heavy-bone threshold's pronounced influence on the 54$ bow's 'baseline group' would be absent.

Now let's compare the 70# bow's performance against the 54# bow's penetration enhanced arrows. The average penetration outcome for the 70# bow's 'common arrows' having random single-blade broadheads is not greatly different than that shown by the 54# bow's test Set 1 (normal FOC with Pro Big Game); less than 1% greater. Penetration shown by the 70# bow's '190 Grizzly' group is about the same that for the 54# bow's Set 2 (the normal FOC arrows with 190 Grizzly); being only 2.4% greater.

It must be remembered that most of the 70# bow's arrows did not possess as many of the penetration-maximizing factors as the 54# bow's arrows in Sets 1 and 2. A (very) few of the 70#'s arrows are below the heavy-bone threshold; several have either 'Hill type' serrated, micro-serrated or file sharpened edges; and some have a barrel-tapered shaft. Among the 'all single blades' set there would also be variations in mechanical advantage, ferrule-diameter to shaft-diameter ratio, blade profiles, cutting angle, edge angle and tip profile.

There is an up-side of making a comparison in which these many differences are present. It gives the light-draw shooter who uses a penetration-enhanced arrow an indication of how his arrow's penetration-potential stacks up against a heavier-draw bow, when the heavy-bow shooter pays little or no attention to enhancing his arrow's penetration potential (other than having perfectly tuned arrows).

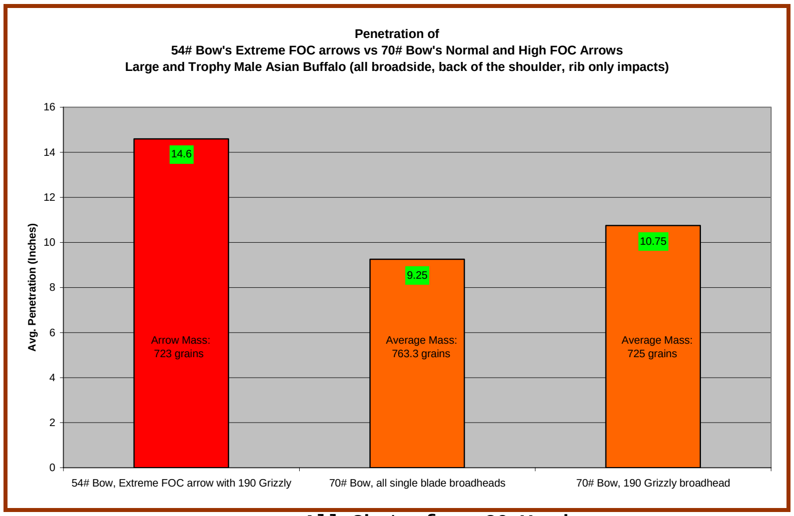
It also shows the fallacy of using a bow's draw-weight as the guide to the likely outcome tissue penetration you can expect.

The demonstrated outcome is that the penetration-enhanced *normal FOC* arrows from the 54# bow produced penetration virtually identical to the 'common arrows' from the 70# bow. *Between these bows of like-efficiency, penetration-enhancing the lighter bow's normal FOC arrows equated to applying 16# pounds of additional draw-force to a 'common arrow'.*

The 54# Bow's *Extreme FOC* Arrows vs. 70# Bow's 'Common Arrows'

While comparisons of the 54# bow's penetration-enhanced normal FOC arrows against the 70# bow's 'commonly used' arrows show virtually equal penetration, such is not the case when Extreme FOC enters the equation. The 54# bow's Extreme FOC arrows show a 63.3% penetration-increase over the 70# bow's 'all single-blades' group. Considering only the same broadhead, the 190 grain Grizzly, the 54# bow averages 39.3% more penetration.

The following graph depicts these comparisons.



All Shots from 20 Yards

Here the *demonstrated outcome* is that penetration-enhancing the 54# bow's arrows AND adding the penetration benefits of Extreme FOC equates to adding far more than 16# pounds to the bow's draw-force. To get a better idea of how much more bow-force this equates to, let's compare the performance of the 54# bow's Extreme FOC arrows to that of 'common arrows' from the 82# bow.

The 54# bow's Penetration Enhanced Extreme FOC vs. 82# Bow's 'Commonly Used' Arrows

We already have our comparison set for the 82# bow. It's the same set we used when making a performance-comparison of the 70# bow's Extreme FOC arrows, in current Updates, Part 3. *Remember that all the arrows are tuned for perfect flight, negating quality of arrow flight as a penetration factor.*

The 82# bow's 'all single blades' group has: average arrow mass, 736.29 grains; average penetration of 9.83". The 'same broadhead' group (190 gr. Grizzly) shows: average total mass, 692.23 grains; average penetration of 12.15". As with the 70# bow comparison, it must be remembered that many of the 82# bow's arrows did not possess as many of the other penetration-enhancing features (those factors *other* than Extreme FOC) as the 54# bow's arrows.

Once again, note the penetration-boost shown by the 'common arrows' from the 82# bow when the 190 gr. Grizzly's higher MA and single-bevel advantage enters the equation; here 23.6%, even though the Grizzly's group again has lower average mass. *Again note how high MA and/or the single-bevel effect dramatically overshadows the influence of the multitude of random variables, again indicating its extraordinarily high level and consistency of influence on outcome tissue penetration.*

Why is the Grizzly's 23.6% penetration increase shown by the 82# bow a greater amount than the 16.2% shown with the 70# bow? The major disparity results from differences in the arrow sets. Arrows in the 82# bow's random-broadhead group contain a greater range of single-blade broadheads. Few of the 70# bow's shots were with *extremely poor* MA broadheads; the wide-short or 'radical' profiles; while the heavier bow's group contains many.

As far back as the original Natal Study, the *routinely occurring* outcome differences among broadhead types has screamed out that high MA broadhead was making a significant difference in penetration, and they *strongly suggested* single-bevels might also be a significant factor; ergo, the reason for conducting further, more focused testing to verify and quantify their *average effect* across a broad range of shot situations; determining the '*likely outcome*' difference they make.

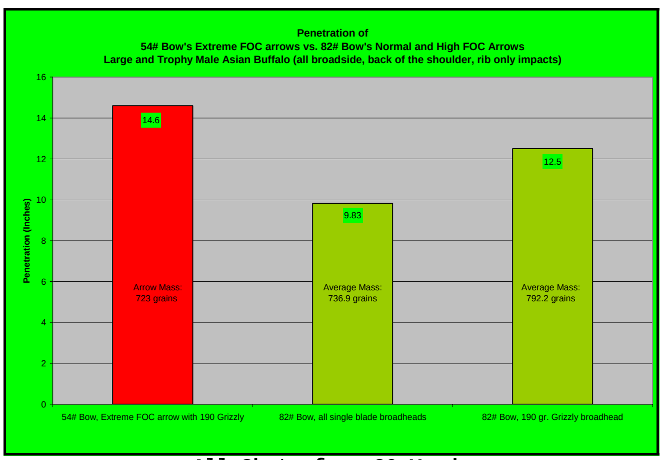
Food for thought: the highest MA *multiblade* broadhead tested – the Wensel Woodsman - has a poorer MA than *almost* any single-blade. Exceptions are among the 'single-blade' mechanicals, such as the G-5 Tekan, and a few radical designs; such as the highly-concaved Sharks and severely-truncated Bone Buster. However, the Woodsman's MA is only slightly worse than many short-wide single-blade 'delta profile' broadheads; and the data reflects this.

The Woodsman averages *almost* as much penetration on back of the shoulder rib-only hits as the *double-bevel* 'delta profiles'. However, this does not hold with *single-bevel* 'delta profiles', which significantly out-penetrate the Woodsman on such hits; one more indicator of the single-bevel's advantage on bone impacts.

One often sees the Woodsman referred to as a 'three to one' broadhead. Technically, this can made a true statement by comparing *one blade's* cut dimension to the broadhead's length, but it is not comparable to the three-to-one ratio Howard Hill refers to. Hill's ratio compares *total cut width* to blade length, and reflects the blade's mechanical advantage. The Woodsman has a MA of 1.43; less than half that of the Howard Hill broadhead. In order to have a MA of 3.0, at its current cut-width the Woodsman would have to be just over 5.4" long!

On average, the 54# bow's penetration-enhanced Extreme FOC arrows out-penetrated the 82# bow's normal/high FOC arrows with 'random single-blades' by a whopping 48.8% - almost half again as much penetration. Even when considering 'same broadheads', the 54# bow's Extreme FOC arrows still average a 17% penetration increase!

The following graph shows these comparisons.



All Shots from 20 Yards

Implications

To say the implications are good news for those hunting with lighter draw-weight bows is an understatement. Here's what the results indicate for a bow in the mid-50# range:

Using perfectly tuned Extreme FOC arrows with a mass above the heavy bone threshold, and which also incorporated most other penetration-enhancing factors, was analogous to adding at least 30 pounds to the bow's draw-force; when compared to a similarly-efficient bow using perfectly-tuned normal or high FOC arrows having 'common' penetration features.

Does this mean that a bow drawing 30 pounds and using a penetration enhanced Extreme FOC arrow can be made to penetrate as well as the average 'commonly used' arrow does from a bow drawing 60 pounds? Well, that's certainly what the data *implies*. However, there are other penetration-dynamics that need to be considered. Even with a fully penetration-maximized arrow having a mass above the heavy bone threshold, at some point there also has to be a minimum threshold of applied force to breach any given bone. Thus far, that parameter hasn't been thoroughly investigated.

Somewhere 'down the road' the Study hopes to do much more investigation with low-poundage bows and penetration-enhanced arrows, on feral goat and pig size animals. Many would prefer this testing be conducted on whitetails, but the reality is that testing on whitetails is not, and likely will never be, a possibility. With restricted seasons and off-take limits, it is impossible to amass the amount of *methodically-collected* shot data required to develop any meaningful data base of outcomes. Collection of a moderate amount of *correlating* whitetail data is the most one can hope for.

The 54# bow's Penetration Enhanced Extreme FOC vs. The Highest Kinetic Energy Arrows Tested

It is also very interesting to compare the outcomes from the 54# longbow's penetration-enhanced Extreme FOC arrows against that of the highest impact kinetic energy arrows contained in the buffalo test data; from compounds.

All the highest impact-KE group's shots are broadside; back-of-the-shoulder, rib-only impacts; from 20 yards; on *large adult* buffalo (male and female). They have a cross-section of broadheads commonly used on such arrows, including such rigid and replaceable-blade favorites as the Muzzy, Montec and Wasp. Note that there is a difference in animal-size between the comparison groups. All shots with the 54# bow were on larger animals; very large, trophy size bulls.

The highest impact KE testing employed arrows of 381 to 450 grains mass (average mass: 417.62 gr.), having favorable shaft-diameter to ferrule-diameter ratios and normal to high levels of FOC. Their average impact kinetic energy was 82.99 ft. lbs. (Range: 76.64 to 94.12 ft. lbs.). Average impact momentum was 0.556 Slug-Ft/Sec. The average impact kinetic energy for the high-KE group is <u>over three times</u> that of the 54# bow's Extreme FOC arrows (Set 3); and average impact momentum is almost one-third greater.

On average, the penetration-enhanced Extreme FOC arrows from the 54# longbow out-penetrated the low-mass, high impact KE group by 19.7% (14.6" vs. 12.2"). Much more telling are the median penetration outcomes. Median penetration for the 54# bow's penetration-enhanced Extreme FOC arrows shows a 35% increase over that for the high impact-KE group (14.19" vs. 10.5"). The median for each group indicates the point where half the arrows show greater penetration, and half show less. To put this in perspective, half of the low-mass, high impact-KE arrows penetrated *less than 10.5"*.

For both mean and median value, the *demonstrated outcome* on these heavy-bone hits is that the penetration-enhanced Extreme FOC arrows from the 54# longbow far out-penetrated the 'commonly used' low-mass, high kinetic energy arrows from the compound. It's noteworthy that 30.8% of the high-KE group's low-mass arrows failed to penetrate the buffalo's entrance rib (a big reason the median value is so low), whereas the rib-penetration rate of Group 3's higher-mass, penetration-enhanced arrows was 100%.

This comparison not only highlights the difference penetration-enhancing an arrow can make, it shows the extreme fallacy of relying on kinetic energy as the indicator/predictor of an arrow's tissue-penetration capacity.

Now ponder this for me: How much arrow kinetic energy is required before your arrow is deemed 'adequate' to hunt a big animal?

Under laws in some parts of Africa, arrow KE is used as the criteria for being legal. In some locations this is combined with a minimum arrow weight and/or type of broadhead for various game classes. However *most* of the light arrows used in the above test, at the *impact* KE levels shown, would be legal virtually anywhere for big game up to buffalo-class. In some locals it would be legal for buffalo too!

Conversely, the penetration-enhanced Extreme FOC arrows from the 54# longbow (with their demonstrated vastly superior terminal tissue-performance) barely meet the minimum KE requirement for *small game, birds and the very smallest class of plains game*! In some countries its kinetic energy is below the legal minimum for game the size of warthog and nyala (about the weight of an average mule deer).

Surprised? You shouldn't be. Those laws were based on the "recommendations", and the little longbow's big-performing arrow's *barely* meet the widely promulgated "recommended minimum KE" for deer and pronghorn, and falls far short of the "recommended minimum KE" for US-dwelling pigs too!

I hope and pray sanity prevails, and ***all*** reference to "what arrow kinetic energy is enough" dies a quiet death, never again escaping its "recommended" category! However, I won't hold my breath.

Kinetic energy is highly dependent on arrow speed, and speed sells. It flattens arrow trajectory. It makes hits at longer-ranges easier. It minimizes the time and hunting skills required to get "in range", increasing the number of "shot opportunities". Far more emphasis is currently placed on increasing the ability to hit game than on the ability to kill cleanly on the hits being made.

The 54# Bow's Penetration-Enhanced Arrows vs. Buffalo

It must be emphasized: The above results ***do not*** imply this particular 54# bow, even when used with the Extreme FOC arrows tested, is adequate for buffalo; but then neither is the 70# or 82# bow when used with 'common' arrow setups.

As for any big and potentially dangerous animal, the *minimum* criteria for a fully-adequate buffalo setup is one capable of completely traversing the thorax of a trophy-size bull 100% of the time, on *any* well-placed shot from *all* reasonable shooting angles. Such penetration allows the minimum acceptable margin of error for anyone hunting purely for sport.

There's no doubt a buffalo could be killed with the 54# bow and the Extreme FOC arrows tested here … when all went right. However, these particular Extreme FOC arrows do not achieve adequate 'average penetration' to be acceptable for sport hunting buffalo. Most hits gave a solid one lung hit, merely nicking the second lung. A one-lunged buffalo *usually* lives a long time. A long and highly dangerous follow-up situation is likely … and that's unacceptable for either hunter or hunted.

It is possible, though unlikely, that use of higher broadhead MA (such as the Modified Grizzly), Teflon™ broadhead coating, a higher mass Extreme FOC arrow, and/or a tapered shaft Extreme FOC setup with this particular bow *might* give a 'reliably adequate outcome' on buffalo. The actual performance of such an arrow setup could only be determined by more real-world outcome testing. However, it's entirely possible that a different 54# bow, of higher efficiency and using an Extreme FOC setup fully penetration-maximized, might well meet those criteria. In fact, I would say it's likely; especially if those 54# happen to be at a long draw-length. This *speculation* is based on test outcomes by Cher Lacey, using an ACS-CX drawing 52#@26" and 800 grain normal-FOC arrows that incorporated most other penetration-enhancing features. However, at this time I can not conclusively say it would be.

Subjective Shooting Impression

The 724 grain normal and Extreme FOC arrows used in testing with the 54# longbow represents 13.4 grains of arrow mass per pound of bow draw-force. What was it like, shooting this modest-performing 'Hill style' longbow and that much arrow mass?

I shoot instinctive, and use a split-finger release, anchoring middle finger at the corner of my mouth. At 20 yards, it 'felt' as though I was pointing directly at the spot I wanted to hit. Trajectory was sufficiently flat that I had no trouble hitting accurately to that distance, without any 'felt compensation' for arrow drop. In order to hit at 25 yards, I became aware it was necessary to hold higher than I do with the heavier bows I generally hunt with. I would 'guesstimate' the amount of 'hold-over' to equate to 'pointing at the back-line' on a whitetail.

Hunt-records for the last 607 big game animals I've shot reveals my average kill distance to be less than 16 yards; with 88.3% of kills occurring at 20 yards or less, and 96.2% being 25 yards or less. For my personal style of hunting, using such a setup would pose little genuine handicap. I'm primarily a stalking hunter. It's likely that I *could* have taken a portion of those longer-range kills from close range, had that been *required*. My biggest problem would likely come from the release problems I have with light draw-weight bows.

It's worth noting that this bow became *incredibly quiet* when using these high mass arrows. The shot's sound was very low-pitched, soft and dull. It also *seemed* the sound from the arrow's fletching during flight diminished noticeably at the lowered velocity.

Comments

Don't misread any of the above. I'm not advocating that, purely by choice, you take a light draw-weight bow and hunt a buffalo; or any other truly big, big game. In order to evaluate performance-influencing factors it's necessary to work near or below minimum-adequate force levels for the size animal being used. If the arrow exits it becomes impossible to measure penetration changes.

Result from such testing provides information about when setups are borderline, or clearly inadequate, and make it easier to detect factors which improve the arrow's terminal performance. Their purpose is not to tell you that you don't need, or won't benefit from, using all the bow-force you can effectively handle.

It is a data-verified fact that an inferior performing bow using a great arrow setup will far out-perform a far superior bow using a poor arrow setup, even when both have perfect arrow flight. However, for all hunting the best setup is more-than-adequate bow-force, with the absolute best arrow performance you can get from it – regardless of the size of big game animal hunted. It's a formula that rarely fails to turn a hit into a clean kill.

While one Study purpose is to find ways for you to get the maximum terminal performance from your arrows, regardless of what bow you are *capable* of using, another is to define the performance *characteristics and capability* of various arrow design features. This provides you a way to know and anticipate 'likely outcomes' of your particular hunting setup, helping you decide what shots you should take, and which you should pass up.

For example, knowing the skip angle of the type broadhead you're using tells you when the shot-angle is *likely* to result in a deflection in the arrow's intended course of tissue penetration; and knowing the bone-penetration characteristics of your setup gives you an indication of how much importance you must place on avoiding shots which *might,* inadvertently, result in heavy-bone impact. The greater your setup's penetration-potential (and that includes skip-angle), the more leeway you have in shot selection, and the greater its ability to compensate whenever my old friend Murphy decides to lend you a hand.

For hunting any big game, regardless of whether it's a Texas Whitetail or a record-class buffalo, the best advice I can offer is to use the heaviest draw-weight bow *you can handle*; but regardless of what that draw-weight is, use an arrow setup that gets the absolute maximum performance possible from it … and *then* take shots only within your personal 'zone of certainty' with that setup. To the maximum extent possible that confines 'bad hits' solely to ones resulting from the animal's reaction to the shot.

A good-hit always helps the 'likely outcome', but bad hits happen. Regardless of your accuracy and how hard you try, if you hunt much at all you'll end up with plenty of 'less than perfect' hits. That's where 'over-kill', in both your bow and your arrow setup, often makes a difference.

Virtually any arrow CAN work if hit conditions are perfect. Moose have been cleanly killed, instantly, with a metal blunt. Most hunting arrows work when hit conditions are favorable. Only a few work when things go badly. It's all a matter of *lethality frequency*, and there's one irrefutable fact: Any arrow which "has enough" to work when hit conditions are at their worst will also work on every favorable or perfect hit.

A lot of animals, and tons of meat, are lost annually because of arrows that arrive with 'too little' terminal performance. To spin a bit of Nathan Bedford Forrest wisdom; it's best to show up with the most'est you can muster, 'cause you never rightly know just how big a fight you might be step'n into.

Testing with this lighter draw weight bow has provided a great deal of useful information about FOC and its degree of effect. Coupled with the earlier test, it *confirms* that Extreme FOC offers a significant penetration boost, making it possible for a penetration-maximized Extreme FOC arrow from a light draw-weight bow to equal or exceed the terminal tissue penetration of 'commonly used' arrows from similarly efficient bows of substantially greater force.

In the next Update we'll compare the terminal performance of the penetration enhanced Extreme FOC arrows from each of the longbows, to see how bow-supplied arrow force correlates when the playing field is leveled. We'll also wrap-up some lose ends, and begin discussion of results from other new testing.

Addendum

Despite previous attempts to explain what outcome studies are all about, it appears many still do not grasp the value and validity of their results. The following is another attempt to edify.

In any situation with a large number of random occurring variables outcome studies provide the most reliable indicators of the likely result of an event. In our case, the 'event' is; what's the most likely outcome when a given arrow, of given force, impacts real tissues? Our 'goal' is to find the arrow that gives the greatest likelihood of the best possible outcome on the highest potion of all possible tissue hits.

Lab-based studies can't provide information applicable to such scenarios. They are designed to show what occurs under controlled conditions; something not present in real-world events. In our case, there's no such thing as a 'standard hit' that a lab can use; each hit is, in some way, different to the next – the hit's features randomly occur.

Where lab research relies on repeatability of outcome on a single static-scenario, outcome research uses 'most likely outcome' across a collection of dynamic-scenarios. It wants to know what gives the desired results most often. Outcome research uses whatever sample-size it must to determine *the probable even result*. If a particular outcome only happens 5% of the time it doesn't show up often in the *sample*, and it takes a much larger sample size to validate its occurrence. If something routinely appears, over and over, it takes fewer replications to verify its *likelihood of occurrence*.

In outcome-driven, real-world testing, *highly significant* event-influencing factors become blatantly manifest. They overshadow the multitude of randomly introduced variables, providing a tip-off to their importance. This tells you that, even when the multitudes of 'real world' things that ***can* and *are*** happening are considered, here's a factor that *routinely* makes a huge difference in the *likely outcome*. This is an important feature missing in classical, lab-based testing.

Perhaps the difference in *purpose* between these scientific investigative methods is easier to understand if you think of how each applies to finding the correct arrow spine for your bow.

In the lab it's possible to mount your bow in a shooting machine and, with a given point weight, precisely define what shaft deflection gives the closest to absolute perfect dynamic spine, and arrow flight, on every shot. It requires only a few shots to verify if an individual shaft's spine is correct or incorrect *when the bow is fired from the machine*.

However, how the arrow flies in a lab's totally controlled environment doesn't accurately forecast how it will perform in real-world usage, where multiple variables capable of affecting its flight randomly appear, shot to shot. To determining the correct dynamic arrow spine when *YOU* hold that same bow in YOUR hand and YOU release the string *requires* that YOU make the shot. For almost everyone the 'most correct' dynamic arrow spine when THEY shot a bow isn't going to be the same as what a shooting machine indicates for that same bow.

A shooting machine can't account for our random shot-to-shot variables: the pattern of your hand pressure on the bow; the type and quality of your release; how good your follow-through is; the stability of your bow arm; any bow-torque you apply during the shot, precise degree of bow cant, etcetera. None of us are perfectly consistent. The variables 'in play' will be different on each shot, and we can't predict which, when, or to what degree each will occur. Their cumulative combined effect will affect what shaft deflection will be closest to perfect *on that individual shot*.

When tuning your arrow the 'desired outcome'; your goal; is dynamic spine giving as near-perfect flight as possible, on as many of YOUR shots as possible … and that has to happen *while all those variables you don't have control over are present*. To get that correct, you must rely on the *average quality of flight;* the *most likely* arrow flight each time YOU fire a shot.

During tuning you change the variables *you do have control over;* such as static spine, point weight, shaft length and nocking point; one at a time. Then you test that new scenario. After each series you evaluate the *average result.* Then you compare that 'average outcome' against your previous 'average outcomes' to ascertain the *effect* of whatever you've changed. *That tells you* what *effect* the change YOU made has caused in the 'average outcome'. Did it produce a desirable or undesirable change in outcome? If you measure the difference in outcome; for instance, the average impact distance from the target center; you can quantify the average outcome, and determine the precise degree of difference between the various outcome-sets.

Your *ideal goal* is perfect arrow flight on 100% of your shots, but we all know that isn't going to happen. There are simply too many "what if's" we can't control. However, you're not willing to settle for 'average quality' flight on 100% of your shots either. So, your task becomes to find what shaft-spine gives the *highest frequency* of your *desired outcome* – perfect flight - when all those uncontrollable variables are present, and across the full gamut of all the good, bad and ugly shots YOU make. You seek the one shaft-spine that's *most likely* to give you perfect flight from each shot. That will be the one that *averages* the highest percentage of perfect arrow flight (with whatever point-weight, FOC, fletching, etcetera, you're using during the testing).

Along the way, outcome testing invariably comes across specific things that that significantly influence the desired outcome, for both better and worse. These they try to identify and quantify. For instance, how does nock tension on the string influence the quality of your arrow's flight? What nock-tension shows the most consistent results? How does changing arrow-rest surface area or pressure-point against the shaft affect the arrow's flight? What amount of area/pressure give 'best flight' most frequently? What combination of all the *controllable variables* gives the best 'average' arrow flight'?

Each time you tune your arrow's spine, what you're actually doing is you own outcome-driven research project.

Now, consider the two research methods. Which do you think gives the more 'scientifically valid' answer to your "desired outcome"; the most consistently perfect arrow flight you can get when *YOU* shoot *YOUR* bow? If you chose the shooting machine, you should definitely avoid an appearance on, "Are You Smarter than a Fifth Grader".

This basic difference in *purpose* between lab-based and outcome-driven research is the precise reason auto makers spends billions annually to outcome-test lab-designed and engineered cars and components under 'real world' conditions; cold, hot, wet, dry, urban, open-road, rough road and off-road - every highway and byway condition they can find. It's also why aircraft designers employ test pilots, and why the military spends trillions of dollars field-testing everything from shoe soles to super-carriers … after they have been test-tube developed, lab engineered and fabricated to "rigid government specification".

Outcome testing shows *what can happen, what's likely* to happen*, how often* it happens, and *what, how and by how much* the various controllable factors can influence the outcome*.* It indicates what's *most likely to happen* each time something is used 'out there' in the real world, under the multitude of possible situation that *might* occur. You simply can't find that answer inside a lab.

Outcome-research is the bread-and-butter of *Consumer Reports*, *Underwriter's Lab* and *Mythbusters*. It's the *norm* in such diverse fields as forensic investigation, seismology and vulcanology, quality assurance, public safety, proof-testing, risk evaluation, political science, pharmaceutical trials, education, financial investment, surgical procedures, military strategic planning, crisis intervention, computer programming, hospital care, hostage negotiation/rescue, disaster planning and, yes, terminal ballistics.

Dr. Frank Chamberlin's post-WWII outcome-driven testing of Geneva Convention compliant military bullets and cartridges on anesthetized mules, pigs and goats remains the recognized benchmark research on the tissue effects of military small arms projectiles. Marshall and Sanow's retrospective outcome-driven 'actual shootings data' is widely considered the definitive work on the 'real world effectiveness' of defensive cartridges, loads and bullets. Many of the Arrow Lethality Study's testing protocols and procedures are modeled on those used by Dr. Chamberlin.

The Study began a quarter century ago, with the work in Natal. That data was from hunted animals, taken under controlled culling conditions. The 'outcomes' were retrospectively examined, much as Marshall and Sanow did in the 'handgun study'. From there, rather than anesthetized animals, the Study progressed to controlled shots on freshly downed animals; to further investigate, define and refine the influencing factors *suggested* by the initial data. Simultaneously, the 'actual kill' data-base was also continued, to provide correlation cross-reference.

For a quarter century, the Study's *specific results* have been incrementally put forth. That provides everyone access to the *exact outcomes* found and the *methodology used* in deriving them. This provides the information required for anyone to set up their own comparative study, retesting and comparing outcomes.

It is perfectly proper to challenge Study outcomes, observations and/or explanations. That's precisely why the *specifics* were presented, rather than generalized statements, such as "this is what I've found works best". It offers everyone the opportunity to compare, verify, challenge or refute them. However, to have credence this must also be based on *data and specifics*, rather than rhetorical, subjective or anecdotal 'comparisons'. It is hoped the Study will inspire many others to do their own documented research and, even if limited, present their outcomes. From that, all bowhunting can benefit.

Study findings are freely presented. They are there for all researchers and interested bowhunters to examine and/or use. Each individual is free to use or ignore any or all the information.

Outcome-research has long been academically accepted; its credentials and validity fully recognized. The Study is not lab-based, but does represent valid research.

A Google search of the *phrase* "outcome research" returns way over a half-million results. Outcome-driven studies are commonplace, and neither new nor unorthodox. They are a scientifically valid, widely used research method of long standing; one academically recognized as *the research method of choice for multidimensional 'real world events', accurately reflecting the likelihood of specific outcome(s)*.

