2007 Study Update, Part 3

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The 2007 testing was primarily devoted to two areas; Internal Footings (IF's) and the effect of Extreme FOC on penetration. FOC testing used three longbows; 82#@27", 70#@27 and 54#@27".

Let's begin with the heavier bow. In prior testing, Extreme FOC arrows from this bow reached the measurable-penetration barrier, making it impossible to quantify penetration gain. In this round the heavy bow was used primarily for testing IF's; all of which were Extreme FOC setups.

In way of a refresher; "Normal FOC" is Study defined as anything up to 12%, measured using the AMO Standard formula. "High FOC" is defined as 12% to 19%. "Extreme FOC" is defined as 19% or greater.

Testing the Internal Footings; Extreme FOC and the 82# bow

Initial IF testing involved 'punishment shots', having direct or adverse-angle heavy bone impact. The upper leg bone was the primary target. Shots were concentrated at or just below the shoulder's ball-joint. It's hard to imagine a more difficult penetration adversary on an adult buffalo, unless, perhaps, the head.

All IF shafts had 100 grain brass inserts and steel broadhead adaptors. The 190 gr. Grizzly was used on all except one set, whose performance will be discussed in detail.

Punishment shots were taken from close range, with arrows in paradox at impact, stressing shafts to a greater degree. Several hits imbedded deeply into the bone, but most exhibited violent deflections - exactly what the test was looking for. Several hits resulted in large chips being removed from the bone. All IF shafts come through unscathed, as did every broadhead, insert and adaptor.

Additional IF testing focused on a single set of Extreme FOC arrows. These were used on both adverse-angle scapula shots and broadside back-of-the shoulder shots.

In the absence of structural failure, almost all the higher-mass Extreme FOC arrows previously tested routinely produced thorax-traversing hits with the 82# bow, with several providing exit wounds. Those arrows had many penetration-enhancing factors, but not all. How well would an 'optimized' Extreme FOC Internally Footed arrow work at this force level? This test series was as good a time as any to find out.

The 190 gr. Grizzly used in most prior testing was replaced with the Modified version, because of the higher mechanical advantage (MA) offered. The arrows incorporated all penetration-enhancing factors except a Teflon™ broadhead coating and a tapered shaft.

The setup for this test set was: Carbon Express Heritage shaft, Internally Footed; 100 gr. brass insert; 125 gr. steel adaptor; Modified Grizzly. Total mass was 790 grains. FOC was 26.3%. Impact Momentum: 0.523 Slug-Ft/Second. Impact KE: 38.94 ft. lbs.

The scapula shots

Scapular impact testing was done at ten yards, on very large adult male buffalo. Six shots were taken from a 45^0 shooting angle, quartering from the front. This gives a scapula impact angle of 37^0 to 38^0, approaching the Modified Grizzly's skip-angle of circa 45 degrees.

One shot penetrated both scapular-flat and on-side rib, giving a one lung hit. Penetration was 14.125". Two shots penetrated the scapular-flat, embedding deeply in the on-side rib. They showed penetrations of 10.5" and 11.125". One stopped in the scapular flat and two in the scapular ridge.

The average penetration for all six scapular impacts was 9.96". Three of the four shots (75%) impacting the scapular-flat penetrated it from this extremely adverse angle. This was a surprise. No other shot from a 45^0 shooting angle had managed to penetrate the scapular-flat on any buffalo, of any size.

The broadside shots

Six broadside-shots were taken from 20 yards, on very large adult male buffalo. Five hit back of the shoulder, with rib only impacts. One was a somewhat high shoulder hit, barely missing the scapula's edge. It penetrated 18.875", with the broadhead passing through the off-side rib. Average *measurable penetration* for all six shots (including the shoulder hit) was 21.86".

All five back of the shoulder hits gave exit wounds, exceeding measurable-penetration. Their average *measurable-penetration* was 22.5", with a range of 19.25" to 24.750". Median measurable-penetration was 23.875". An excellent 'casual gauge' of penetration is that each penetrated to the fletching; like peas in a pod.

Look back at the 2005 Update, part 4; *Buffalo Arrows*. Examine Chart 6. Find the "Trophy Size" group. Those are comparable animals. For back of the shoulder rib-only impacts, average arrow mass and impact momentum required for a normal or high FOC arrow to fully-traverse the thorax (reach the off-side ribs) was 900 grains and 0.53 Slug-Ft/Second. At virtually the same impact force these Extreme FOC arrows not only gave a 100% thorax-traversing rate, they did so with significantly less mass-weight, while also providing an exit-wound on every hit.

At the impact-force levels used in testing no normal or high FOC arrow from *any* of the test bows has given an exit wound; on any shot from any angle on any size buffalo … not one. Among those are 249 shots from broadside having back of the shoulder rib-only impacts, using this same 82# bow. These normal/high FOC test shots have included many double-shaft and high-mass hardwood arrows, several with mass-weight exceeding 1000 grains and carrying as much as 0.68 Slug-ft/sec. of impact-momentum. A number also had the Modified Grizzly broadhead. Also included are all compound bow test shots; using lighter, faster normal FOC arrows with as much as 0.66 Slug-ft/sec. of impact-momentum and 94 ft. lbs. of impact kinetic energy.

Why did the Extreme FOC arrows penetrate deeper when they had less impact momentum and mass? As will be shown, Extreme FOC's conserved force is of tremendous magnitude. That means more 'useful force' is available. When other penetration-enhancing features are used to apply that extra 'useful force' with greater efficiency the time of impulse is markedly increased. The two, force and time, are *multiplied* to derive the total impulse of force. Though many normal and high FOC arrows carried greater impact-force, more of their force was squandered; spent on items not 'necessary or useful'. The enormity of that wasted force will become clear as we progress through these Updates.

How other penetration-enhancing factors affect Extreme FOC

While uniformity is maintained between comparison-sets, be mindful that penetration-enhancing factors differ between the various Extreme FOC groups tested. Examining outcomes between these and comparing them to normal FOC outcomes on similarly-dimensioned arrows reveals paradoxical features.

Extreme FOC penetration remains affected by other penetration-enhancing factors. Each factor remains relevant, but their effect becomes *greater* with Extreme FOC. For example, increasing broadhead MA shows the same relational outcome with Extreme FOC arrows as normal and high FOC arrows; it increases penetration. The difference is the *degree* of increase shown.

Extreme FOC arrows show lower penetration-resistance; a result of reduced shaft-flex. At any given impact force this provides the broadhead's MA more 'useful momentum' to apply towards penetration. Higher broadhead MA means the additional 'useful force' is more efficiently applied. This results in the additional force being retained for a longer period of time during penetration. Penetration gain due to broadhead MA now equals a greater linear distance through the tissues than it would on an equal-force arrow lacking Extreme FOC. As a percentage of the force they impact with, Extreme FOC arrows benefit *more* from broadhead MA than normal and high FOC arrows of equal force. This is similarly demonstrated by the other penetration-enhancing factors. We'll look at this in more detail later.

Extreme FOC's Implications

Extreme FOC has a marked effect on tissue-penetration. Results imply the lower mass-limit required for a penetration-maximized Extreme FOC arrow to give a 100% thorax-traversing rate on a trophy size buffalo, from all reasonable shooting angles, is somewhere below 790 grains; *at this force level*. A look back at the outrageously misused Chart 4 (2005 Update, Part 2), shows data *suggestive* that it may be at, or slightly below 700 grains - when enough other penetration-maximizing factors are present.

Do not read the forgoing as meaning the Study advocates use of the minimum adequate arrow mass for buffalo, or any other game. The purpose in seeking the minimum is merely to establish where the lower threshold of 'adequate' lies. Even when every other penetration-enhancing feature is present, more arrow weight means a longer time of impulse and more penetration.

No one has ever lost an animal because their arrow penetrated too much. The more penetration potential your arrow has the better. When hunting any animal it's always best to err on the side of 'more than minimally adequate'. Doing so becomes even more important as animal size becomes greater.

I've never heard a bowhunter say, "I need a lighter draw weight bow for buffalo", or "My arrow is too heavy for buffalo". You should never ask, "How little can I get away with using". Ask, "How much am I capable of using". If what you can use doesn't reach - or, preferably, well exceed - the minimum threshold, then you need to work up to a setup that will. Otherwise, don't even try. Any wounded animal is a tragedy; a wounded buffalo can be deadly!

Other FOC heavy-bow test

An attempt was made to revisit the heavy bone threshold, to see if *degree* of FOC has any effect on the threshold (See 2005 Update, Part 6). The plan was to use a *similar* arrow at gradually increasing levels of FOC. The Pro Big Game broadhead comes in several weights. Shifting gradually up in broadhead mass would give progressively greater FOC with a *similar* broadhead.

To maintain arrow mass as close as practical, the starting arrow was weighted with weed-eater line. This permits pieces to be progressively removed as broadhead mass is increased, maintaining total mass relatively constant as FOC is elevated. Trial runs indicated fairly good flight throughout the range; hopefully good enough to see if any FOC effect on the heavy-bone threshold was *suggested*. If so, new test with precisely matching arrows could be developed.

This testing hit a major glitch. It started with four arrows setup and ready to go. These were the lowest FOC arrows. They had a mass of 553 grains. Four broadside rib-impact shots were taken from 20 yards. Three of the four resulted in cracked shafts, with failure to penetrate the entrance rib. Average penetration was 5.21". The lone structurally-intact arrow penetrated the rib, giving penetration of 14.125".

The glitch came when I went to make more arrows. I had failed to bring spare shafts. The test was terminated. Though little useful information resulted, the low frequency of penetrating the on-side rib does correlate with that of low-mass Extreme FOC arrows previously tested. Both are *suggestive* that the heavy bone threshold is persistent for Extreme FOC arrows, and at or near the same level as for normal and high FOC arrows. However, structural-failure rate has to be considered. It is possible that IF combined with Extreme FOC *might* show some effect on the heavy bone threshold. This remains undetermined.

Extreme FOC Testing with the 70# longbow

This longbow's efficiency is typical of older bows. The performance shown, though impressive, should not be equated by draw weight to more efficient bows. It was selected because the goal was penetration not encountering measurement constraints.

The arrow setup was: Total mass, 756 grains; Grizzly 190 grain broadhead; Cabela's 45-60 Outfitter shaft; 100 gr. brass insert; 125 gr. steel adaptor. Arrow FOC: 27%. Impact Momentum, 0.477 Slug-Ft/Sec; Impact Kinetic Energy, 33.84 ft. lbs. (Shaft shown is correct. Similarly set up and bare-shaft tested a full-length 60-75 shaft shot strong-spine from this non-center-shot bow. Even the 45-60 shafts had to be left a tad long.)

Nine shots were taken, broadside from 20 yards on very large male buffalo. Three were placed low on the shoulder. Each shoulder shot impacted the leg bone. One suffered a small shaft fracture back of the insert's lip. It broke a large chip off the bone and stopped in the on-side rib, giving 9.75" penetration. Among the other two, one chipped the leg bone at the joint, deflected, penetrated the on-side rib and entered the heart, giving 11.375" penetration. The third shot struck squarely on the leg bone, burying the broadhead into the bone, giving 6" of penetration; over 3" of which was into bone.

The remaining six shots were back-of-the-shoulder rib-only hits. Averaged penetration was 15.65", with a range of 12.75" to 19.5". All reached the second lung. One gave a very shallow double-lung hit, three gave deep double-lung hits, and two traversed the thorax to reach the off-side ribs. Both thorax-traversing shots stuck solidly through the off-side rib, but neither penetrated the rib. ('Penetrating' a bone implies passage of the *entire broadhead* through the bone.)

Though effort was made to select a bow that would not result in the Extreme FOC arrows encountering penetration constraints, 33.3% of the rib-impact shots traversed the thorax, limiting measurable-penetration. However, we will make comparisons as best permitted.

Extreme FOC comparison: 70# vs. 82#

In making comparisons between the 70# and 82# bows, penetration-barrier and measurable-limits must be considered, as well as differences in arrow setups. Besides the obvious IF, there is major difference in broadhead MA. Whether or not an IF has any penetration effect, other than forestalling shaft failures, is undetermined at this time.

The Modified Grizzly's MA is 3.25; an 18.2% increase over the 190 Grizzly's MA of 2.75. In earlier testing (see 2004 Update, Part 1) the Modified Grizzly demonstrated a 26% average-penetration advantage over the 190 Grizzly; on matching-profile normal FOC shafts having favorable shaft-diameter to ferrule-diameter ratios, equal mass and impact force.

Comparing the two Extreme FOC arrows, those from the 82# bow have 4.5% greater mass and carry 9.6% more impact-force. FOC is near equal; 26.3% and 27%. *Measurable* penetration was 39.7% greater with the 82# bow.

This comparison demonstrates the greater benefit broadhead MA imparts to Extreme FOC arrows.

Though impact-force is only 9.6% greater, Extreme FOC arrows from the 82# bow arrived at the off-side ribs with sufficient retained-force to overcome the bone's resistance, with all except the shoulder hit carrying on to provide exits. This indicates enormous retained force - much more than the impact-force difference suggests; based on the penetration increase shown by normal and high FOC arrows having a similar impact-force difference.

Other than IF, the arrows are near identical in dimensions except for broadhead MA. Though both arrows have a favorable shaft-diameter to ferrule-diameter ratio, the 70# bow's 0.005" (1.6%) smaller shaft diameter *might* provide it a tiny edge. The heavier arrow's 34 grain mass advantage would contribute a modest amount to its momentum-retaining ability.

Ignoring the undetermined IF influence, which may or may not be present, and the 34 grain mass difference; outcome is *suggestive* that differing broadhead MA was the most significant factor. But should (or could) that amount of MA difference result in such an enormous penetration difference? The answer is yes.

Going step by step: (1) The arrows are very similar except for broadhead MA; (2) The Extreme FOC arrows from the heavier bow exceed measurable-penetration; (3) Measurable-penetration difference was 39.7%; (4) Actual penetration difference would be greater than 39.7%.

The Modified Grizzly's *demonstrated* penetration increase <u>in normal FOC testing</u> *exceeded* the percent of MA advantage-increase; showing a 26% gain for the 18.2% MA advantage. This results from greater *retained* momentum during penetration, due to increased broadhead efficiency. This, in turn, results in a greater *time* of impulse. Each *multiplies* the effect of the other.

Working with the known numbers:

(a) The previously demonstrated broadhead penetration-increase (26%) plus the difference in impact force (9.6%) would suggest an average *total* penetration increase of 35.6% between the two arrows; *in the presence of no penetration-measurement constraints*.

(b) The difference between the two broadhead's MA (18.2%) plus the difference in impact force (9.6%) would suggest a total penetration increase of 27.8%. The casual inference is that average penetration should fall somewhere between these; but it doesn't. Even with measurement constraints, both average and median penetration was greater. Actual penetration gain was far greater than 35.6%. This implies MA-supplied penetration-gain was greater than the 26% shown when tested on normal FOC arrows.

The 35.6% suggested-increase is far too low. Why and how could the Modified Grizzly's MA advantage result in such a greater degree of penetration-increase than previously demonstrated?

Understanding the increased effect shown by MA when used with Extreme FOC goes back to the earlier discussion of the impulse of force, in Part 1.

Extreme FOC arrows have less shaft-flex at impact and during penetration, resulting in lower shaft drag. Because it conserves a portion of the impact force, the Extreme FOC arrow carries more 'useful' penetration-yielding momentum than the normal FOC arrow. This means broadhead MA has more useful force to apply to the 'work' of penetrating tissues.

When broadhead MA is increased, on either normal or Extreme FOC arrows, the available force is used more efficiently, resulting in a longer time of impulse. At equal impact force the Extreme FOC arrow has more 'useful', penetration-producing momentum; ergo, the higher MA has more force to work with. This means an even greater time of impulse, yielding a greater depth of penetration. As described in Part 1, these two factors; *additional retained force* and the *time factor* of the impulse; have a multiplying effect on each other - they equal more than the sum of the parts. Because of this, broadhead MA affects an Extreme FOC arrow's penetration to a greater degree than it does an arrow having normal FOC.

The bottom line is that momentum's impulse of force formula indicates the Extreme FOC arrow *should* show a greater amount of penetration increase as a result of higher broadhead MA; and it does. The same result, for the same reason, is manifest for the other penetration-enhancing factors.

The impulse/penetration relationship is emphasized because comprehending the profound influence even small penetration-enhancing factors have requires an understanding of what force is, and how its *impulse* influences achievable penetration. The kinetic energy concept (as a penetration-predictor) has no mechanism to predict or explain such outcomes; simply because it is not, by its very definition, applicable to *force* or how *force* is used.

Though there are presumptions in the forgoing example, such as the ignored IF, the deductions are based on *data demonstrated* facts: (a) for *identical arrows*, average tissue-penetration increase is *directly proportional* to momentum increase; (b) broadhead MA shows a predictable effect on penetration increase and; (c) Extreme FOC data *consistently* demonstrates the compounding effect. The event-sequence follows both that *implied* by the data and *dictated* by the mechanics of the impulse of force. Persistence and consistency of data correlation *indicates* they are correct.

Later, this compounding-effect of more retained momentum used more efficiently will be graphically illustrated.

Extreme FOC arrows from the 70# bow vs. normal and high FOC arrows from the 82#' bow

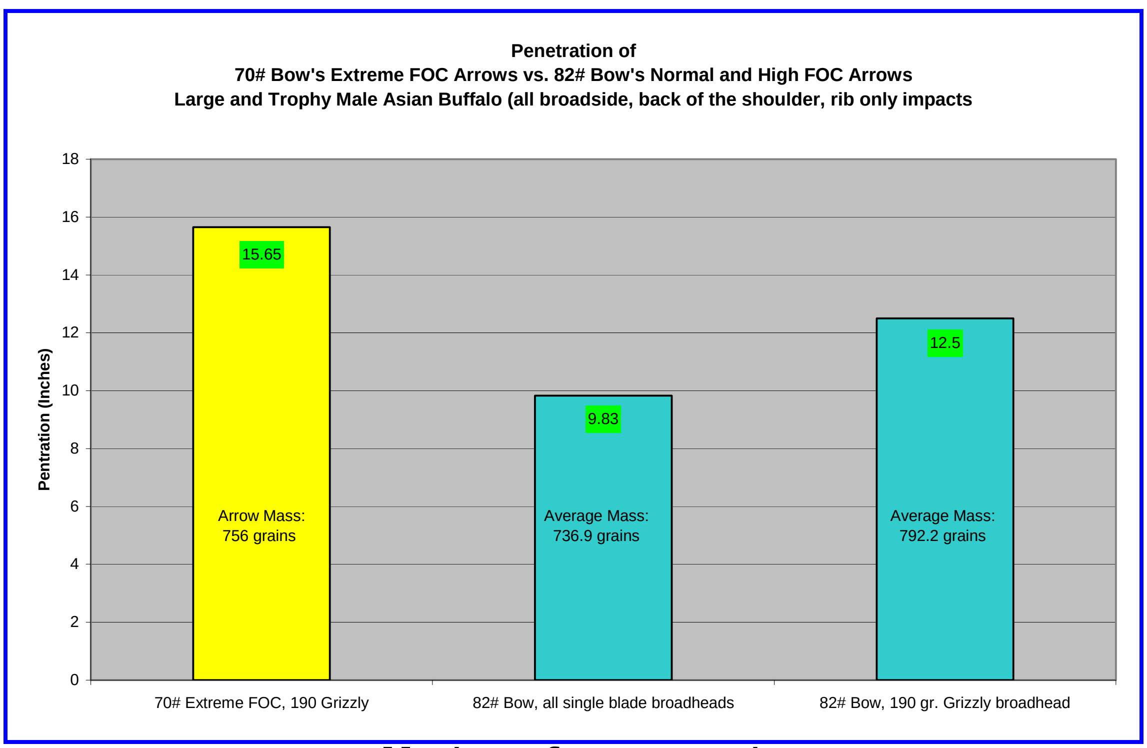
To make a comparison between the 70# bow's Extreme FOC arrows and the 82# bow's 'normal arrows' more applicable, let's consider only the heavier bow's arrows at or below a total mass of 800 grains, for all shots where no arrow structural-failure was encountered. We'll also consider only those having single blade broadheads. Only broadside, back of the shoulder chest hits from the same shooting distance on comparable size buffalo are included.

For the set comprising all single blade broadheads, total arrow mass averages 736.29 grains. Average penetration is 9.83".

Next, let's isolate only arrows in this group having the same broadhead (190 gr. Grizzly). Average mass is 692.23 grains, and penetration averages 12.15". Though of lower mass, note the *exhibited effect* of high broadhead MA (and the Grizzly's single-bevel bone splitting effect) on penetration. Excepting only its modified versions, the 190 gr. Grizzly has the highest MA among tested broadheads.

While comparing, remember that most arrows in the 82# bow's groups do not possess as many of the other penetration-maximizing factors as the 70# bow's Extreme FOC group. Some have a poor ferrule-diameter/shaft-diameter ratio, several have either 'Hill type' serrated, micro-serrated or file sharpened edges, and some have a barrel-tapered shaft. Among 'all single blades' there is great variation in mechanical advantage, blade profiles, cutting angle, edge angle and tip profile. However, collectively taken, they represent a typical aggregate of 'commonly used arrows' and single blade broadheads.

The following graph compares penetration-outcomes between the 70# bow's Extreme FOC test arrows and all comparable-shots from the 82# bow, when it is used with 'common' normal to high FOC arrows with single blade broadheads.



All Shots from 20 Yards

Inferences

With Extreme FOC arrows having *most* (but not all) penetration-enhancing factors the 70# bow produced tissue penetration exceeding the 82# bow, when the heavier bow was used with 'common' arrows; not penetration-enhanced or maximized. They show 58.7% more penetration than the 82# bow's 'random single blade' group, and 25.2% more when the same broadhead (190 gr. Grizzly) is considered.

This brings us closer to quantifying Extreme FOC's effect on penetration, but a grey area remains because of measurement-constraints. The *demonstrated* fact is that the 70# bow, with its Extreme FOC arrow setup, substantially outperformed a bow 12# heavier (of similar efficiency) when the heavier bow used 'common' arrows.

There's more to come. In the next update we'll look at the 54# bow's Extreme FOC arrows, and how they stack up to both the 70# and 82# bow. If you hunt with a lighter draw bow, stay tuned. You won't want to miss this. It's highly useful 'campfire debate' information!