2008 Study Update, Part 6

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Previous 2008 Updates have been devoted to the Heavy Bone Threshold and terminal performance of the Ultra-EFOC arrows. In Part 6 we'll try to quantify FOC's effect on penetration and examine some other implications of the FOC testing.

How Much Does Increasing FOC Affect Penetration?

Earlier testing with arrow sets matching in all aspects except FOC has shown that from 19% FOC upwards there is a measurable gain in arrow penetration. There is now sufficient comparative data between Normal FOC, EFOC and Ultra-EFOC arrows to make some observation about the degree to which increasing FOC affects outcome penetration, at least for shots impacting heavy entrance-side bone.

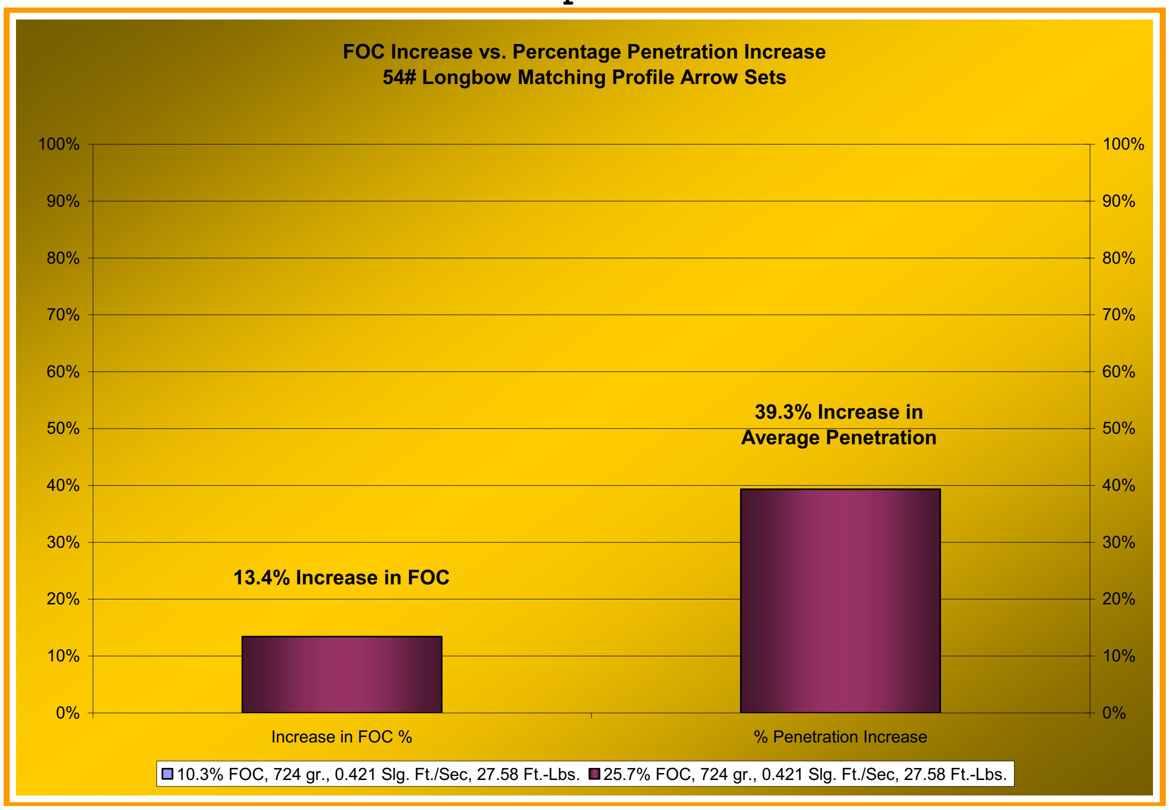
Some may wonder why a comparison of Normal, Extreme and Ultra-EFOC arrow penetration in soft tissue is not also being done. That answer is really simple. The penetration enhanced EFOC and Ultra-EFOC arrow setups have demonstrated exceedingly high levels of soft tissue penetration; so high that an all-soft-tissue target *many feet thick* would be required to begin the process of quantifying results.

The following graphs make a series of comparisons between several different arrow-setup groups from bows of several different draw weights. The arrows in each comparison have identical or very near identical external profiles but differ in their degree of FOC. All have the same broadhead; the 190 grain Grizzly. All shots in each set are on comparable size animals. All shots are from the same shooting distance, 20 yards, and the same shooting angle, broadside. All shots reflect only thorax impacts. All reflect only shots with arrows that maintained total structural integrity. Each arrow set was carefully bare shaft tuned, eliminating quality of arrow flight as a variable. As adjustment of shaft length is used when tuning the arrow's dynamic spine, there are differences in overall shaft length.

Except for comparison sets containing the Ultra-EFOC arrow, which was tested from both the 64# and 82# longbows, each Graph reflects arrows closely matched in weight and shot from the same bow. You will recall from the 2008 Update, Part 4, that this particular Ultra-EFOC arrow, originally developed and tuned for the straight-end 82# longbow, was tuned to the higher-performance 64# ACS-CX by adjusting the thickness of the arrow plate, and that the chronographed velocity from the two bows was identical, as were average penetration results; thus allowing their consideration as a single set.

First, let's lay out the data in a series of graphs then analyze what that data tells us.

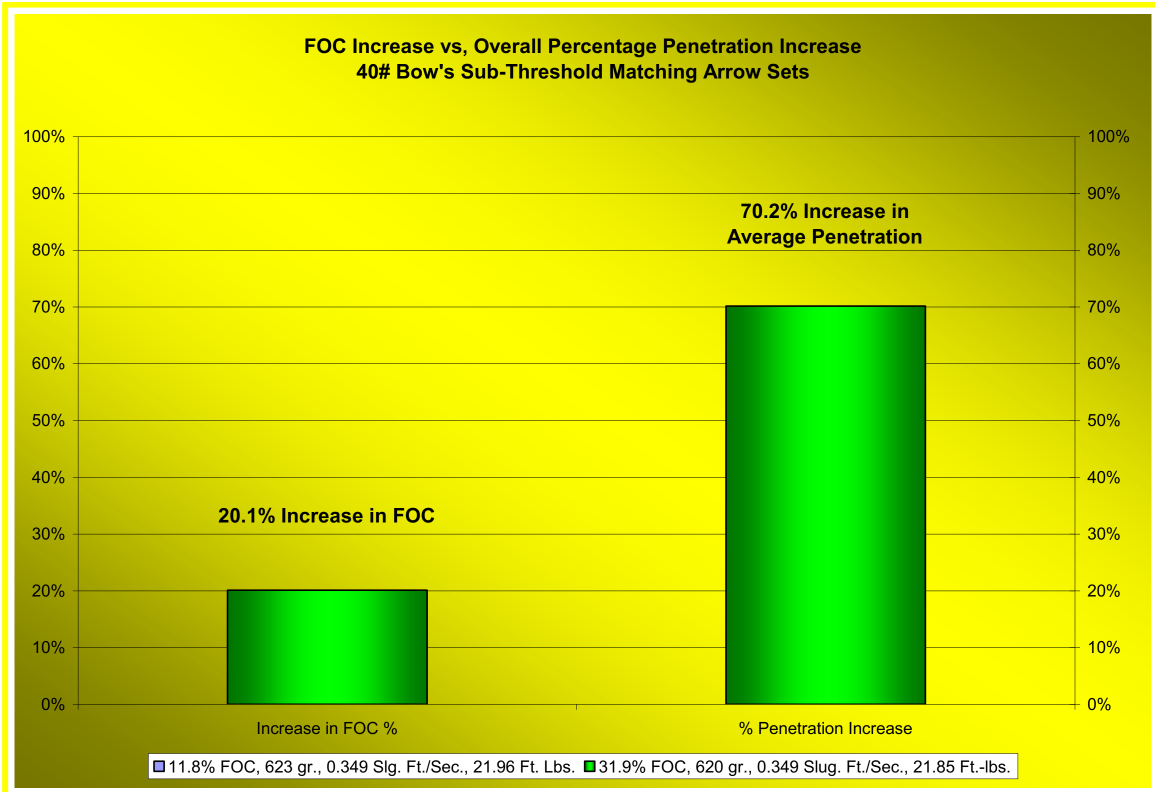
Graph 28



The arrow sets in Graph 28 are those tested from the 54# longbow. Specifics of the setup can be found in the 2007 Update, Part 4. The specifications pertinent for our purposes are: Set 1; 10.3% FOC, 724 grains, 0.421 Slug-Feet/Second of Momentum and 27.58 Foot-Pounds of Kinetic Energy (KE). Pertinent specifics for Set 2 are: 25.7% FOC, 724 grains, 0.421 Slug-Feet/Second of Momentum and 27.58 Foot-Pounds of KE.

The bar on the left side of the graph depicts the change in arrow FOC. The bar on the right side reflects the corresponding change in average outcome penetration. With these arrows, identical in all aspects except their degree of FOC, increasing the FOC by 13.4% resulted in a 39.3% increase in penetration for shots impacting an entrance-side heavy bone; the buffalo's rib.

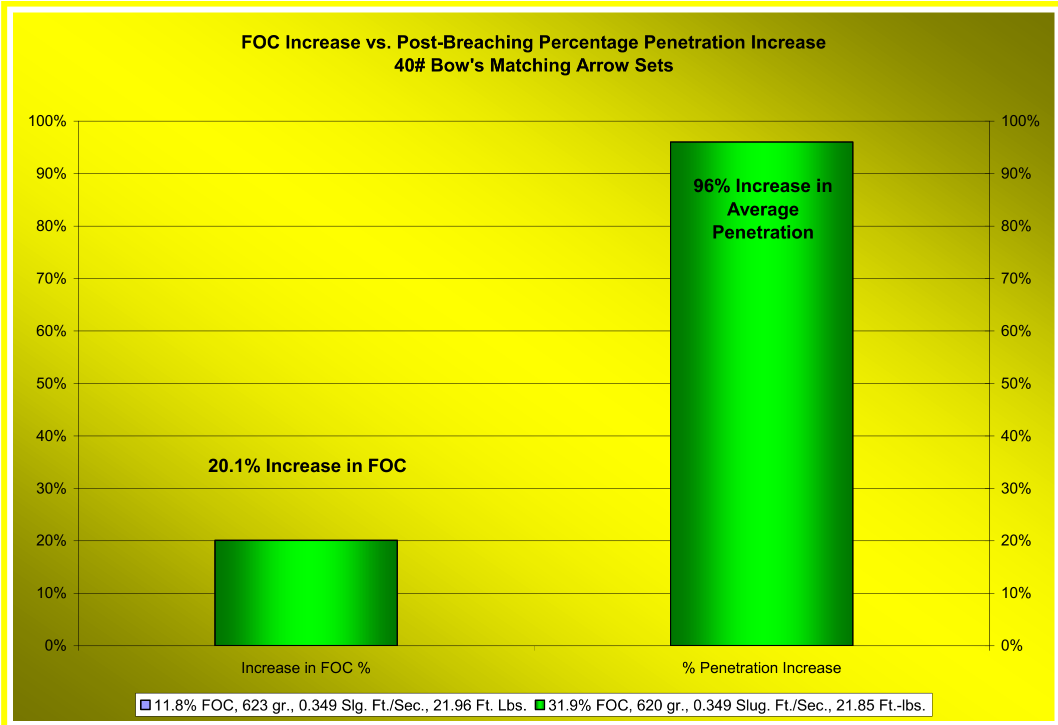
Graph 29



Graph 29 shows the similar FOC-to-penetration relationship for the sub-threshold mass Normal FOC and Ultra-EFOC arrows tested from the 40# recurve. The setup specifics are contained in Part 1 of on the current Update series. The pertinent specifications for each set are: Set 1; 11.8% FOC, 623 grains, 0.349 Slug-Feet/Second of Momentum and 21.96 Foot-Pounds of KE. Set 2: 31.9% FOC, 620 grains, 0.349 Slug-Feet/Second of Momentum and 21.85 Foot-Pounds of KE.

Graph 29 reflects the outcome for all 12 shots taken with each setup; the overall average of all shots. Examining these outcomes, for a FOC increase of 20.1% the average outcome penetration increased 70.2%. As you no doubt remember, only 50% of the below-threshold arrows in *each* of these arrow sets managed to breach the entrance side rib, so let's do the same graph and make the same comparison for the six bone-breaching shots with these same two arrow sets.

Graph 30

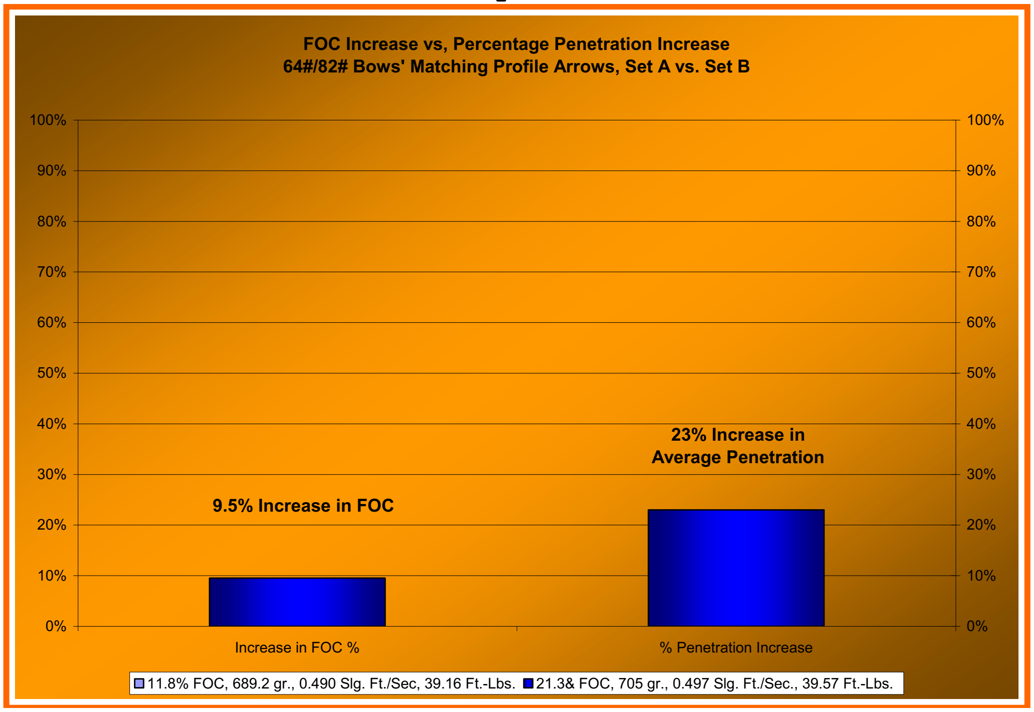


When we examine only the bone-breaching shots for the two sets of sub-threshold arrows from the 40# recurve (Graph 30) that same 20.1% increase in FOC shows an increase in average penetration of a whopping 96%.

With Graph 31 we begin a comparison between three arrow sets fired from either/or the 64# ACS-CX longbow and 82# straight-end longbow. For convenience we'll label these three arrow sets as Set A, B and C. Remember that both bows were used with only one arrow set; Set C, the 655 grain Ultra-EFOC arrow; and that this setup gave *exactly equal* velocity from both bows. Exact setup specifications for this Ultra-EFOC arrow can be found in Part 4 of the current series. The other two sets; Sets A and B, contain only shots with the 82# longbow, and their data is drawn from the database. The arrows in both Set A and B have carbon shafts, and carry the same broadhead as Set C. The shaft diameter for Set's A and B is equal, at 0.313". Set C's shaft diameter is eleven-thousandths of an inch (0.011") smaller; a negligible difference.

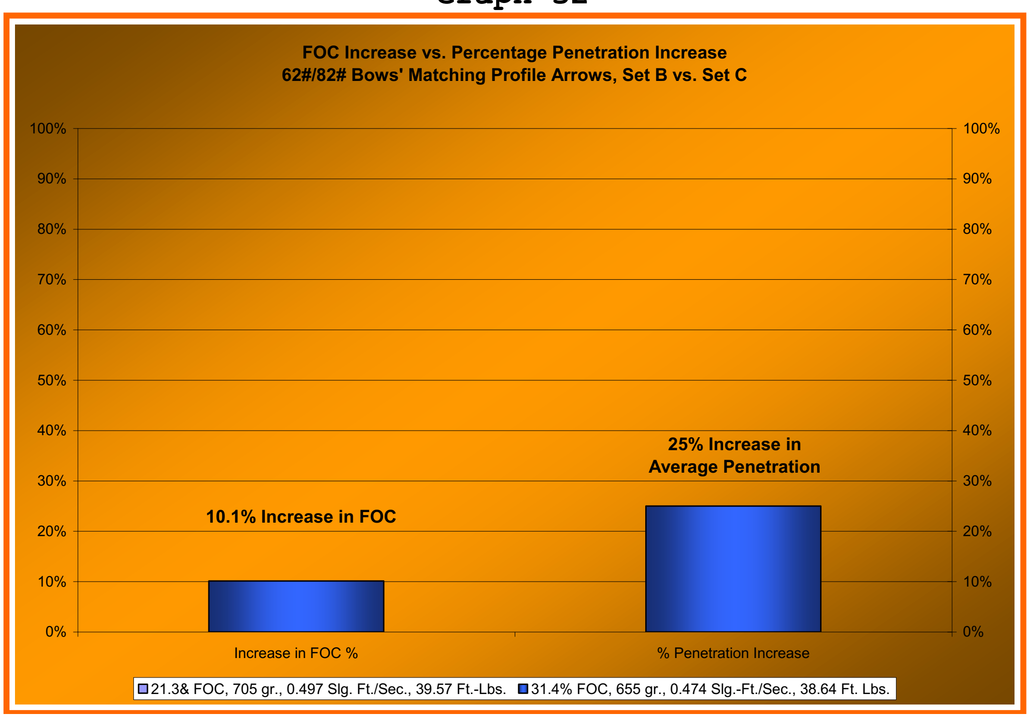
The other pertinent specifications for Sets A and B are: Set A: 11.8% FOC, 689.2 grains, 0.490 Slug-Feet/Second of Momentum and 39.16 Foot-Pounds of KE. Set B: 21.3% FOC, 705 grains, 0.497 Slug-Feet/Second of Momentum and 39.57 Foot-Pounds of KE.

Graph 31



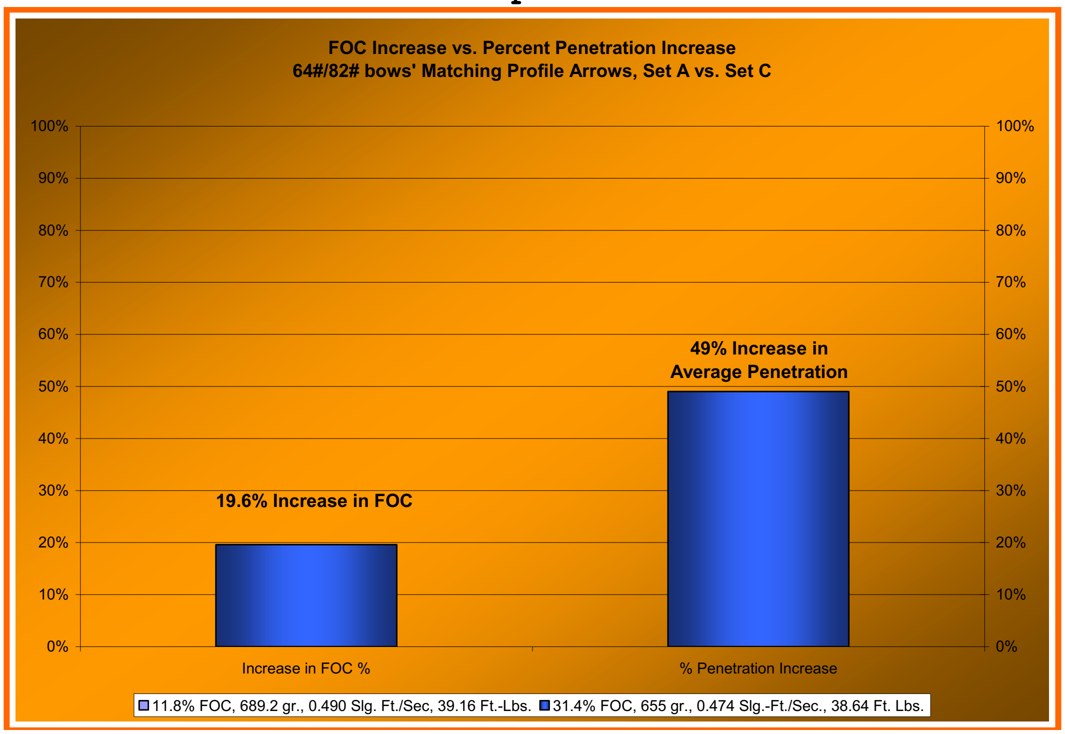
Graph 31 compares Set A against Set B. Both sets are fired from the 82# longbow. Here we find that a 9.5% increase in FOC resulted in an average penetration increase of 23%.

Graph 32



Graph 32 compares Sets B and C. In this comparison a 10.1% increase in FOC resulted in a 25% increase in average penetration.

Graph 33

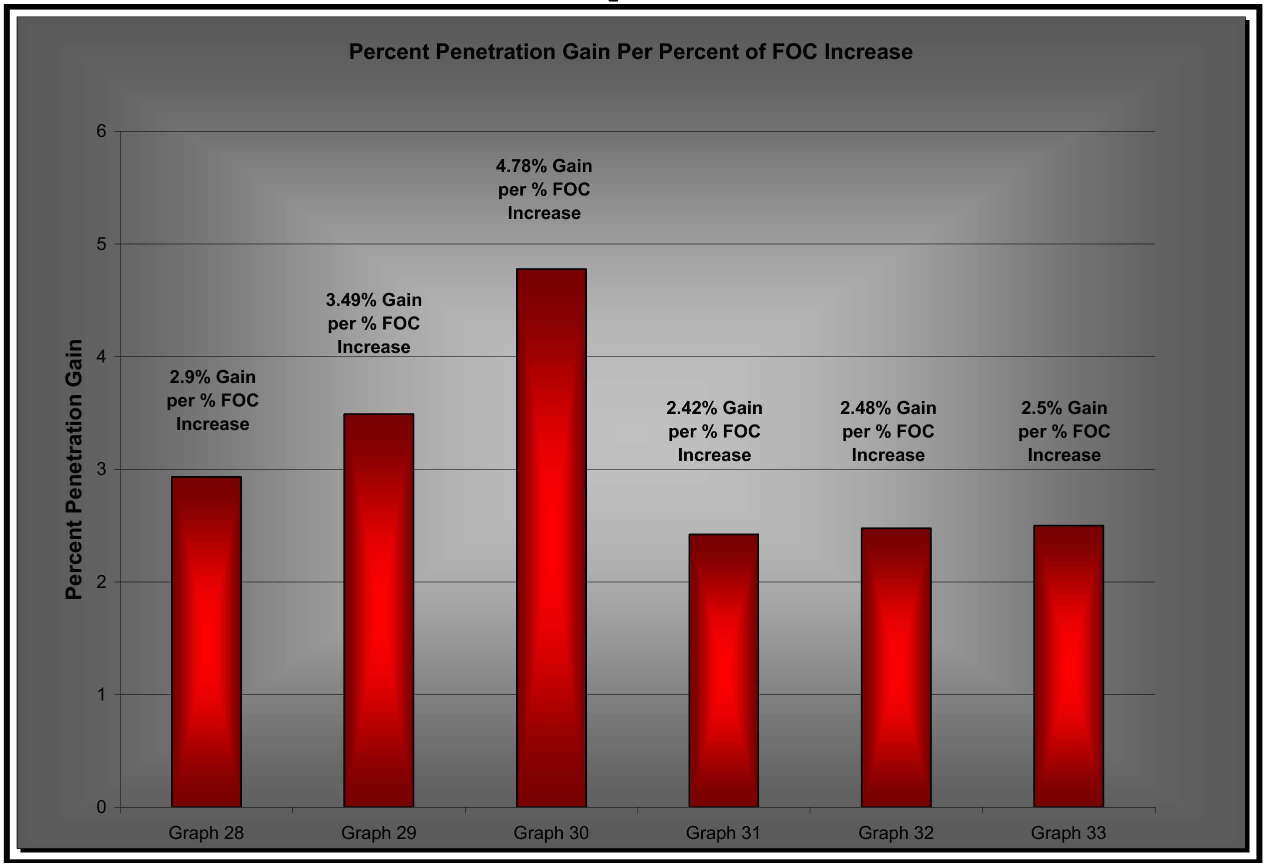


Graph 33 is a comparison between Sets A and C. Here we find that the 19.6% increase in FOC yielded an increase in average penetration of 49%.

Now, that's all well and good. In each case the matched-dimension arrow having the greater degree of FOC penetrated more, but how can we use this information to get an idea of how much penetration you can expect to gain if, without changing arrow mass or profile, you change your arrow's setup from Normal or High FOC to EFOC or Ultra-EFOC? What does it tell us about the relationship between increasing FOC and the resulting increase in average penetration?

Let's break the change down to see what the relationship looks like for the penetration increase yielded for every one-percent increase in FOC, for each of the comparison sets tested.

Graph 34



Now we have something more meaningful to work with, but why does the relationship look so different between results shown for Graphs 28 through 30, compared to that shown for Graphs 31 to 33? Again, the explanation is simple.

Fully 90% of the EFOC and Ultra-EFOC arrows represented by Sets B and C in Graphs 31 through 33 fully traversed the thorax, reaching the off-side rib penetration barrier. Having breached the ½" thick on-side rib and fully traversing the chest cavity they then slammed into another ½" thick heavy-bone. Lacking sufficient retained arrow force to breach this second set of heavy bones created a limiting effect on the measured penetration. How much more soft tissue penetration would the arrows have shown had this second heavy-bone barrier not been encountered? That is an unknown.

Remember that the degree of FOC shows no effect on the Heavy Bone Threshold. Encountering that second set of heavy bones is no different than encountering the initial set; the ability to breach the bone(s) is going to depend on the arrow's impulse of force and, as we've seen, many factors will affect the bone-breaching rate. Here's where paying attention to the small factors can add up to big results. Consider that, at the force levels used in the testing, the 790 grain Internally Footed, penetration enhanced EFOC arrow *carrying the ultra-high mechanical advantage (MA) Modified Grizzly* is the **only** setup reported in the Study (so far) that's shown a 100% breaching rate **of the *off-side* rib barrier**. Along with that 100% off-side rib breaching-rate it's also given a 100% exit-wound frequency. Consider too that when this same arrow setup is used with the regular 190 grain Grizzly it *does not* routinely breach the off-side ribs, and has *never* provided an exit wound. That's a pretty dramatic demonstration of the difference increasing broadhead MA can bring to even an arrow setup that's already penetration enhanced.

Only a few of the arrows represented in Graphs 28 through 30 reached the off-side penetration barrier. In fact, the only ones to reach to off-side ribs were three of the shots with the 40# bow's Ultra-EFOC arrows. Thus, the shots depicted in graphs 28 through 30 give a clearer picture of the potential post-breaching penetration rate-of-gain you can expect as the amount of EFOC increases.

So, here are some things we can deduce from the data shown in Graph 34. For shots impacting hard bone, the minimum rate of penetration gain shown by any comparison set appears in Graph 31 is a 2.4% penetration increase per 1% FOC increase. This *implies* that, on the average, the *absolute minimum* penetration increase for each 1% your arrow's EFOC is increased would be *more* than 2.4%.

What? Why would the absolute minimum increase be *more* than the minimum increase shown? It's because earlier testing of like-arrow setups, on like shots, showed no discernable penetration advantage until arrow FOC reached 19%. Ergo, since Graph 34's comparison for the arrow groups from Graph 31 is between an arrow having 11.8% FOC and one having 21.3%, with a penetration gain of 25%, and measurable penetration gain doesn't appear until FOC reaches 19%, we can make a *reasonable assumption* that the 25% penetration gain occurred between 19 and 21.3% FOC. That would *suggest* a rate of penetration gain of 10.9% per 1% increase in FOC above 19%.

This *implies* that, once into the EFOC range, penetration gain per percent of FOC increase should be far greater than that shown by any of the graph-comparisons that start with a FOC level below 19%. Then why doesn't this higher rate of gain show in Graph 32, where the comparison goes from EFOC into Ultra-EFOC. It's because of that second ½" of heavy bone. The off-side penetration barrier is forcing a limit to the measured penetration for both arrow sets in this comparison-group.

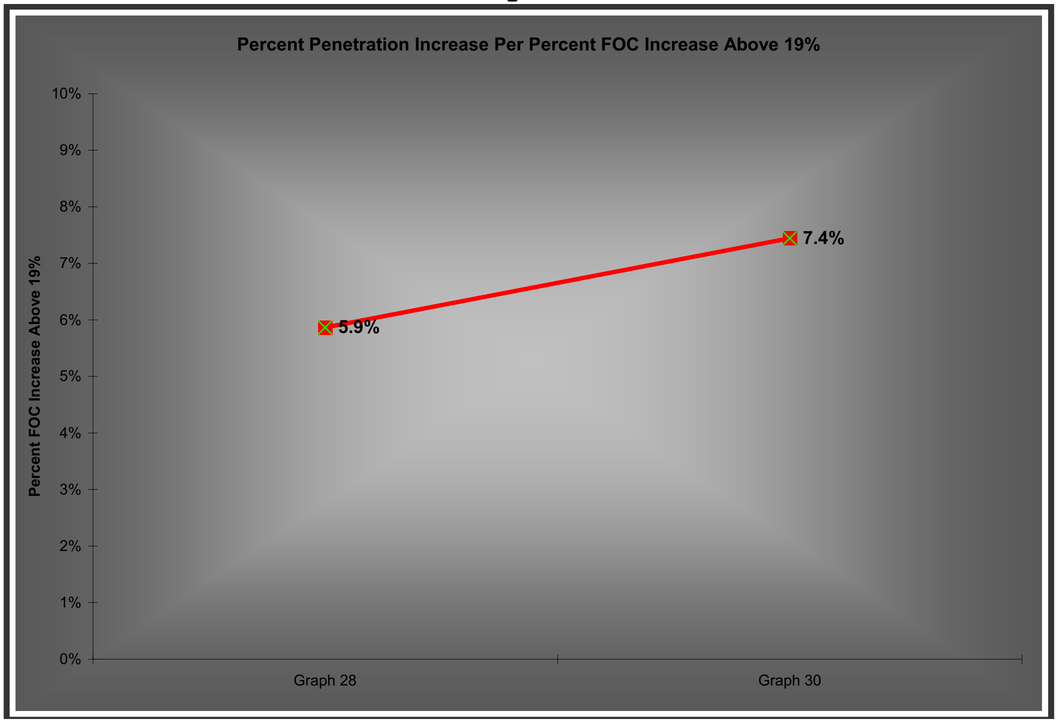
If we look at the percent penetration gain per percent FOC change ratio shown for Graph 31; the comparison between all bone-breaching shots for the 40# recurve; we see a 4.78 to 1 ratio. The Normal FOC set in Graph 31 had 11.8% FOC; well below the 19% FOC 'starting level' for penetration gain. Now, consider that one-half of the arrows shown for the Ultra-EFOC set (three of six) also reached the off-side ribs, limiting their penetration. This is opposed to none of the shots from the Normal FOC set reaching the off-side penetration barrier. This is *highly suggestive* that the actual percent penetration gain per percent FOC change ratio for shots breaching a heavy entrance-side bone, when starting from the EFOC level of 19%, would be significantly higher than 4.8 to 1.

Let's take a look at the percent increase in penetration per 1% increase in FOC above 19%, but limit our examination to only those sets showing the least influence from either the Heavy Bone Threshold or the off-side penetration barrier. With the data available we can't eliminate all bone-barrier influence, but we can minimize its influence on the data to the maximum degree possible.

Graph 28 fits our criteria, with all arrows breaching the bone and no arrows reaching the off-side ribs. Graph 29 doesn't fit, because in includes a 50% arrow stoppage rate on the entrance side ribs. Graph 30 eliminates those arrows stopped by the entrance side rib, showing only the bone-breaching hits, but there is some off-side barrier influence on the Ultra-EFOC arrow set, where 50% of the shots stopped on the off-side penetration barrier; less than an ideal comparison, but usable.

For the arrow sets in Graph 31 all shots breached the entrance ribs, with some of the arrows in both sets reaching the off-side penetration barrier; not usable. For Graphs 32 and 33, where both arrows were above threshold mass and carried high amounts of FOC, 90% of all the shots reached the off-side penetration barrier. That's far too much barrier influence to be useful for our purpose. So, let's take a look at the percent of penetration gain shown for ever 1% increase in FOC above 19% for the arrow sets in Graphs 28 and 30.

Graph 35



The red line in Graph 35 shows the average percent increase in penetration for every 1% the arrow's FOC was increased above 19%. This analysis for Graph 28's data indicates an average 5.9% increase in penetration for every 1% FOC was increased above 19%. Graph 29's analysis indicates an average of 7.4% increase in penetration per 1% increase in FOC above 19%. This implies that, above 19%, the *rate of penetration gain* is progressively increasing as the degree of arrow FOC is increased.

This data *suggest* that the higher your arrow's FOC is to begin with the greater the penetration gain you'll realize for each 1% you increase the FOC.

Only time and more testing will tell if this is correct, but for now there's one certainty; once your arrow begins to exceed 19% FOC, and once any entrance-side heavy-bone is breached, the absolute minimum average-penetration increase per 1% increase in FOC will be *far greater* than 2.4%. Until much more data is amassed at EFOC and Ultra-EFOC levels the precise penetration gain you can realize by increasing your arrow's FOC; once within the domain of EFOC and Ultra-EFOC; can only be conjectured on. However, **it's reasonably certain that we are dealing with a progressively increasing rate of penetration gain as FOC goes up**, and not merely because of the data shown in the above graphs. When a comparison of the penetration of lower mass arrows having higher FOC is compared to matching, or near matching, arrows of higher mass and lower FOC, the penetration outcome differences can only be logically explained if FOC above 19% is showing a progressively increasing rate of penetration gain. Let's look at what that data indicates.

FOC and Arrow Mass

The Asian buffalo testing has produced some real surprises. When the 790 grain, Modified Grizzly tipped, Internally Footed EFOC arrow turned in performance that consistently bested all the super heavy arrows it was amazing. Here was a sub-800 grain arrow that far outperformed the classic super-heavy, over-900 grain 'buffalo arrows'. Not only did it provide reliable thorax-traversing hits, it unfailingly breached the off-side rib and carried on to provide exit wounds.

Testing of other penetration enhanced, above-threshold EFOC arrows from lighter draw weight bows confirmed the significant penetration advantage offered of EFOC arrows. Now we have initial results from Ultra-EFOC testing, and they are even more startling than those from the EFOC tests. No matter which Normal, High or EFOC arrow group(s) we compared against, as long as the same bow and same broadhead was used and arrow profiles were comparable the barely above-threshold (655 gr.) Ultra-EFOC arrow equaled or exceeded their performance. Too apply that great Southern yardstick, the penetration-enhanced 655 grain Ultra-EFOC arrow stood tall in mighty high cotton.

Few bowhunters who've taken Cape or Asian buffalo, me included, would have ever considered *any* 655 grain arrow capable of giving *consistently* adequate penetration on massive bodied buffalo bulls. Yet here we are, confronted with one that has done so. On every thorax hit this 655 grain Ultra-EFOC arrow fully traversed the thorax and imbedded deeply in the off-side rib; and it did so at an impact force of only 0.474 slug-feet/second (and impact KE of only 38.64 Foot-Pounds). What would such an arrow setup be capable of at higher impact force?

In the 2007 Update, Part 5, I bounced around some ***theoretical*** calculations and assessed the results against what empirical data I have available. Those calculations *suggested* that the penetration 'break-even point' between an EFOC arrow and a comparable-profile Normal/High FOC arrow *likely* occurs somewhere around an *approximate* 20% reduction in arrow mass. Those calculations were based on assumptions that: (1) the normal and Extreme FOC arrows have 'like external profiles', with equal broadhead MA and matching edge-bevel type, (2) have equal quality of flight and, (3) when heavy bone was impacted arrow mass was above threshold value.

I attempted to apply the same calculation rational to like-profile Normal/High FOC and Ultra-EFOC arrows, but ran into an immediate problem. When I tried to compare like shots on like size animals, no Normal/High FOC arrow gave average performance anywhere near equivalency with the lightweight, above-threshold Ultra-EFOC arrow. A comparison was then done against the EFOC arrows, but there is a lesser amount of data available than for the Normal and High FOC arrows. Nonetheless, the calculated penetration 'break even point' for the available data falls somewhere between a reduction in mass of 15% to 25%; between a matching profile Ultra-EFOC arrow and one having EFOC.

This calculated penetration difference between matching-profile EFOC and Ultra-EFOC arrows would *imply* that the break even point between an Ultra-EFOC and a Normal/High FOC arrow of matching profile would be somewhere between a 35% and 45% reduction in arrow mass. That increasing and arrow's FOC from the Normal/High range to the Ultra-EFOC range would allow a 35% to 45% reduction in arrow mass to yield the same level of penetration is an astonishing implication, yet this is clearly what the data implies; and that's for a shot impacting a heavy bone, too boot!

CAUTION: It must be remembered that, at this point, the above calculations are *theoretical*. They are based on the limited Ultra-EFOC testing done so far. While it accurately reflects what the current data shows there may well be a significant difference when more data is available. However, without question, the current differences in outcomes are of massive magnitude. **This makes it a near certainty that, between Ultra-EFOC and lower amounts of arrow FOC, to achieve an equal amount of penetration there *will* be a very significant difference in required arrow mass.**

What does this penetration difference between lower and higher FOC arrows indicate? It represents the net penetration effect gained by reducing the amount of wasted arrow force. Back in the 2008 Update, Part 3, there's an example of just how little change in arrow efficiency it takes to produce a significant change in the 'useful', penetration producing impulse of force.

Do these EFOC and Ultra-EFOC results mean that arrow weight is no longer an important penetration factor, so long as the arrow's mass is above threshold value? No, that's not the case at all. In *every* comparable test-set to date - whether with Normal, High or EFOC arrows - increasing arrow weight *while maintaining equal external dimensions and degree of FOC* increased penetration. Basic physics dictates that the same mass and penetration relationship will hold true for Ultra-EFOC arrows.

All EFOC and Ultra-EFOC testing indicates that increasing FOC *while maintaining external arrow profile* allows a lower mass arrow to equal or exceed the terminal performance of a heavier arrow having lower FOC. But all data also indicates that adding an equal amount of FOC increase to a matching profile arrow having the same mass will result in a greater *amount* of penetration gain (the measurable inches of penetration increase).

At the moment you won't see me changing the construction of my 'serious hunting' arrow setup from the Internally Footed, 790 grain EFOC arrow and Modified Grizzly I'm currently using. It's proved to be the most effective arrow I've used to date. On the other hand, if further testing of Ultra-EFOC arrows results in a better performing arrow, which I firmly believe it will, you can bet I'll be changing the setup of my 'serious hunting' arrows. Even though, with the heavier draw-weight bows I prefer to use, it's unlikely that I'll ever need more terminal arrow performance than the arrow setup I currently use I keep thinking, "What if …."

Preparing for the best terminal arrow performance I can achieve, on the worst hit I can imagine, has served me well. It's prevented disappointment on a lot of marginal hits, on critters large and small. Nowadays I'm finding that those "what if" scenarios my mind plays and replays not only includes the marginal hits, it includes the reality that I won't always be able to use my heavy draw-weight bows. It's time I at least begin thinking, "If *this* were the bow I'd have to use, what arrow setup would give me the best chance of making a clean, successful kill on as many *potential hits* - good and bad - as possible".

No matter what bow I have to use, that's the arrow setup I want on the string; the one that gives the highest probability of success, no matter what the hit. If, on the other hand, you shoot and hunt so skillfully that you never, ever make anything short of a perfectly placed hit then you're arrow selection won't ever matter all that much. But, for us mere mortals there are going to be some bad hits, and the arrow we've chosen to use is going to make a difference between success and failure.

In the next Update we'll take a look at applying the Study's information to your own arrow setup.