Arrow Lethality Study Update – 2005
Part II
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Weight Forward of Center (FOC)

Focal studies to evaluate the effects of an arrow's FOC on arrow penetration in animal tissue yielded information of significance.

Before discussing FOC, some definitions need to be established. Based on both fabrication limitations and the results from the focal testing, arrow FOC is being divided into three divisions.

Arrows with up to 12% FOC are designate as "Normal FOC". Weight FOC up to this amount is obtainable with many common shafting materials.

Arrows having a FOC between 12% and 19% are designated as "High FOC". High FOC can be achieved with most shaft materials through the use of the lower shaft weights, heavier broadheads and/or shaft footings. The upper limit for high FOC is based on what appears to be the point at which a clearly defined change in penetration characteristics was noted in the focal study.

"Extreme FOC" arrows are designated as those with a FOC of 19% or greater. Achieving this percentage, or greater, of weight FOC requires the use of significant weight at the front of the shaft, as well as fairly light shaft weight *relative to the weight of the point*.

The method used to determine FOC also needs to be specified. Several differing methodologies exist in current text. In this testing the percent FOC was determined by: measuring the length of the arrow's shaft from the bottom of the nock's throat to the start (most rearward portion) of the broadhead taper. This is the "shaft length".

With the chosen broadhead, target, or field tip mounted on the shaft, the point of arrow balance is determined by balancing the arrow on a knife edge. The distance from the bottom of the knock's throat to the balance point is measured.

Next, one divides the distance from knock throat to balance point by the shaft length. This gives the decimal equivalent of the percentage of overall shaft length at which the balance point falls. From this quotient one subtracts 0.50, the decimal equivalent of 50%. The resultant decimal fraction is converted to the percent FOC by multiplying it by 100 (or simply moving the decimal point two places to the right).

In formula format one has:

$$\%FOC = \left[\left(\frac{\text{Dist. knock throat to Balance Point}}{\text{Shaft Length}}\right) \text{minus } 0.50\right] X\ 100$$

The resultant answer will give the arrow's FOC as a percentage of the shaft's length.

Accompanying this article is an easy to use table for 19% FOC; for shaft lengths from 20" to 34". To use it one merely measures the shaft length; bottom on knock throat to start of broadhead taper; in either inches of millimeters then looks up the corresponding point at which the shaft must balance to have 19% weight forward of center. This balance point measurement will be the distance from the bottom of the knock's throat to the balance point. It is easier to get precise measurements in millimeters, unless one has an inch ruler marked in $1/10^{ths}$ inch.

If one wishes to develop such tables for other percentages of FOC it is very simple. For each shaft length the corresponding balance point will equal the shaft length multiplied by the decimal equivalent of the FOC plus 0.50. For example, the 24% FOC balance point for a 29" (737mm) arrow would be 29 multiplied by: [.24 (the decimal equivalent of 24%) plus 0.50]. In equation form: Balance Point = 29" X .74; which is 21.46". In metric it would be: Balance Point = 737mm X .74; which is 545.4 mm.

Due to both shaft mass and flexional characteristics of shaft materials, it is extremely difficult to achieve extreme FOC with any shafting other than carbon, while maintaining good arrow flight characteristics.

With the advent of carbon shafting several individuals began 'forward loading' carbon arrows to achieve very high amounts of weight FOC. Many claims have been made regarding the extreme gain in penetration being achieved on game.

The rational stated for the penetration gain is that with most of the weight towards the arrow's front there is less weight towards the arrow's rear to cause shaft flexion at impact and during penetration. In effect, they are saying that with extreme FOC arrows the arrow shaft is being pulled through the tissue by the point's weight. With normal to high FOC arrows the point is being pushed through the tissue by the mass of the shaft.

A good analogy of what they are saying can be demonstrated with a piece of string. Lay a piece of string on the floor and pull it along by one end. It pulls smoothly, in a straight line. Try pushing it from the back and it bends. Though it is stiffer, and bends far less than a piece of string, an arrow shaft would show the same effect, just to a lesser degree.

No doubt exist that the degree of shaft flexion at impact, and while penetrating, is a major factor in the resistance impulse exerted by the tissues upon the arrow. At close shooting ranges; distances where the arrow is still in violent flex from paradox; measurable penetration is greatly reduced from that shown after the arrow has recovered from paradox, and is flexing to a lesser degree. The theory behind the extreme FOC arrows is plausible.

Three focal study series were developed to test the anecdotal performance claims for extreme FOC arrows.

The first series started with sets of identical Carbon Express shafts, mounted with 145 gr. Eclipse broadheads, with tips modified to a COI Tanto profile. As in all testing post-2004, broadhead edges were finished shaving sharp, with honed and stropped edges. Each set consisted of two arrows.

Arrows in set one were converted to a double shaft, with a Beman Hunter shaft inside the Carbon Express, and fit with aluminum broadhead adaptors, giving 10.3% FOC, and a mass of 840 grains. The second set was forward weighted, with 185 grains of ¼” threaded steel rod back of the insert plus a 125 gr. steel broadhead adaptor, giving 24.3% FOC, with a mass of 847.5 grains.

For additional comparative purposes a third test set of carefully matched tapered hickory shafts, mounted with the same broadhead, and each having a total mass of exactly 840 gr., were also used. These had a FOC of 10.02%. The extreme spread in mass was for all six arrows is 7.5 grains.

Two shots were taken with each set from 20 yards, broadside, on a large adult male buffalo. The extreme FOC Carbon Express showed a 19% increase in average penetration over the double shafted, normal FOC, carbon express, and an 18.24% increase over the tapered hickory shaft. More impressive was that each shot with the extreme FOC arrows not only reached the off-side rib, one stuck *solidly* into the off-side rib, with most of the blade protruding through the rib, and the second penetrated the off-side rib.

Test series two started with two identical sets of Carbon Express shafts. Each set consisted of three arrows. The first set was fit with weight tubes plus two sections of 2.7mm weed-eater line, hollow aluminum BH adaptor and 125 gr. Grizzly broadheads, for a mass of 689.3 gr. and FOC of 11.8%. The second set was fit with 125 gr. steel broadhead adaptors and 145 gr. Grizzly broadheads. (The 125 and 145 gr. Grizzly have virtually identical physical dimensions, excepting blade thickness.) Mass weight for the second set was 682.3 gr., and the FOC was 20.4%.

Test perimeters for this second series were the same as for the first series. The extreme FOC arrows averaged 62% more penetration than the normal FOC arrows. No shot with the normal FOC arrows reached the off-side rib. Every shot with the extreme FOC arrows reached the off-side ribs.

Test series three consisted of Epic shafts. Each set contained four arrows. Set one was weighted with two pieces of 2.7mm weed-eater line and fit with an aluminum broadhead adaptor and the 150 grain Grizzly, for a mass of 643 grains and 15.6% FOC. The second set was fit with 125 gr. steel broadhead adaptors and 190 gr. Grizzlies, giving a mass of 620 gr. and FOC of 25.3%. (As with the 125 and 145 gr. Grizzlies, the 150 and 190 gr. Grizzlies have virtually identical profiles but differ in blade thickness.)

Test distance and shooting angle was the same as in the above testing, excepting that that test animal, though an adult male buffalo, was younger and smaller than those from series one and two testing.

In this third series, the *extreme* FOC arrows averaged 58% greater penetration than the *high* FOC arrows. Both sets in this series showed difficulty in penetrating the entrance rib. For the high FOC’s, two were stopped by the entrance rib, with two giving one lung hits. For the extreme FOC’s: two were stopped by the entrance rib; one reached the off-side rib, sticking solidly; and one penetrated the off-side rib.

It was of little surprise that 50% of these relatively low mass arrows were stopped by the on-side ribs. That a threshold minimum arrow mass for consistently breaking *heavy* bone exist, somewhere in the vicinity of 650 grains, and which appears to be more of a function of the time of impulse than of the degree of applied force, is a data feature that consistently surfaces. A closer look at this heavy bone threshold will be presented in a later update. What was surprising was the degree of penetration achieved by the two, relatively light, extreme FOC arrows that did manage to breech the entrance rib.

After completion of the pre-planned series of focal test a number of other extreme FOC arrows were set-up and tested. Graph 1 depicts the average penetration of the arrows from the FOC focal study and the additional extreme FOC arrow set-ups tested. All extreme FOC test shots were on adult male buffalo, ranging in size from average to massive trophy bulls. The 'dip' in penetration at 25.3% FOC reflects the light mass weight extreme FOC arrows from test series three.

Graph 2 shows the relationship between arrow mass and penetration for the extreme FOC arrows tested. The long, almost level line at approximately 20" penetration reflects a degree of penetration reaching the off-side ribs.

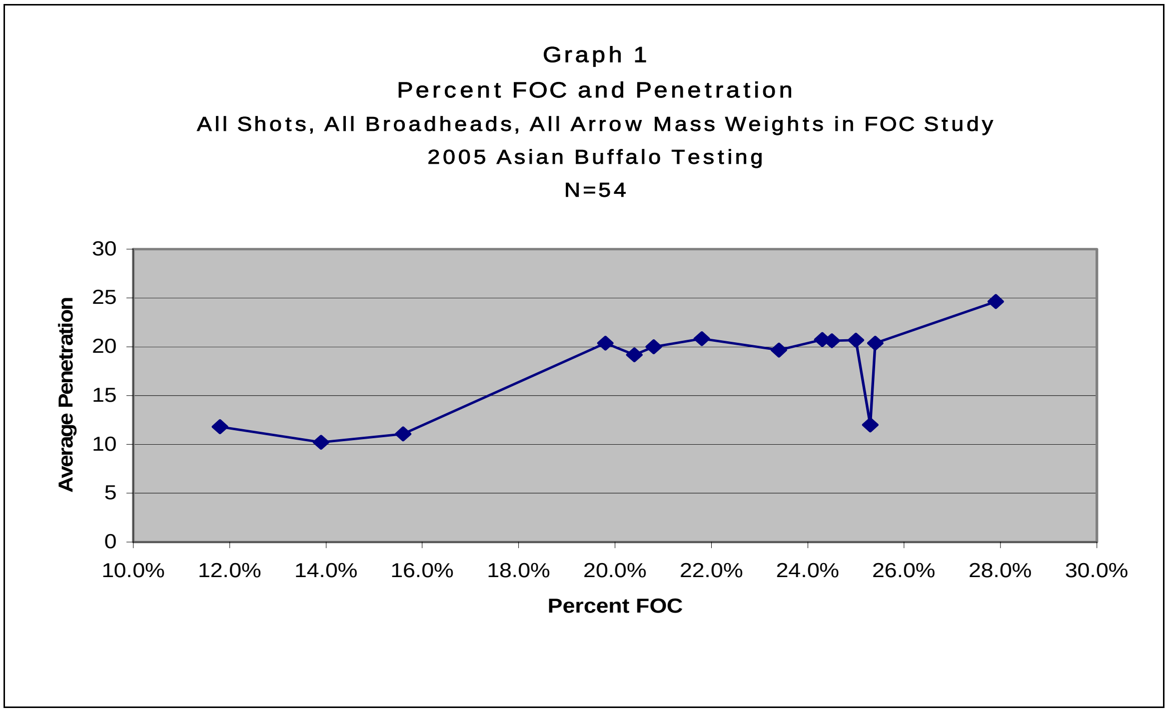
A more detailed look at the impressive penetration of the extreme FOC arrows is presented in Chart 4. With the exception of the low mass arrows in test series 3, every extreme FOC arrow penetrated deep enough to reach the off-side ribs, and four shots achieved exit wounds. This means that 92% of the extreme FOC shots reached the off-side ribs; 41% penetrated the off-side rib; and 10.3% gave an exit wound.

In order to put the above in perspective, in the field records database there are 257 shots on buffalo with normal and high FOC arrows which strike a rib on entrance. Only sixty-five of these shots (25.3%) reached the off side rib. Only 7 shots (2.7%) penetrated the off-side rib. None gave an exit wound.

Though the sample size in this initial test of extreme FOC arrows is small, there is a clear tendency towards a high incidence of increased penetration. The extremely high frequency of this occurrence makes it highly unlikely that the observed outcome is an aberrant occurrence.

All indications are that extreme FOC arrows do, indeed, offer a substantial gain in arrow penetration and that the substantial gain first becomes manifest at some point very near 19% FOC. It should be noted that what little data is available at this time is suggestive that only the flexional characteristics of carbon shafts allows one to achieve an extreme FOC while maintaining good arrow flight. None of my initial attempts to develop an extreme FOC arrow with wood or aluminum shafting have been acceptably successful.

A great deal more testing on the effects of extreme FOC on penetration remains to be done, but early results indicate that it may offer highly significant gains in penetration when broadhead/arrow integrity are maintained.



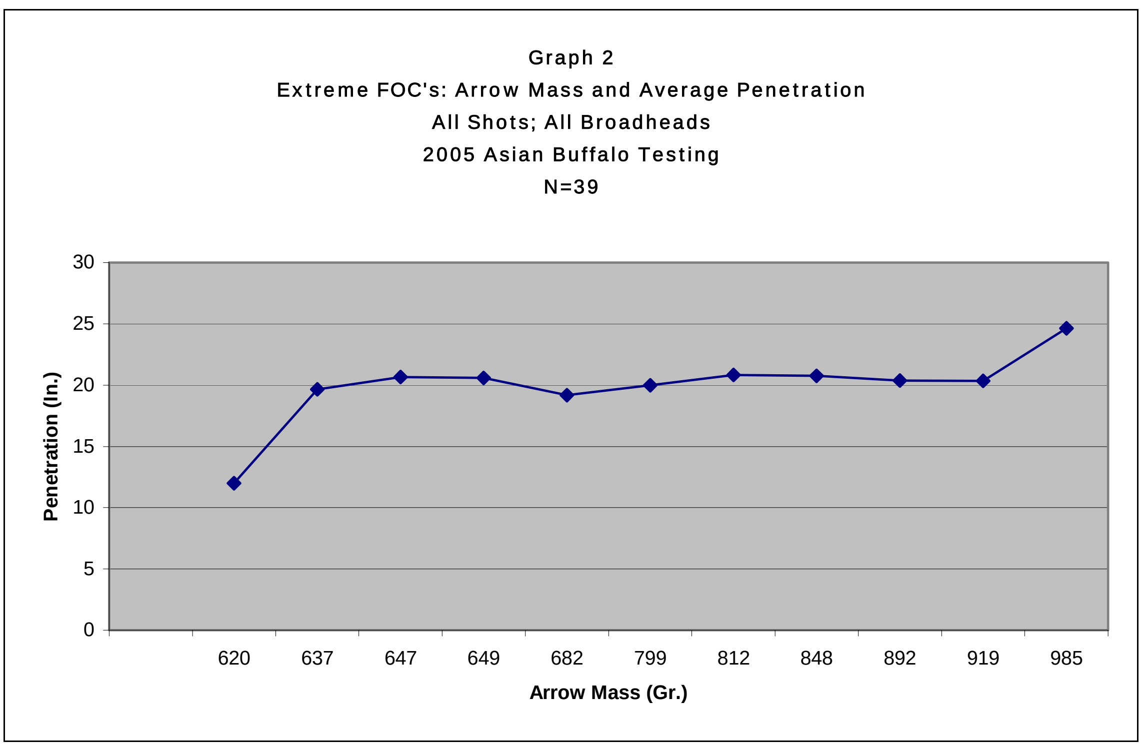


Chart 4
Summary: Extreme FOC's
N_{Total}=39

						% To	% Pen.				
	%	Arrow	Avg.	Imp.	Imp.	Offside	Offside	%		BH	#
N=	**FOC**	**Mass**	**Pen.**	**KE**	**Mo.**	**Rib**	**Rib**	**Lethal**	**Broadhead**	**Wt.**	**Exits**
4	25.3%	620	12	35.24	0.44	25%	25%	**50%	*Grizzly	190	None
7	23.4%	637	19.66	35.30	0.45	100%	42.9%	100%	*Wolverine/STOS	160	2
3	25.0%	647	20.67	36.77	0.46	100%	100%	100%	*Mod. Grizzly	170	None
3	24.5%	649	20.60	34.62	0.45	100%	0%	100%	Pro Big Game	174	None
3	20.4%	682	19.17	40.49	0.50	100%	0%	100%	*Grizzly	145	None
1	20.8%	799	20.00	33.78	0.49	100%	100%	100%	*Mod. Grizzly	170	None
2	21.8%	812	20.82	34.83	0.50	100%	50%	***50%	*Eclipse	145	None
2	24.3%	848	20.75	35.31	0.52	100%	50%	100%	*Eclipse	145	None
6	25.4%	892	20.38	40.22	0.57	100%	50%	100%	*Mod. Grizzly	170	2
7	19.8%	919	20.36	35.76	0.54	100%	28.6%	100%	*Grizzly	190	None
1	27.9%	985	24.63	35.83	0.56	100%	100%	100%	Pro Big Game	258	None

* Modified to COI Tip
** Two shots failed to penetrate entrance rib.
*** One shot just back of diaphragm, missing liver.

Balance Point Chart For 19%
Weight Forward of Center (FOC)

Shaft Length In Inches	Balance Point In Inches		Shaft Length In Millimeters	Balance Point In Millimeters
20.00	13.80		508.0	350.5
20.50	14.15		520.7	359.3
21.00	14.49		533.4	368.0
21.50	14.84		546.1	376.8
22.00	15.18		558.8	385.6
22.50	15.53		571.5	394.3
23.00	15.87		584.2	403.1
23.50	16.22		596.9	411.9
24.00	16.56		609.6	420.6
24.50	16.91		622.3	429.4
25.00	17.25		635.0	438.2
25.50	17.60		647.7	446.9
26.00	17.94		660.4	455.7
26.50	18.29		673.1	464.4
27.00	18.63		685.8	473.2
27.50	18.98		698.5	482.0
28.00	19.32		711.2	490.7
28.50	19.67		723.9	499.5
29.00	20.01		736.6	508.3
29.50	20.36		749.3	517.0
30.00	20.70		762.0	525.8
30.50	21.05		774.7	534.5
31.00	21.39		787.4	543.3
31.50	21.74		800.1	552.1
32.00	22.08		812.8	560.8
32.50	22.43		825.5	569.6
33.00	22.77		838.2	578.4
33.50	23.12		850.9	587.1
34.00	23.46		863.6	595.9