Arrow Lethality Study Update – 2005
Part IV
By
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Buffalo Arrows

Extreme FOC arrows, which appear to require carbon shafting, may radically alter the parameters of heavy game arrows in the future, but current data is insufficient to define the boundaries. Performance with conventionally weighted arrows is defined with more certainty.

Sufficient data exist for normal and high FOC arrows to permit recommendations for minimum arrow mass and impact force adequate for hunting buffalo. Chart 6 presents summary information for the average arrow mass; average penetration; average impact momentum and average impact kinetic energy for the test shots, excluding the Extreme FOC arrows, which traversed the thorax (reached the off-side ribs).

The information in row one of Chart 6 is for all shots. This includes shots on young adults and adult cows, as well as the larger animals. Row two is all data from *adult* bulls; row three is all *large adult* bulls; and row four is *trophy* bulls.

Graph 3 shows the mass weight distribution of test arrows. It shows an even distribution. The Q1 value means that 25% of the test shots were below 663 grains mass. The median indicates the mass weight where 50% of the arrows are lighter and 50% heavier. The Q3 value indicates where 75% of the arrows are lighter in weight; and 25% are heavier.

The average mass of arrows traversing the thorax, for all animals, falls in the upper one-half of the mass test range. For trophy bulls, the average is well into the upper 25% of the mass range for all test shots.

Chart 7 shows the averages for arrow groups having mass weights of 700 grains and below; comprising 27% of all shots. The impact kinetic energy for those in the less than 400 and 400-500 grain group is substantially greater than any listed in Chart 6. The impact momentum of both the less than 400 gr., and 600-700 gr., group falls well within the range of those in Chart 6. This is an example of how arrow mass, and the resultant change in the *impulse of force,* influences penetration.

From the above data it is possible to develop some guidelines for heavy game arrows of normal to high FOC which can be expected to *reliably* give adequate penetration on rib impact shots from all reasonable shooting angles. (See “Shot Placement for Asian Buffalo” in Part II of the 2004 update.)

The following recommendations are predicated on the use of a “best quality broadhead”. Ninety-four percent (94%) of the shots shown in Chart 6 (normal and high FOC arrows traversing the thorax) were tipped with a “best quality” single blade broadhead; 62.2% of which were modified to a COI Tanto tip design. Multiblade broadheads on arrows having a mass weight exceeding 805 grains (the lowest *average* mass in Chart 6) comprised 37% of the ‘rib hit’ shots, but comprise only 6% of the shots traversing the thorax.

Broadhead ferrule-diameter-to-shaft-diameter ratio is also an important feature. Of the thorax-traversing hits, 97% had a shaft diameter at least 5% smaller than the ferrule diameter, with the majority being in the 8%-12% range. Good flight characteristics are essential. This can be the most challenging feature to achieve in the finished arrow, especially with double shafted arrows, but is a ‘must have’ feature for buffalo arrows.

If the above arrow and shot placement parameters are met, the lower limit of recommended arrow mass is 800 grains, with 900 grains being ‘ideal’ for hunting trophy bulls. *Impact momentum* should be at least 0.53 Slug-Feet/Second. These are recommended minimums for normal to high FOC arrows. There is no maximum.

Is it possible to make a clean kill with arrows falling below these guidelines? Certainly it is. There are numerous incidences of that in the data. The question is one of *frequency*, how reliably one can count of that outcome from any individual well-placed shot. The guidelines assure adequate penetration for a double lung hit, with a high probability of reaching the off-side rib, on *all* shots meeting placement criteria.

Arrow Shafting

To the list of wood shafting materials found to be good performers during last year’s buffalo testing, more can be added. A number of shafts from Allegheny Mountain Arrow Works were tested this year. Penetration with laminated Birch shafts is on a par with the hickory shafts of like profile tested last year, as are Purple Heart shafts. An outstanding performer among wood shafts was the Ipe shaft. Ipe can be highly recommended for a buffalo arrow, and easily makes up into small diameter 900-plus grain arrow (over 1000 grains with the heavier broadheads).

Some testing was done with Ash shafting. The amount of data is low, but it exhibits a higher breakage rate than the others tested. The most common break for all shafts is at a point just back of the broadhead taper, and its occurrence is more frequent on angling impact shots.

If one does not wish to develop a double shaft arrow for heavy game, or simply prefers to use a wood shaft, there are some excellent choices ‘off-the-shelf’. Among wood shafts, Hickory, laminated Birch, Forgewood, Purple Heart and Ipe; coupled with one of the better penetrating broadheads; offer good performance on heavy game. My clear preference for buffalo would be Ipe. Following in a dead tie for second are Hickory; laminated Birch; Purple Heart and Forgewood.

In off-the-shelf synthetic shafting there are outstanding choices from Alaska Bowhunting Supply. The Big 5 and Safari shafts, with brass insert and steel broadhead adaptor, performed very well. Some shafts did split just back of the insert, but every instance occurred when a broadhead bent or broke; failing to penetrate the bone and abruptly increasing the peak resistance-force.

Big 5 and Safari shafts; coupled with brass insert, steel broadhead adaptor and a 125 gr. point; will be right at 900 grains mass in a 28″ arrow, and over that with a heavier broadhead. With a 190 grain broadhead they will also meet Extreme FOC specifications.

Shaft Durability

A long-reported weakness of synthetic shafting has been bending of aluminum broadheads tapers and inserts. During testing with steel broadhead tapers no incidences of an aluminum insert bending were encountered. Frequency of these inserts bending has been high, and its absence is suggestive that the steel broadhead adaptor’s shank is sufficiently strong to retard the insert’s bending rate. It is also possible that the steel adaptors resisted initial bending, which may have been a ‘trigger’ for the bending of the aluminum inserts.

Graph 4 shows the usage and damage rate for all shots by shaft type. Wood is often singled out as not being as durable as synthetic shafting. Testing does not bare this out. The wood shafts used in the test are among the tougher woods available, but the aluminums and carbons used are also tough versions from top line manufacturers. Most aluminums were XX75’s, with a high number of these being the 2219; the remainder were Game Getter shafts. Carbon shafts used include: Easton Epic and Obsession; Carbon Express Terminator Hunter; Gold Tip XT Hunter; and Grizzly Stick Alaskan, Safari and Big 5. Other than the Forgewoods, all wood shafts were hardwoods from Alleghany Mountain Arrow Works and Sticks and Feathers, and included: Ipe; Purple Heart; Ash; Hickory; Laminated Birch; and Cedar footed with Purple Heart.

With the lowest usage rate, aluminum had the highest damage rate, comprising a percentage of damaged shafts equaling carbon shafts; which had a usage double that of the aluminum. Wood shafts were used on over 50% of all shots, yet comprise only 7.6% of the damaged shafts. This clearly indicates that hardwood shafts proved significantly more durable than either carbon or aluminum shafting.

For shafting of all materials, broadhead damage and penetration failures play a major factor in shaft damage. For all damaged shafts, 69.2% were on shots where the broadhead was damaged, and 76.9% were on shots failing to penetrate a bone; 80% of penetration failures occurring on ribs and 20% on other “heavy bone”.

Broadhead failure and failure to penetrate a bone have commonalities. Both cause a “resistance spike”; an abrupt increase in resistance force during penetration. Though the total applied-impulse and resistance-impulse would the same as when the arrow penetrates normally, the resistance’s *time* of action is shorter; the *time of the resistance-impulse* has been altered. This requires resistance to apply a higher level of force upon the arrow.

The effect is easy to understand. Traveling in a car at 60 miles per hour (MPH); a velocity of only 88 feet-per-second; slowly break to a complete stop. Now try the stop from 60 MPH again, except slam on the breaks as hard as you can. In both cases the total resistance-impulse required to stop the car is the same. What is different is the *time* over which the resistance acts. The shorter the impulse-time the higher the force level of the encountered resistance-impulse will be.

Understanding the effect of time in the impulse of force helps one understand why lighter, higher velocity arrows show far less outcome-penetration, even at grater levels of impact force. Not only does the resistance force encountered increase exponentially as velocity increases, but the lower arrow-mass results in a shorter impulse-time at any given level of impact-force. The shorter impulse-time means that the peak impulse-force will be greater. The arrow will stop in a shorter time period. As data clearly shows, in tissues the heavier the arrow the greater the outcome-penetration; when all else is equal. It also clearly indicates that a *massive* increase in impact-force is required for a significantly lower-mass arrow to equal the outcome-penetration of a high-mass arrow.

It is easy to comprehend broadheads and shafts being damaged by impact on a hard surface. It is more difficult to understand the importance of reducing peak and overall resistance during arrow penetration as a method of belaying damage and maximizing penetration. The above example is an easy way to think of the concepts involved in arrow penetration, and the advantage gained when resistance’s impulse-force is lowered (has a longer time of impulse). A damaged broadhead “slams-on the arrow’s breaks”; very short impulse-time with a high amount of resistance impulse-force. The arrow system is highly stressed. Any weak point in the system is more likely to fail.

Broadheads of high mechanical advantage not only increase the *work* an arrow can do with whatever force it possesses, the resistance it encounters occurs over a longer time period, ‘applying the breaks’ more gradually. The higher an arrow’s mechanical advantage the more gradual the ‘breaking’, regardless of ‘driving conditions’; be it soft tissue or the hardest of bone.

Chart 6
Comparison of Averages by Animal Size
For Shots Traversing Thorax
(Excludes Extreme FOC Arrows)
$N_{Total} = 65$

	Average Arrow Mass	Average Penetration	Average Impact Momentum	Average Impact Kinetic Energy
All Shots	825.6	16.6	0.51	36.37
Adult Bull	811.8	17.4	0.48	31.86
Large Adult Bull	805.8	16.4	0.53	41.80
Trophy Bull	899.7	17.4	0.53	32.69

Graph 3

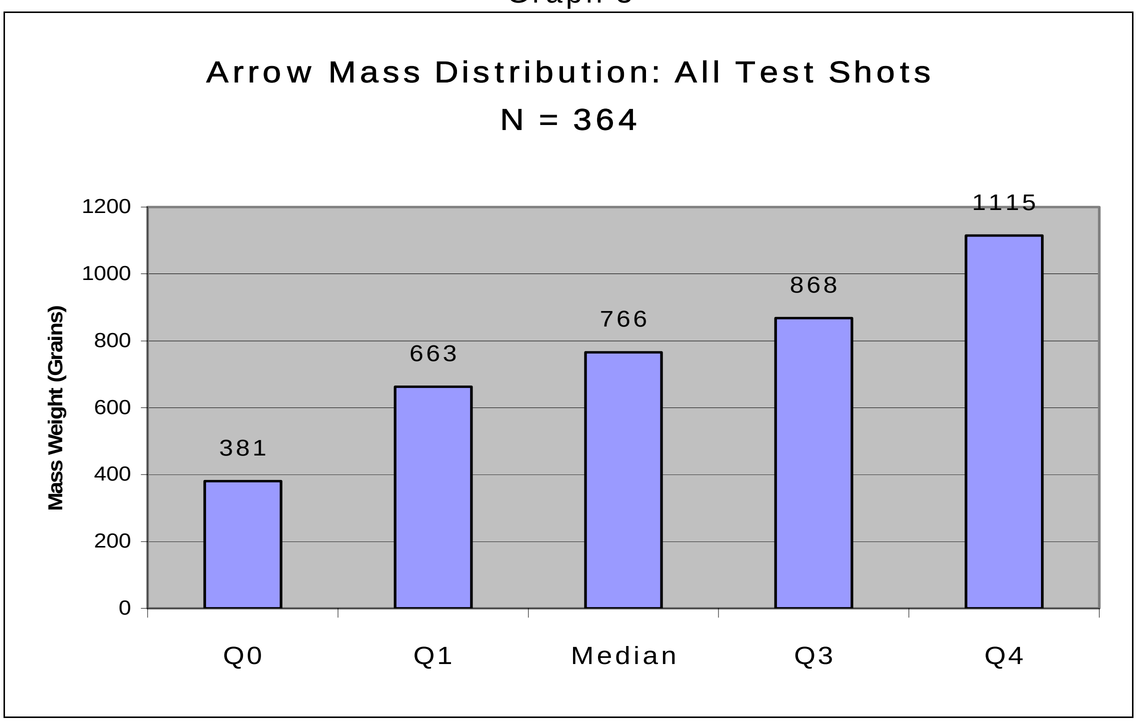
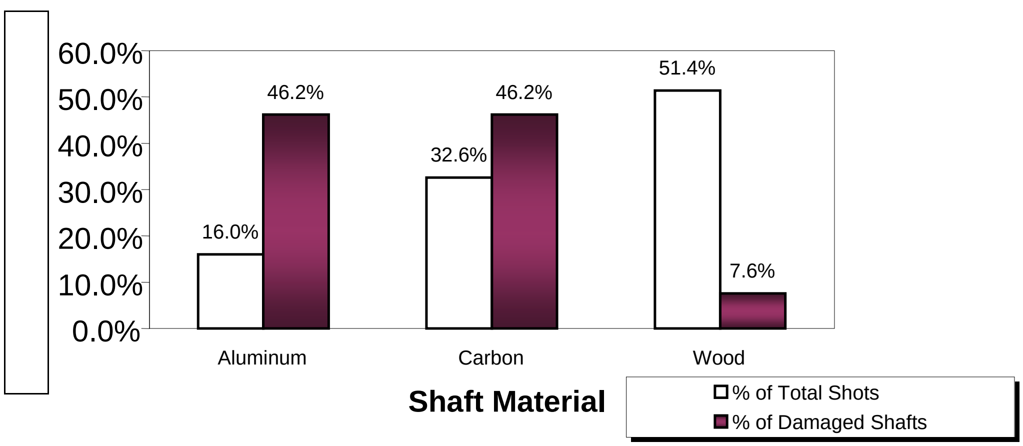


Chart 7
Averages for Low Mass Weight Arrows
All Test shots
N = 97

Arrow Mass	Average Arrow Mass	Average Penetration	Average Impact Kinetic Energy	Average Impact Momentum
<400	384	9.70	78.59	0.52
400-500	451	8.53	55.68	0.45
500-600	564	9.94	35.42	0.41
600-700	658	12.50	39.70	0.48

Graph 4
Shaft Usage and Damage Rate
By Shaft Material
All Shots: 2004-2005 Asian Buffalo Testing



This aluminum adaptor and insert, on heavy double shaft arrow, gave way on right angle impact, fracturing the shaft (Courtesy of Kai Fisher).

Carbon shafts often break or split at weak point of broadhead to shaft juncture when broadhead, broadhead taper or insert becomes damaged.

The most common point of wood shaft failure is also at the taper.

Steel adaptor and long insert prevented bending back of taper, but bent broadhead deviated arrow's path, reducing penetration and breaking this carbon shaft further up. Predictable performance requires total arrow integrity: broadhead, broadhead taper, insert and shaft.