The Dr. Ashby studies.
Breakdown. Part 2

In part two, I will reference the charts in arrow lethality 2005 update part 5. (1) The data is shown in the charts. I'm going to show the charts and list thoughts and questions, most being the test being skewed and giving people false outcomes on how we should be looking at things to improve our ability to build a lethal arrow.

Let's start with chart 8

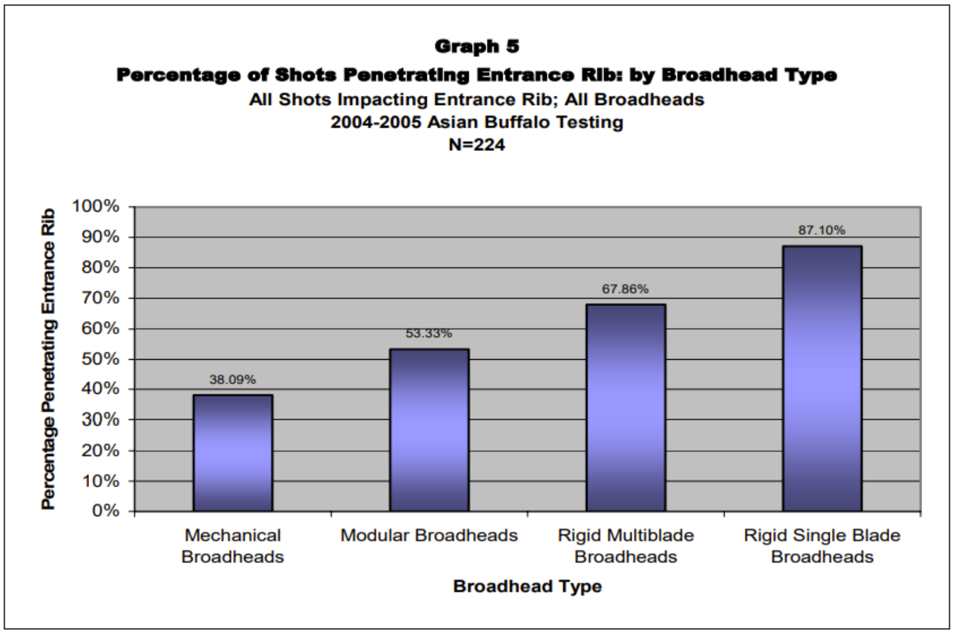
Chart 8
Average Penetration, Impact-kinetic-energy and Impact-momentum
All Shots
2004-2005 Asian Buffalo Testing
N = 364

Broadhead Type	Avg. Penetration	Avg. Impact KE	Avg. Impact-momentum
Mechanical Broadheads	7.32"	50.74	0.47
Modular Broadheads	9.23"	45.25	0.46
Rigid Broadheads	11.41"	34.76	0.49

In this chart, he shows that mechanical broadheads have less penetration. we would assume it's due to a higher resistance during impact. Now, this is true. But what I want to point out is to look at the average impact K.E. The mechanical broadhead has 50.74 KE, 12.13% greater than the modular broadheads, and 45.97% greater than the ridged broadheads. Is there an issue with this data, Yes?

We know that by shooting arrows from the same bow, as mass increases, K.E. increases. Since we see three different K.E. readings, we can determine that he uses data from three different bows. Next, we look at the momentum. What this shows is the mass of the arrow is not the same. This chart's data cannot be used as a determining factor on broadheads as the data is from three different setups. Testing like this shows a bias in testing.

"In evaluating Graph 5, consider that all mechanical broadhead shots (100%) are broadside, with perpendicular impact angle. Modular broadhead data includes 57.7% broadside shots and 43.3% shots quartering from the rear (qfr) at an impact angle of 200 . Rigid multiblade shots include 10.7% qfr at 450 ; 7.1% qfr at 200 ; and 82.2% broadside shots. Rigid single blade data includes 9.7% qfr shots impacting at 450 ; 9.0% qfr at 200 ; 3.2% qfr at 150 ; and 78.1% broadside. Findings are consistent with prior data." (Dr. Ashby)



This chart and how he tested shows that mechanical broadheads did not compare. It also shows the advantage of two blades vs. multiple bladed broadheads. The data here is good for a short draw and or low draw weight.

In chart 6 he lists the % of damaged heads.

Graph 6

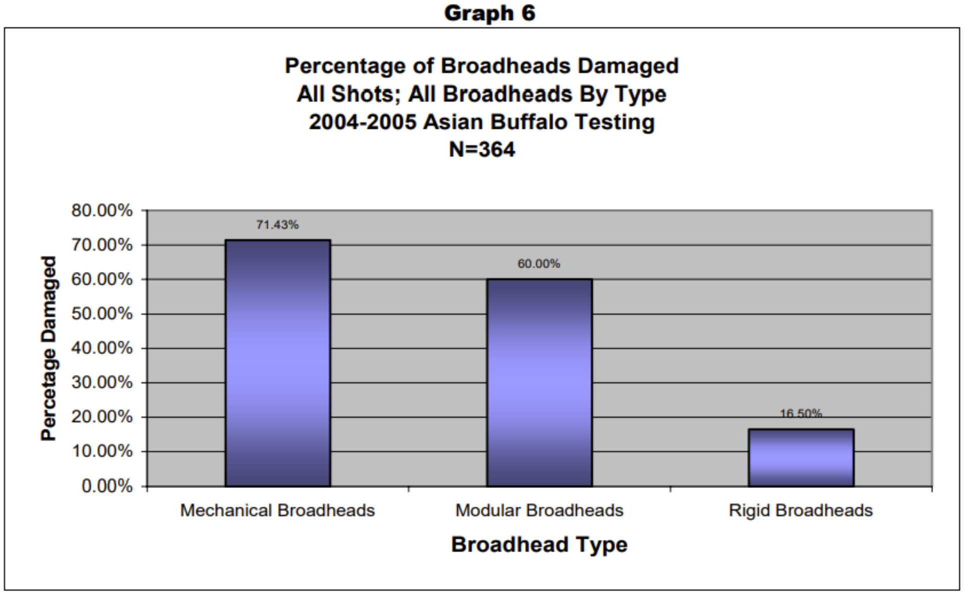
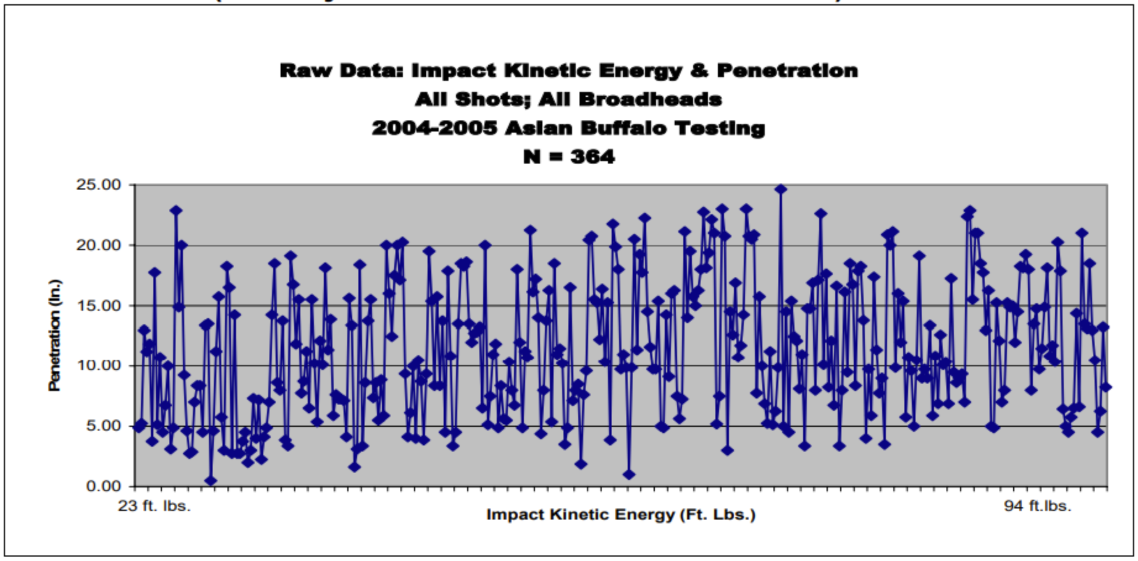
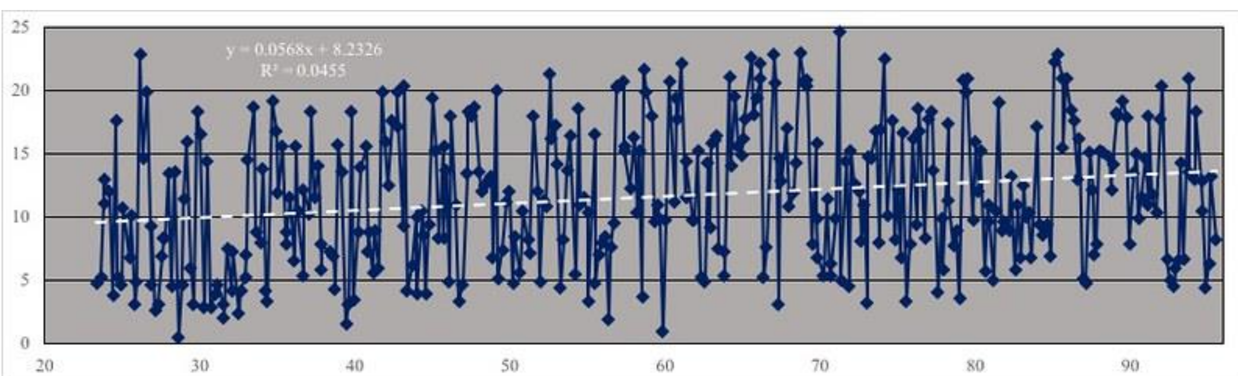


Chart 7 is an interesting one. It shows all of the impact K.E. shots in testing up to this point. He then asks, do you see a correlation?

Graph 7
(Does anyone see a correlation? I can find none.)



"First, correlation cannot be deciphered by the human eye. We should use a computer to determine if there is a relationship between K.E. and penetration. This is accomplished with Excel[2] or another spreadsheet software. I generated the following graph, which is a replica of Ashby's chart with linear regression performed on the data. The dotted white line is the best fit linear trend line to the data and the line's equation given on the graph.



We will take this line as a sort of "running average," indicating the average penetration at each energy point on the spectrum. The line shows that penetration increases with increasing energy. Correlation is, however, weak, as indicated by the r^2 value.

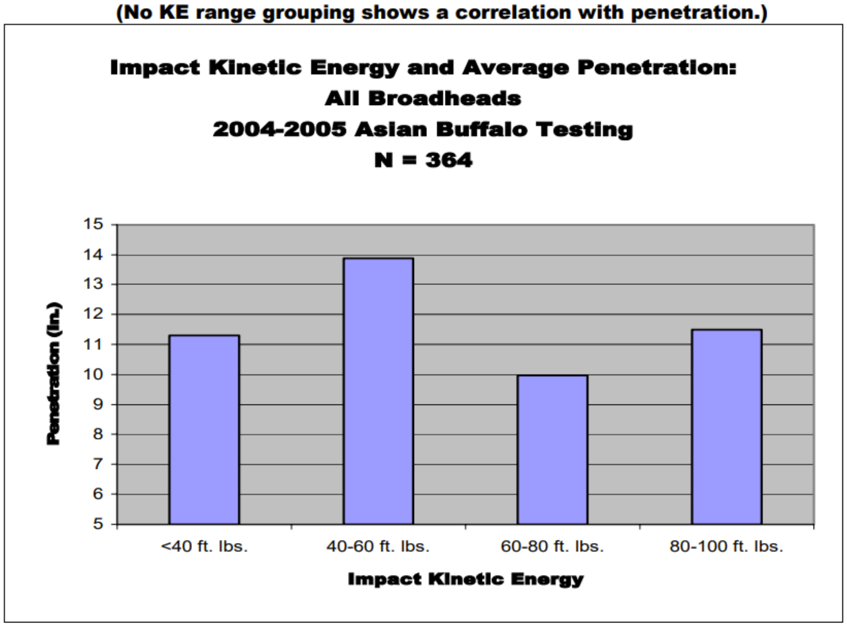
To better demonstrate that K.E. does influence penetration, let's look at chunks of the data at either end of the spectrum. For shots ranging between 20–40 ft·lbf K.E., the average penetration was 9.0 inches, with a standard deviation of 4.9 inches, and the average kinetic energy of 31.6 ft·lbf. For shots ranging between 80–96 ft·lbf K.E., the average penetration was 12.4 inches, with *a standard deviation of 4.6 inches, and the average kinetic energy of 87.8 ft·lbf. The higher K.E. systems exhibited a 36% increase in observed penetration. This is instructive, but not good enough from a statistics standpoint to make any factual statements about the data. There is much random variation in the data, so it could be that this apparent increase in penetration is merely random noise in the data and that K.E. doesn't matter.*

To check this, we must use a statistical test to compare the difference of means[3] (i.e., the difference between the two groups' average penetration values). The higher energy bows showed 3.2 inches better penetration, on average than the low energy bows. I completed a statistical test on the difference of means at the $p < 0.05$ level. At the 95% CL, the difference of means is 3.2" ± 1.5"—roughly meaning the difference could be as small as 1.8" or as large as 4.7". (For those of you that know statistics, I know this is not exactly what a CI indicates, but it is close enough for the current purpose.) More importantly, this test is conducted at the 95% confidence level. This means that assuming kinetic energy does not matter to observed penetration. There is only a 5% chance that Dr. Ashby would have observed these results. If this experiment were repeated 20 times, only once would we see this large of a difference in penetration between the low energy and high energy data sets. We can be 95% confident that this result would hold upon multiple repeated trials.

NOTE: In actuality, the p-value obtained for this data is 2×10^{-5}; our confidence level here is much, much higher than 95%."
Information provided by Jared Spencer, PhD

Next is graph 8

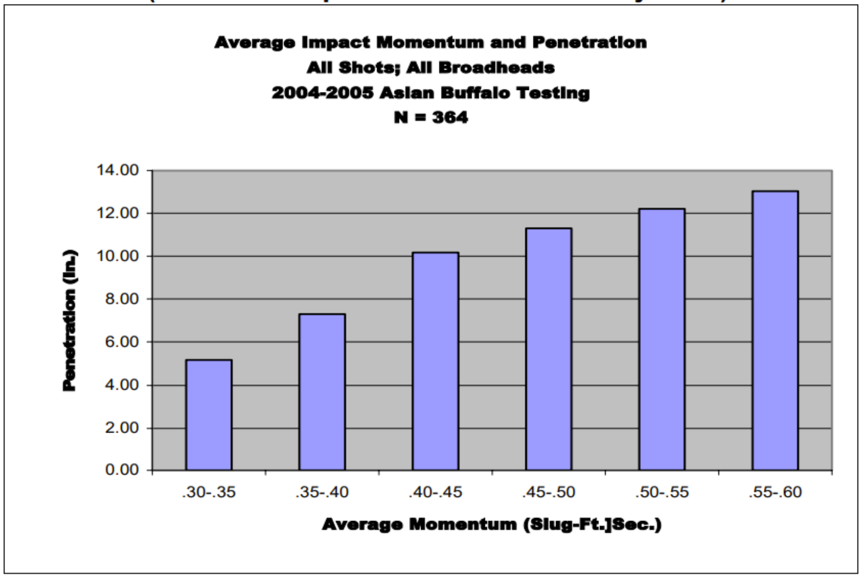
Graph 8
(No KE range grouping shows a correlation with penetration.)



Here he is showing that K.E. does not correlate. Why is he saying this?

Next is graph 9

Graph 9
(Momentum and penetration correlation is easy to find)



"Graph 8 shows a 'penetration peak' shows in the 40 to 60 ft.- lb. impact-kinetic-energy range. It results from most heavy arrows falling into this group; the balance falling below the 40 ft.-lb. level. A major goal of testing is to find minimum impact-force levels giving reliable penetration. No testing with high mass arrows has been conducted above the 60 ft.-lb. level. A relevant relationship exists between mass and momentum as 'predictors' of outcome penetration. The less than 40 ft.-lb. group has an average impact-momentum of 0.48 slug-feet/second and average mass of 793.7 grains. The averages for the other groups are: 0.52 slug-feet/second and 799.8 grains for the 40- 60 ft.-lb. group; 0.51 slug-feet/sec. and 483 grains for the 60-80 ft.-lb. group and; 0.57 slug-feet/sec. and 431 grains for the 80-100 ft.-lb. group. The 60-80 ft.-lb. group has higher impact-kinetic-energy and higher impact-momentum than the less-than-40 ft.-lb. group, yet averages 12% less penetration. With more than double the impact-kinetic-energy and 16% more impact-momentum, the 80-100 ft.-lb. group exceeds the less than 40 ft.-lb. group's penetration by only 1.7%! This paradox results from the differing contribution each group's arrow mass makes to the momentum. Arrows in the highest kinetic energy group, 80-100 ft.-lbs., have the lowest mass arrow weight. The contribution of arrow mass to resultant momentum is low. Lower mass contribution to momentum means a shorter time of impulse. How long the force acts upon the tissues is a key component in outcome tissue penetration. Arrow mass, through its contribution to the momentum, is the prime determiner of how long the force is applied to the tissues; on any given shot. The importance of the time factor of applied impulse of force is clearly discernable.

Graph 9 illustrates the impact-momentum for all 364 shots; grouped into .05 slug-feet/second increments, and compared to average penetration. Though the relationship between impact momentum and penetration is not at a one-for-one level, it shows a positive correlation trend with outcome tissue penetration. Note that arrow mass is not considered in either Graph 8 or 9. These graphs are looking at whether kinetic energy or momentum, considered alone, shows a correlation with outcome tissue penetration." (Dr. Ashby)

Let's break down graph 8 and 9. I do not know why Dr. Ashby is so adamite about showing K.E. has nothing to do with penetration, but it is obvious in this subject's bias. He does at least say that the graphs show we cannot predict with K.E. or momentum alone. We must understand that mass is the predictor of penetration potential.

Graph 8 K.E. vs. penetration. in the ,40 ft-lbs he tested a 793.7gr arrow at .48 slug-ft/s. giving us a 33.1 ft-lbs (K.E.). This group shows the penetration of estimate 11.25". The 40 -60 ft-lbs shows to have estimated 13.875". the average mass in this part is 799.8gr at a .52 slug-ft/s. This means this arrow has a K.E. of 38.1. before going to the next two K.E. in the graph, let's look at the two at <40 to 40-60. If we look at the numbers, there is only a .77% increase in mass, but yet an estimated 23.33% increase in penetration. How is this possible? It's possible because he increased the K.E. by 15.11%. The only way to do this is by changing bows. Again he is showing you a penetration increase but saying K.E. does not correlate. This is a false statement. In this part of the graph, it is very easy to look at the mass and the K.E. to predict penetration potential.

Now we look at the second half of graph 8, starting with 60-80 ft-lbs. In this group, he is showing 10" penetration with a 483gr arrow at .51 slug-ft/s vs. the group in the 80-100 ft-lbs. with an arrow at 431gr at .57 slug-ft/s with 11.5" of penetration. The question now is how did an arrow that is 12% more mass lose in penetration by 13.04%. we look at the kinetic energy. The 485gr has 60.8 ft-lbs, and the 431gr is at 84.9ke. Again, he shows data from two different bows and compares all, and then states the K.E. does not correlate. In reality, in his trying to prove K.E. does not correlate, he has shown it does.

Let's make this a little easier to look at.

					gain/lost % based on the 793.7gr.			
mass	ke	momentum	pen "		mass	ke	momentum	pen."
793.7	33.1	0.48	11.25		793.7	33.1	0.48	11.25
799.8	38.1	0.52	13.875		0.77%	15.11%	8.33%	23.33%

					gain/lost % based on the 431gr			
mass	ke	momentum	pen "		mass	ke	momentum	pen."
431	84.9	0.57	11.5		431	84.9	0.57	14.875
483	60.8	0.51	10		12.06%	-28.39%	-10.53%	-13.04%

Now we can look at it and see what is going on—looking at the 793.7gr. vs. 799.8gr. There is only .77% difference. What caused the penetration increase of 23.33%? If all other factors are equal, the increase of 15.11% in K.E. is what caused the penetration increase.

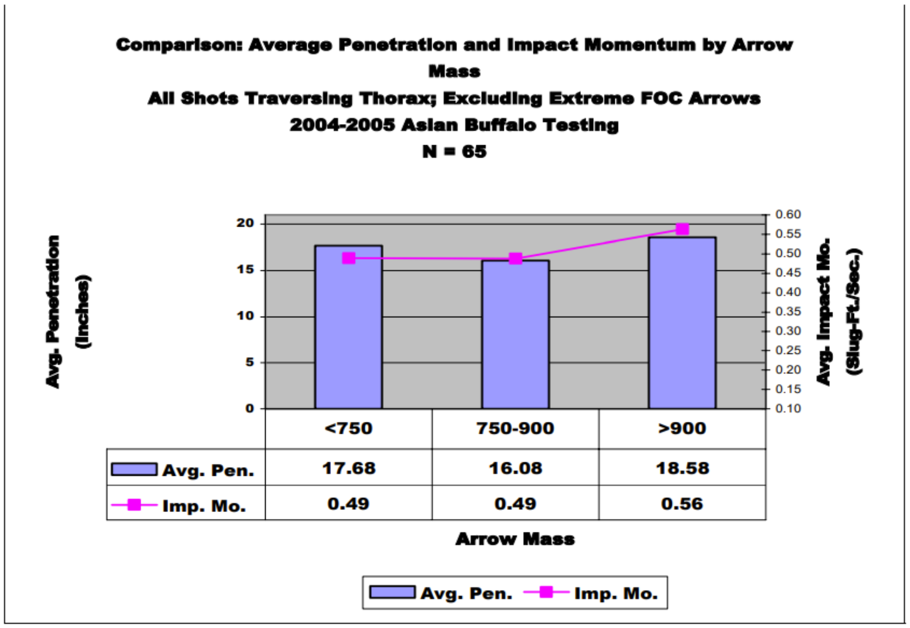
Looking at the 431gr vs. the 483gr, how can an arrow with 12.06% mass have a 13.04% loss in penetration? It's easy to see the 28.39% gain in K.E. is what gave the advantage to the 431gr arrow.

I realize it's not easy for people to understand. K.E. is how hard an arrow will hit. Momentum is how hard it is to stop or change the direction.

Finally, graph 9. In this graph, he is showing momentum, and as momentum gains, so does penetration. This is true. But there are only two ways to increase momentum by increasing mass or increasing K.E. (velocity). We can all say momentum is what the predicter to penetration is. But we must also understand we can do the same with mass and K.E. depending on the situation.

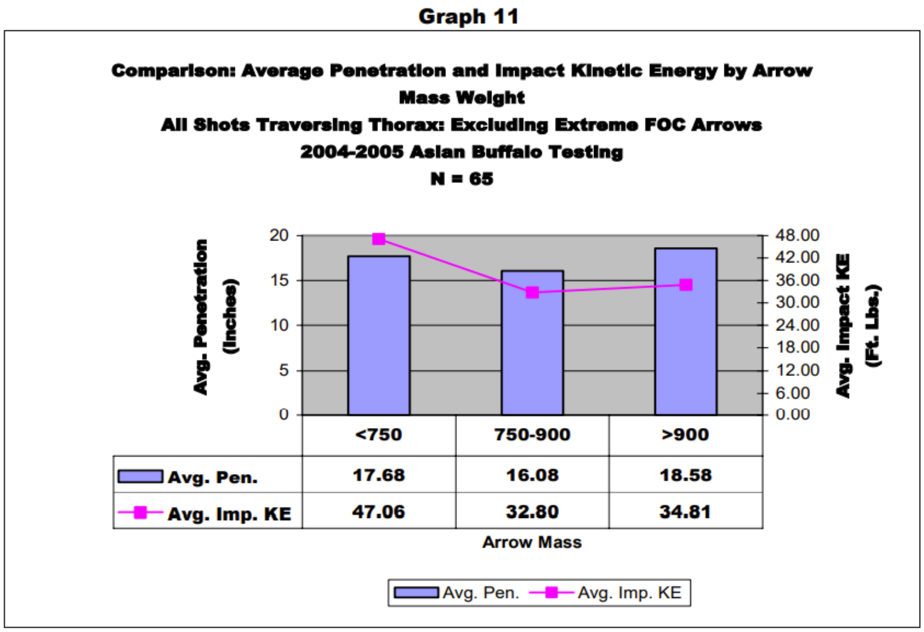
Graph 10.

Graph 10



In graph 10 you will notice he is showing three groups. A <750, 750-900 and a >900. In this setup, the only way to get an equal momentum means he had to increase the K.E. in this test. By increasing the K.E., he increased penetration. Personally, I would have left group one off the chart. When testing and trying to give data, you must keep everything as equal as possible and only change one variable. In this chart, he changed two.

Graph 11



Graph 11 shows that K.E. is only being outrun by mass. Now in reading how he got here does talk about the small samples at the lower weight arrows. But this shows problems in testing to get true numbers.

From the Dr. Ashby in this section.
"A positive kinetic-energy to penetration correlation appears only when a single arrow setup is considered; with average penetration increasing as impact-kinetic-energy goes up. However, the increased velocity required to yield higher kinetic-energy also increases the "given arrow's" momentum. The penetration-increase to kinetic-energy-increase relationship is not proportional; it shows marked decrement. Mathematically, "proportional" means "having the same or a constant ratio." "Decrement" means the rate of penetration increase decreases as the impact-kinetic-energy increases. In other words, the gain in penetration becomes smaller each time impact-kinetic-energy is increased by a set amount."

This is a good statement, and all true. This is why mass is the main predictor of penetration when shooting the same bow.

There are two more graphs, but by now, we can see what is going on for this section of the study.

Reference
1. [Ashby Reports — Ashby Bowhunting Foundation]