

TO BARE SHAFT TUNE OR *NOT* TO BARE SHAFT TUNE . . . ?

by Dennis La Varenne

INTRODUCTION

Some of you may recall a debate on the subject of the need for the modern technique of bare shaft tuning in which I was involved in January of 2014 with some Ozbow members.

Whilst in that debate at no stage did I disagree with the fact that the technique of bare shaft tuning does work in fact, my point which seemed to be repeatedly missed was that it was not as necessary as proposed in order to obtain good/optimum bow-arrow matching and good arrow flight.

My contention is still that its importance is seriously overblown. As requested by members, I was given a range of references on technique which I promised to follow up on and test for my own information.

I have done that using wood arrows using those remarkable removable Top-hat screw on heads I got from John MacDonald. These heads have the exquisite benefit of being able to be screwed off and replaced for the technique of bare shaft tuning. I used two head weights – 60 grains and 100 grains.

Beginning with 3 bare shafts of 5/16" shafts which I had previously tested to be in the range of 20 – 30 lbs at their full length of 29", I methodically cut ½ inch from the shafts and shooting them with alternating 60 grain and then 100 grain heads.

My draw length these days is barely 26 inches, so the dynamic spine of these shafts is further reduced by the fact of having the head weight plus the additional weight of the shaft ahead of my 26" draw weight.

It has been long established that any mass in an arrow forward of the draw length has no effect on the static spine of the shaft. However, as the mass ahead of the draw length is decreased, dynamic spine *increases*.

The mechanics of why arrows bend under string force is the result of what engineers refer to a 'columnar compression'.

Fundamentally, the shorter the column against which a force is applied to either end, the less that column will deflect from straight. If there is a restriction on the direction of bend such as a stiff reinforce against one side of the column (the bow), then the column (arrow) will bend away from that restriction.

This is what happens in real life when an arrow is forced forward from the impulse of the bowstring and for some time after it actually leaves the bowstring.

Free of the restriction of the bow's arrow plate, the effects of columnar compression forces continue in the form of oscillation of the arrow across its plane at right angles to the long axis of the bow.

When we match the stiffness of our arrows to any particular bow, what we are all endeavouring to do is trying to reduce the amplitude of this oscillation so that the arrow travels in as close a line of direction as possible to that of the line of vision.

Generally, the greater the amplitude of the oscillation, indicating lower spine, the more likely is the arrow to shoot away to the opposite side of the bow. The stiffer the arrow and hence the smaller the oscillation, the more likely is the arrow to shoot away from the shooting side of the bow. This is the generally accepted teaching about the effects of arrow spine and it holds true in most but not all cases.

Bare shaft tuning is one way to address the problem of archer's paradox.

WHAT IS ARCHER'S PARADOX?

Most archers today have very little concept of what archer's paradox truly describes.

A paradox is simply a fact which is demonstrably true but which seems to belie common sense and logic.

The term was first used by Horace Ford⁽¹⁷⁾ as far back as the early-mid 19th century in his seminal book on modern archery - *The Theory and Practice of Archery* - where he described the apparent 'paradox' of the observable fact that the arrow clearly travelled in the direction of the line of sight despite the other fact that when it was mounted on the bow before and during the act of shooting, it clearly pointed across the line of sight and away from the side of the bow's arrow plate.

Archer's paradox is not and was never a descriptor of the oscillation of the arrow shaft during its travel.

What actually happened to the arrow during its early travel from the bow until it 'went to sleep' and flew straight to its mark was never actually observed or observable to the human eye until in the late 1920s – early 1930s, when the American physicists, Dr Clarence N. Hickman and Dr Paul Klopsteg used a method of spark photography used previously by firearms ballisticians to trace the path of bullets.

Using a modification of this technique described by Dr Paul Klopsteg in '*Archery – The Technical Side*⁽²³⁾' (pages 134 – 146, and later on pages 178 - 185), this method of high speed 'spark' photography allowed archers to see for the very first time what actually happened when an arrow is propelled by the bowstring and a short distance beyond. It also allowed archers to see how the string behaved from the instant of loose until the bow ceased recoiling after the arrow had left the string.

None of these observations was what archers of the time had any serious inkling of.

These observations were a revelation, and set in train the much more precise measuring techniques of what controlled the stiffness of arrows and to what degree the oscillation could be controlled, as well as the means of measuring that resistance to oscillation which today, we refer to as arrow spine or stiffness.

These machines progressed through all degrees of refinement up until the now standardised method of using a 2lb weight suspended from the middle of the arrow shaft between supports which are 26 inches apart which equates to the required stiffness at an actual 28 inch draw. The degree of bend is measured in thousandths of an inch.

The lower the number, the stiffer the arrow shaft and vice versa. This measurement takes no account of such important considerations as the mass of the arrowhead or the centre of gravity of the armed shaft, which need to be arrived at by other methods.

THE EARLY DAYS OF PARADOX

Drs Hickman and Klopsteg wrote papers collected together in 'Archery – The Technical Side' which dove into the topic in some detail, but for long afterwards, practising target archers (not bow hunters usually unless they were both) used a method of test shooting their arrows and matching them by how they grouped.

Arrows which grouped together not larger than the 'gold' of the target were regarded as matched. The old Victorian archer who was one of the founders of target archery in Victoria – Gerry Hevey – described this matching technique as 'clocking' the arrows in a conversation we had in the early 1980s as I was just beginning to learn bowery.

Clocking one's arrows referred to the noting of the grouping consistency of each arrow in an '*o'clock*' relationship to the gold of the target. It didn't matter where they grouped on the target. It was more important that the group sizes and point of impact of each arrow matched the others was the same. Correction was by means of shifting the sight. I have seen it written about elsewhere in at least one early Australian archery periodical owned by Jeff Challacombe wherein a champion NZ archer described the very same thing by another name.

Clocking one's arrows was the method of shooting each arrow individually and noting where it struck on the target in relation to the gold and the group size of that individual arrow. A set of arrows for target shooting was 6 arrows and perhaps a couple of spares.

Each of these arrows was shot similarly and its 'personal' group size and point of impact was noted. Those whose group size and distance from the gold were the same or close were regarded as matched. Those which fell outside the maximum group size and at a different point of impact were discarded from the set, but may have been re-used as part of another set having similar properties.

The archer then had only to move the sight on the bow to correct for the trajectory and the horizontal dispersion of the arrow set.

As you can imagine, this method was hugely time consuming, but could be done very efficiently by an expert archer with minimum wasted effort.

In another publication I have entitled - *BOWMAN'S HANDBOOK, Technical Notes and Gadgets for the Practical Archer, Clover, Patrick, British Archer Publication, 2nd edit.*⁽²⁹⁾, this same technique is described by 'Uncle Arch' under the title of 'The Group Testing of Arrows' on pages 88 and 89. This particular test used aluminium arrows which did not group nearly as well as one would have thought surprisingly.

This time consuming method clearly worked.

Another method of matching arrow spine without the need to shoot them was described in the same publication entitled '*Design and Construction of an Arrow Vibration Frequency Meter*' on pages 60 to 69 by one John Oram which I discussed a long time ago on Ozbow.

From what I can ascertain from my library listed at the end of this paper is that, the clocking method was the most commonly used among high achieving target archers, but barely noticed by bow hunters who used an entirely different and far less scientific method of matching arrows if they bothered at all.

TRADITIONAL METHODS OF MATCHING ARROWS

After the work of Hickman and Klopsteg in discovering the true nature of the archer's paradox in the 1930s, immediately there began investigations into how it could be controlled, not least of whom were these two physicists.

Essentially, all methods eventuated in some version of the current arrow spine jig. The standardization of spine relevant to draw weight was still decades away however. Arrows were spine tested by the static method and then test shot in bows to see which spine rating gave the desired results. This new method clearly obviated the necessity of the old fashioned but clearly effective 'clocking' method and took far less time.

However, it was quickly found that one archer's spine medicine was another's spine poison and that individuals needed to make and use their own spine jigs for their individual use.

There are many methods described in the NFAA 'Archery' magazine ⁽¹²⁰⁾, by that magazine's technical editor – Tracey Stalker - more than once back into the 1940s and 1950s.

However, the problem identified by archers back in the late 1940s and early 1950s has not resolved itself in modern times either. People still select industrially spine graded arrows according to industry charts and find that they do not work nearly as well as the charts would suggest.

Even though they may be well matched in static spine on industrial spine testers to a reasonably high level of consistency, the variables involved in the less than perfectly consistent technique of individual archers makes such charting less than desirable.

It still amazes me how little knowledge modern archers of both that the self-styled new-age traditionalist and the modern mechanical machine age archer has of the nature of spine.

It seems to me that only those of the pre-1967 old-school traditional archery seem to have any genuine understanding of the term and its relevance to the archer's paradox.

The modern solution was to develop the entirely empirical method of 'bare-shaft' tuning – a modern equivalent to the old method of 'clocking' arrows.

HOW CAN PARADOX BE MEASURED

In - *BOWMAN'S HANDBOOK, Technical Notes and Gadgets for the Practical Archer*, Clover, Patrick, British Archer Publication, 2nd edit., 1955⁽²⁹⁾, one contributor, John Oram, wrote an article entitled '*Design and Construction of an Arrow Vibration Meter*' (pp60).

To date, this is the best article I have found which actually explains how it could be possible to measure the amplitude and frequency of the oscillations of the arrow as it is driven forward by the bowstring.

In 'Archery – The Technical Side', (pp134, 215 and 258) there are various articles on what actually happens to the arrow during the power stroke as well as what happens to the position of the bowhand and the loosing hand, all of which are affected by the forces acting on the arrow.

What was discovered in those early days clearly points to the prospect of being able to measure the oscillations of the arrow relevant to the degree of thrust on the arrow from the bowstring which, in turn, is applicable to varying bow draw weights.

The article by John Oram is perhaps the best I have discovered in explaining how to measure the minimum required degree of bend or oscillation to work out which arrow spine is best suited to what bow outside of testing arrows individually by shooting.

Another more recent article is – '*THE MECHANICS OF ARROW FLIGHT UPON RELEASE*' by Lieu, D.K., University of California, Berkeley. (Undated PDF)⁽¹³¹⁾ which is very mathematical but understandable nevertheless.

Both however, fall just short of actually giving an actual amount of bend in mm or inches required to allow clear passage of an arrow around the bow.

Briefly, both Oram's and Lieu's articles set out to describe how to find the nodal points of any arrow, between which the arrow bends or oscillates and the amplitude required to achieve clear passage.

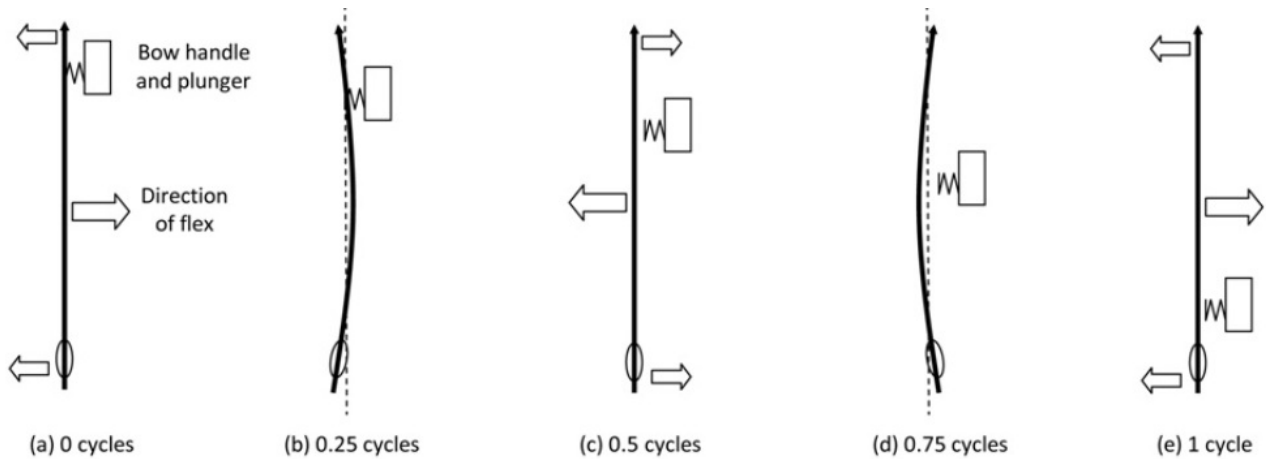
Lieu refers to the arrow's state of straight to first bend to straight to second bend and back again to straight as one bending *cycle*, at the end of which cycle, the arrow's fletches are just about to pass the bow. One bending cycle is the full width of transverse bending on both sides of straight.

I can do no better than use figure 12 from his paper to illustrate this phenomenon. The relative stiffness of the arrow shaft determines the amplitude of the oscillations between these nodes.

Stiffer arrows have a lower frequency cycle and narrower amplitude and vice versa. I consider that both of these aspects can be measured and related to the draw weight of any bow and its draw length.

My own suspicion however still under testing at present is that the amplitude and oscillation frequency with well 'matched' arrows in any bow and arrow set is much the

same. As we all know already, using a differently spined arrow to the optimum in any bow will yield either a greater or lesser degree of oscillation affecting the stability of the arrow's flight or its strike point.



(Figure 12 from Lieu.)

I have done some preliminary testing of my own arrows of known spine by shifting the supports further apart or closer together to match actual draw length and then checking the amount of deflection using the standard 2lb weight. (I will publish the results as soon as the data shows a definite trend in whatever direction.)

Somewhat off-topic, the required *amount* of bend from straight of any arrow shot from any bow of any draw weight and draw length which allows the arrow to pass around the bow with minimum flexing may probably be very similar if not the same over all draw weights and draw lengths. Testing this hypothesis is the difficulty at present.

As everybody knows, the standard international method is to measure the amount of bend in any shaft between 26" supports, then extrapolating that static spine reading to either shorter or longer draw length arrows using certain principles relating to the arrow's forward of centre balance point which affects the columnar distortion of the arrow at the loose.

What could actually be happening is that the amount of bend in a spine-matched arrow shot from a 30lb bow could be just the same as that from a 100lb bow when both are shot from the same draw length.

That is, an arrow from a 30lb bow may only need to bend by say, $\frac{1}{2}$ ", to be able to pass the bow sufficiently to fly well, but also, an arrow from a 100lb bow may only need to bend by the same $\frac{1}{2}$ " to achieve the same result.

Furthermore, the same $\frac{1}{2}$ " bend may be the same for archers with either shorter or longer draw-lengths as well. It may be that a person drawing 30lbs at 26" may still require $\frac{1}{2}$ " of bend as may a person drawing 100lbs at 30". I am well aware that this hypothesis is contentious, but there is no reason to consider that we have understood or investigated the nature of archer's paradox to its conclusion.

If my hypothesis above turns out to be correct, then an archer would only need to verify that any static bend in a shaft is of a defined amount at their personal draw length after allowing for any mass forward of full draw length in order to obtain optimum flight no matter what the draw weight or draw length.

We also need to take into account that any arrow material forward of the point of full draw (traditionally measured from the bow's back) is mass added to the head end of the arrow. The greater the amount of mass forward of full draw, the greater the amplitude of the arrow's oscillation because columnar compression forces will force the shaft to bend between different nodes due to that added forward mass.

Presently, the rule of thumb is that for every 10 grains of arrow mass past full draw point equates to a 5lb lowering of spine value.

Simply measuring the amount of deflection shown by the spine-testing jig doesn't really tell us much about how the arrow will shoot.

To impart any degree of stability to any arrow, the centre of gravity MUST be moved forward of its geographical centre. By doing so, the rear part of the shaft behind the centre of gravity acts as drag on the shaft and keeps the arrow from wanting to tumble or yaw in flight.

It is the same principle as flying a kite where the tail causes drag and keeps the kite pointed in the correct direction and likewise, the pellet from an air rifle where most of the mass is centred in the head with the skirt providing drag to keep the pellet flying straight

(Rifling in an air rifle's barrel has a very slow twist rate because most of the stabilising is done by the pellet's aerodynamics.).

If arrows are long enough, they don't need feathers at the rear to add to the drag effect. We see this in those used by New Guineans whose arrows are often longer than the bow. These arrows often have an obvious centre of gravity well forward because of the increasing diameter of the shaft towards the head with the drag being supplied by the long 'tail'.

But, on average, the northern hemisphere archery tradition practised here uses relatively short arrows which require added drag to achieve the same as indigenous southern hemisphere archery – unless of course, we can match them perfectly to each bow – something with the technique of 'bare shaft tuning' can do.

My contention in this section however, is that if there were a method available which could demonstrate that there was a specific amount of bend required to get an arrow to bend minimally around the bow and fly in a direct line to the mark, then we would not need to go through the lengthy and empirical method of bare shaft tuning our arrows.

Later in this discussion, I will further point out some shortcomings of the bare shaft tuning technique and why it is of little practical benefit to archers who shoot their bows in canted fashion, and particularly those who change the degree of cant with the changing environment in which the shot is taken as many bow hunters do.

I will also discuss why, after assessing the bare shaft tuning method, I have discarded it as of no particular benefit.

WHAT ACTUALLY HAPPENS TO AN ARROW AT THE LOOSE

In the book 'Archery – The Technical Side' and some other publications, one can find series of high speed still pictures of the kind of bending which an arrow undergoes from the instant of the loose until it leaves the bowstring and for some distance afterwards.

Some of these high speed pictures also show the behaviour of the bowstring as well as of the limbs of the bow at the end of the power stroke which are astonishing to say the least. Nothing is as one might expect.

For the purposes of this discussion however, I want to demonstrate as clearly and concisely as possible, the dynamics of the moving arrow and how it does so in relation to the bow. I will include a series of diagrams as well.

Firstly, for those not familiar with the terms, oscillation, amplitude, nodes and frequency as applied to the movement of arrows.

1. *Oscillation* is the actual bending of the arrow from the driving force of the bowstring.
2. *Amplitude* of the oscillation is the transverse width of the bending at its widest point.
3. *Nodes* are those points between which the bending occurs. Interestingly, the nodes always lie on the line of sight as the arrow moves forward, whereas the head andnock ends and the middle of the arrow move to either side of this line until the arrow finally 'goes to sleep'.

From the Balbardie Archers' Reference guide ⁽¹²⁰⁾, pp18, we read –

"2.2.3.1 Node points

The point at which the arrow rests against the button at full draw should ideally be one of the two "node" points, i.e. one of the two points of the arrow which do not move laterally during flight. This will tend to reduce the effect of a poor release as the node points of a shaft in flight tend to stay nearly still compared to the point of the shaft as illustrated below."

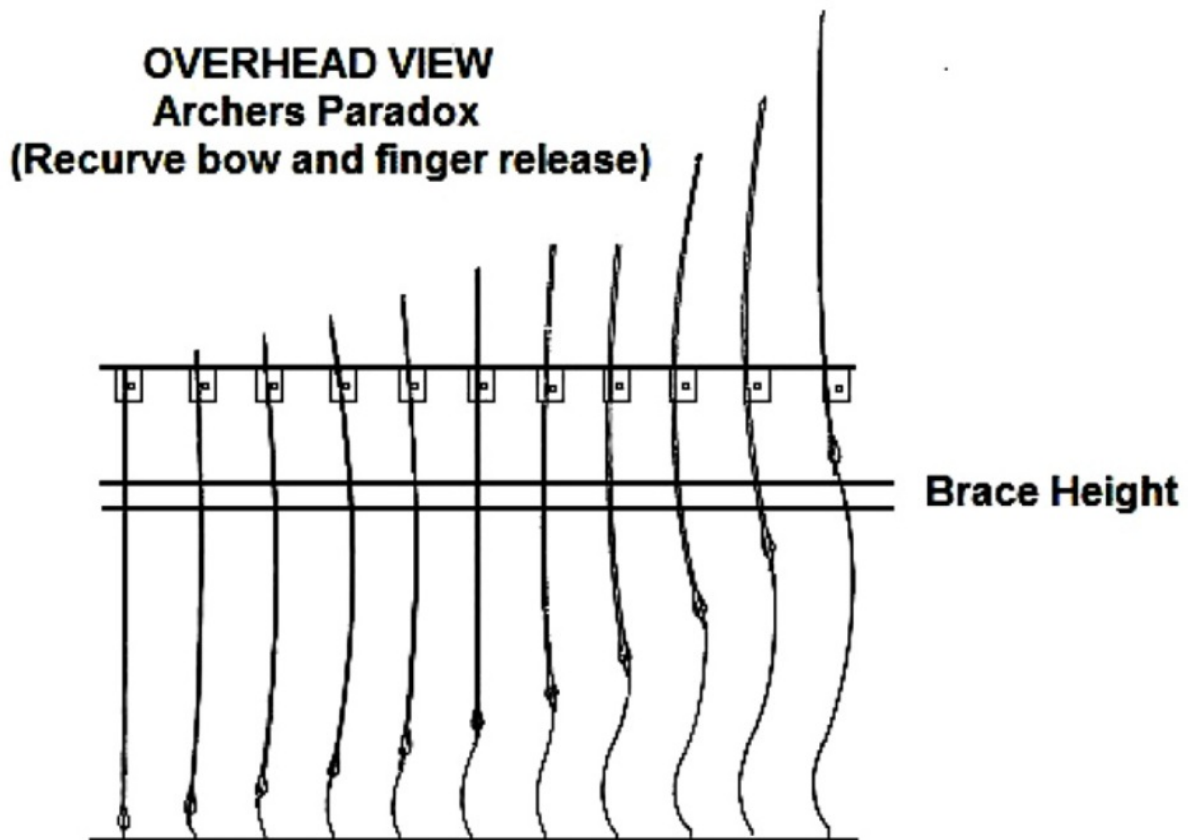
4. *Frequency* describes how often full amplitude bending or one complete cycle occurs between the nodes over a measured distance of travel or time.

Each of these four phenomena occur at right angles to the long axis of the bow and away from the arrow contact side of the bow.

This observation, derived from the work of archery ballisticians, is important in regard to an issue which I intend to raise later in this discussion.

When we endeavour to match the spine of our arrows to a particular bow, we are actually trying to minimise the oscillation, amplitude and frequency of the flexing arrow being driven forward by the bowstring and bow limbs so that the degree of horizontal flexing is at the minimum necessary to get the arrow past the bow and fly closest to the line of sight.

Testing our arrows on a spine jig is the most practical method we have presently and is only a guide. More precise spine must be done dynamically or by actually shooting arrows to see exactly how they perform under the stress of the accelerating bowstring and the columnar loading placed on the arrow's nock end.



The simple fact of arrow dynamics is that the rear of the arrow begins to move before the front end. This is the only way by which the column of the arrow shaft can be made to bend. Not many people realise this fact.

The bowstring wants to travel in a line directly towards the vertical axis of the bow, but it cannot because of the way in which it rolls off the archer's fingers beginning in a wide zig-zag pattern which decreases as it approaches brace height.

The above diagram from the Archery Australia Coach's manual on bare shaft Tuning ⁽¹³¹⁾ below, show both the flexing of the arrow during launch and the path of travel of the bowstring from a finger loose.

From the diagram above, one can see quite clearly that the bowstring does not move in a straight line toward the long centre axis of the bow, but in its own oscillatory manner until it reaches its closest position to the brace-height. Most bowstrings however, continue travelling past this point for another one to two inches below brace height, causing the bow limbs to 'belly' forward from the bow tips after the arrow has left the string. This phenomenon has been captured on high-speed photography many times since the early 1930s ⁽²³⁾.

As I have pointed out above, after the arrow leaves the bow-string, the degree of oscillation gradually decreases until it 'goes to sleep' and travels in a straight line.

However, that straight line could be along the line of sight or to either side of the line of sight depending entirely upon how well the dynamic spine of the arrow is so matched to the columnar force of the bowstring against the bow nock that the oscillation is not so great nor so small that the line of flight of the arrow after it has left the bow-string is to either side of the line of sight.

SO . . . WHERE DOES BARE SHAFT TUNING OF ARROWS COME IN?

Essentially, bare shaft tuning of arrows is a technique enabling best matching of the dynamic spine of any arrow to any bow under certain circumstances and pre-conditions of shooting.

Principle among those preconditions is that the bow is shot in a vertical position.

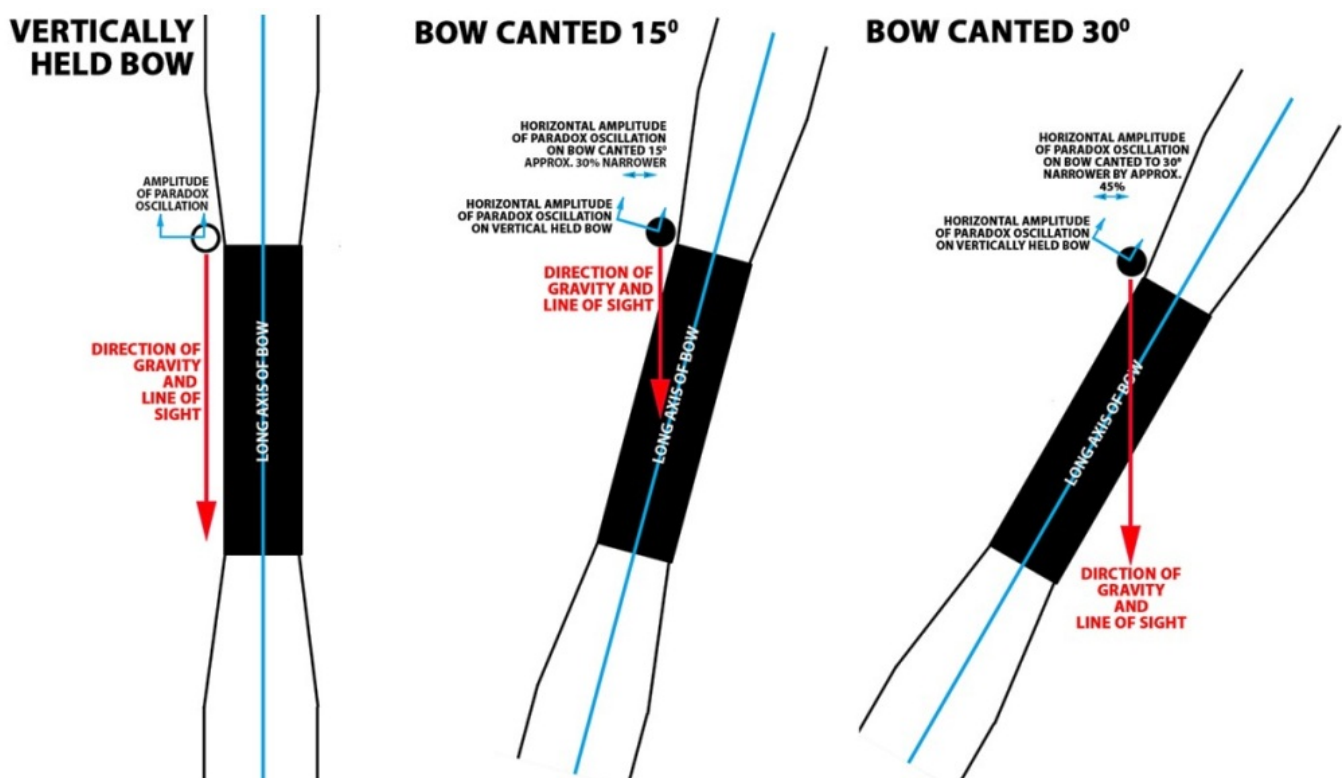
Secondly, no other arrows of different spine or mass can be shot from the same bow with the same degree of accuracy.

If the archer shoots a bow vertically, then there is a clear advantage in the use of the bare shaft tuning technique. There is no doubt about its efficacy.

Can the technique be used successfully when the bow is canted? Yes, it can and does and this is the reason why.

Remember, that the whole purpose of bare-shaft tuning is to enable the arrow to pass the bow with the minimum amount of oscillation as it passes the bow in order that it flies closest to the line of sight.

So, how does canting the bow affect this phenomenon? The following diagrams show the horizontal oscillation of the arrow as it passes the bow against the vertical axis of the bow and the line of gravitational fall which is always at 90° to the line of sight.



This next section may be a little difficult to grasp, however, if you look carefully at each of the 3 diagrams above, it can be seen that as the bow is canted over, the **horizontal** spread of the oscillation of the arrow as it passes the bow is less than with a vertically held bow. That is, its amplitude decreases in relation to the line of sight. The line of sight is also at 90° to the direction of gravity.

Consequently, there is no reason so believe that the trajectory of the arrow is in any way affected from vertical to canted.

It could be extrapolated that for any given amplitude of paradox oscillation, that simply by canting the bow, an arrow of stiffer spine with a narrower amplitude of oscillation could be used, or conversely, that an arrow of lower spine and wider amplitude could also be used successfully.

Simply put, so long as arrow mass is the same, a canted bow allows a greater range of arrow spines to be used with the same trajectory as the vertically held bow.

The point is that when any arrow is bare shaft spined to a bow held in a vertical position, the range of arrows available for use is limited to those which are matched to that bow. But, canting the same bow enables that bow to use a wider range of arrow spines. This observation may help explain why it is that so many of us who have never bothered to bare shaft tune our arrows continued to get quite satisfactory results when we shot instinctively with canted bows.

If this is true, it does explain why those of us who have shot canted bows and never bothered with going to a great deal of trouble with our arrows and their spine have never found any reason to complain about the performance of our arrows.

Certainly in my shooting life, I have generally used arrows which were as much as 15 lbs over-spine when checked statically and never had any issues with their direction of travel relative to my line of sight to the mark.

My only problems have been with arrows greatly under-spine which have a tendency to smack against the arrow plate and bounce away snake-like from my bow. But in this instance, the arrows were as much as 10 – 15lbs under-spined for my bows.

REFERENCE MATERIALS

1. **ABCs OF BOWHUNTING**, Adams, Chuck, AMO Headquarters, North Palm Beach, Florida.
2. **A HANDBOOK OF ARCHERY**, Indian Archery & Toy Corp., Evansville, Indiana (undated).
3. **A History of Target Archery**, Heath, E.G., A.S. Barnes and Company, New York, ISBN 0-498-01434-7.
4. **AMERICAN INDIAN ARCHERY**, Laubin, Reginald and Gladys, University of Oklahoma Press, 1980. ISBN 0 8061 1467 3.
5. **AN APPROACH TO THE STUDY OF ANCIENT ARCHERY USING MATHEMATICAL MODELLING**, Kooi, B.W. and Bergman, C.A., Journal of The Society of Archer-Antiquaries, Volume 34, 1991.
6. **ARCHERY**, Elmer, Robert P. MD, The Penn Publishing Company, Philadelphia 1926.
7. **ARCHERY**, Besco-Layer, Olive, Student hand booklet. Undated. ??1930s.
8. **ARCHERY**, Reichart, Natalie and Keasey, Gilman, A. S. Barnes & Co. New York, 1936.
9. **ARCHERY**, Reichart, Natalie and Keasey, Gilman, A. S. Barnes & Co. New York, 2nd edit, 1940.
10. **ARCHERY**, Brown Physical Education Activities Series, McKinney, Wayne C., Wm C. Brown Co Publishers, 1966. ISBN 0-697-07000-X (2).
11. **ARCHERY**, Wiseman, Howard and Brundle, Fred; W. & G. Foyle, London, 1956.
12. **ARCHERY From A-Z**, Howard Wiseman and Fred Brundle, Faber & Faber, London 1958.
13. **ARCHERY FROM GOLDS TO BIG GAME**, by Keith C. Schuyler, A.S. Barnes, New York 1970.
14. **ARCHER'S DIGEST**, 5th edit., DBI Books Inc. Combs, Roger ed., ISBN 0 87349 114 9 .
15. **ARCHERY, THE BADMINTON LIBRARY**, Longman, C. J. and Walrond, Col. H., Longmans, Green & Co. 1894.
16. **ARCHERY HALL OF FAME AND MUSEUM**, <http://www.archeryhalloffame.com/> with especial thanks for reference materials.
17. **ARCHERY, The Theory and Practice of**, Ford, Horace, revisd and rewritten by Butt, W. MA, Longmans, Green & Co. London 1887.
18. **ARCHERY HANDBOOK**, Burke, Edmund H., Fawcett Publications Inc. 1954.
19. **ARCHERY HANDBOOK**, Gillelan, G. Howard and Stump, William, Trend Books Inc., Los Angeles, California 1958
20. **ARCHERY MADE EASY**, Pearson, Ben, The Perdue Co., Pine Bluff, Arkansas (undated).
21. **ARCHERY SIMPLIFIED**, Rounsevelle, Phillip, A.S. Barnes and Company Inc., New York 1931.
22. **ARCHERY TACKLE – How to Make and Use it**, Shane Adolph, 1936, republished 1990, Bois D'Arc Press, Texas.
23. **ARCHERY: THE TECHNICAL SIDE**, Hickman, C.N., Nagler, Forrest, Klopsteg, Paul E., National Field Archery Association, 1947.

24. **A TREATISE ON ARCHERY 1827**, Waring, Thomas, Kessinger Publishing reprint. ISBN 9781437470420.
25. **BEN PEARSON CATALOG No.33, pp8 1961**.
26. **BETTER ARCHERY**, Heath, E.G., Kaye & Ward, London, 1976. ISBN 0 7182 1446 3.
27. **BOWHUNTING MANUAL**, National Field Archery Association, 1962.
28. **BOWMAN'S HANDBOOK, Technical Notes and Gadgets for the Practical Archer**, Clover, Patrick, British Archer Publication, 1st edit 92pp.
29. **BOWMAN'S HANDBOOK, Technical Notes and Gadgets for the Practical Archer**, Clover, Patrick, British Archer Publication, 2nd edit 118pp.
30. **BOWS AND ARROWS**, Pope, Saxton T., University of California Press, 1962, 3rd Edition reprint.
31. **BOWS AND ARROWS**, Duff, James, 1st Ed., The Macmillan Co, New York, 1927.
32. **BOWS AND ARROWS**, Duff, James, 3rd Ed., The Macmillan Co, New York, 1941.
33. **BOWS AND ARROWS OF THE NATIVE AMERICAN INDIANS**, Hamm, Jim, Lyons & Burford Publishers, 1989. ISBN 1 55821 096 2.
34. **BRAZILIAN INDIAN ARCHERY**, Heath, E. G. and Chiara, Vilma, The Simon Archery Foundation, University of Manchester, 1977. ISBN 0 9503199 1 0.
35. **BYGONE ARCHERY**, Reid, Colin, The Guild of Elizabethan Archers, Newsbury (undated).
36. **CHEROKEE BOWS AND ARROWS**, Herrin, Al., White Bear Publishing, Tahlequah, Oklahoma, 1st Edit. 1989.
37. **CLARENCE N. HICKMAN – The Father of Scientific Archery**, Schumm, Maryanne M. Ed.D, Maples Press Inc. Pennsylvania 1983, ISBN 0-9613582-0-5.
38. **COMPLETE BOOK OF THE BOW AND ARROW**, Gilellan, G. Howard, The Stackpole Co. 1971.
39. **ENCYCLOPAEDIA OF ARCHERY**, Paterson, W. F., Robert Hale, London 1984, ISBN 0 7090 1072 9.
40. **FIELD AND TARGET ARCHERY**, Burke, Edmund, Arco Publishing Co Inc. New York, 1971. ISBN 0-688-008250-3.
41. **FOR THE FIRST TIME BOWYER**, Hulsey, Steve, self published 1991.
42. **FUN WITH THE BOW AND ARROW**, Coevering, Jack Van and Bear, Fred, Bear Archery Co. 1953.
43. **GUIDE TO BETTER ARCHERY**, Forbes, Thomas A, The Stackpole Company, Harrisburg, Pennsylvania 1955.
44. **HENRY VIII's LOST WARSHIPS**, National Geographic, May, 1983, Vol 163, No. 5, pp646.
45. **HERITAGE OF THE LONGBOW, THE**, Bickerstaffe, Pip, Self published, 1999.
46. **HOWARD HILL'S ARCHERY ADVENTURES**, (Extracts from Howard Hill's books), Trend Books Inc., Los Angeles, California 1955.
47. **HOWARD HILL – THE MAN AND THE LEGEND**, Ekin, Craig, Charger Productions Incorporated, 1982.

48. **HOW TO HUNT WITH BOW AND ARROW**, Meuhler, W. M. (Doc), Malibu Archery Co. (undated).
49. **HOW TO IMPROVE YOUR ARCHERY**, Jaeger, Eloise; Norckauer, Mary E.; Clark, Ann; Witt, Jack P.; The Athletic Institute, 1962.
50. **HOW TO MAKE BOWS**, Jennings, Tom and Kettredge, Doug, Sportsman Publications, California 1961.
51. **HOW TO MAKE MODERN ARCHERY TACKLE**, Stalker, Tracy L., Self published, 1954.
52. **HUNTING THE HARD WAY**, Hill, Howard, reprinted by Jerry Hill Longbow Co. Harpersville, Alabama, 1984.
53. **HUNTING WITH THE BOW AND ARROW**, Pope Saxton 1925, Wolf Publishing Co. reprint 1991.
54. **HUNTING THE OSAGE BOW**, Torges, Dean, self-published 1998. ISBN 0 9665107 0 4.
55. **IN AFRICA**, Swinehart, Bob, Boyer Publishing Co., Boyertown, Pennsylvania 1967.
56. **IN PURSUIT OF ARCHERY**, Edwards, C. B., and Heath, E. G. Nicholas Kaye Limited, London, 1962.
57. **INTRODUCTION TO ARCHERY**, Schmidt, Marvin, Ziff-Davis Publishing Co., 1946.
58. **ISHI IN TWO WORLDS**, Kroeber, Theodora, University of California Press, 1965.
59. **Longbow – A Social and Military History**, Hardy, Robert, 5th Ed, Odcombe Press LP, ISBN 978 0 85733 248 6.
60. **MAKING A LONGOW – Teaching the Bow to Bend**, Schilling, Linda and Wlotzka, Michael, Schiffer Publishing, 2014. ISBN 978-0-7643-4595-1.
61. **MAKING WOODEN LONGBOWS**, Homer, Stuart, D.G.Quick publishers (undated).
62. **MAKING WOODEN SELF ARROWS FOR LONGBOWS**, Reid, C.D., self published 1978.
63. **MARY ROSE, The Excavation and Raising of Henry VIII's Flagship**, Rule, Margaret, Conway Maritime Press 1982, ISBN 0 85177 382 6.
64. **MEDIAEVAL WAR BOWS – A Bowyer's Thoughts**, Bickerstaffe, Pip, self published, 2006.
65. **MEDITATIONS ON HUNTING**, José Ortega y Gasset, Charles Scribner's Sons, New York. 1972. ISBN 0-684-18630-6.
66. **MODERN ARCHERY**, Bilson, Frank L., The Paternoster Press, London, 4th edit, 1952.
67. **MODERN ARCHERY**, Lambert Jnr, Arthur W., A. S Barnes & Co., New York, 1929.
68. **MODERN BOW HUNTING**, Grogan, Hiram J, The Stackpole Company, Pennsylvania 1958.
69. **MURRAY'S GUIDE TO ARCHERY**, Series No. 11, Conway, Dallas ed., Murray Book Distributors Pty Ltd, 2007.
70. **NATIVE AMERICAN BOWS AND ARROWS**, Hamilton, T. M., Missouri Archaeological Society Special Publications No. 5, 2nd edit. 1982. ISBN 0 943414 00 8.
71. **NEW GUIDE TO BETTER ARCHERY**, Forbes, Thomas A, The Stackpole Company, Harrisburg, Pennsylvania 1960, 2nd edition enlarged.

72. **PROFESSIONAL AND AMATEUR ARCHERY TOURNAMENT AND HUNTING INSTRUCTIONS AND ENCYCLOPEDIA**, Herter, George Leonard and Hofmeister, Russell, Herter's Incorporated, Minnesota 1st edition 1963.
73. **SHOOTING THE BOW**, Whiffen, Larry C., The Bruce Publishing Co., Milwaukee. 1946.
74. **SHOOTING THE LONGBOW (AND OTHER TIPS)**, Palmer, Dick, Harlo Press Michigan, 1st edition 1980. Harlo
75. **SOME BOWYER'S NOTES**, Arton, Kenneth O, self published, 1953.
76. **STRAIGHT AND TRUE – A Select History of the Arrow**, Soar, Hugh D. H., Westholm Publishing, Yardley, Pennsylvania 2012. ISBN 978-1-59416-147-6.
77. **STUDENTS' HANDBOOK OF ARCHERY**, Rounsevelle Phillip, A. S. Barnes & Co. Inc. New York, 1939.
78. **SYLLABUS ON ARCHERY FOR THE BEGINNER**, York Archery Equipment & The Woodcraft Equipment Co. Independence, Missouri. (Undated).
79. **TARGET ARCHERY**, Elmer, Robert P., Alfred A. Knopf, New York, 1946.
80. **THE ADVENTUROUS BOWMEN – Field Notes on African Archery, Pope, Saxton 1926, Wolfe Publishing, Prescott Arizona reprint 1991.**
81. **THE ARCHER'S CRAFT**, Hodgkin, Adrian Eliot, A. S. Barnes & Co., New York. US edit. Undated (??? 1st edition).
82. **THE ARCHERY WORKSHOP**, Stemmler, L. E. and Gordon, Paul H., Self published, 1935.
83. **THE ARCHERY WORKSHOP**, Stemmler, L. E., Self published, 1935.
84. **THE ART OF MAKING PRIMITIVE BOWS AND ARROWS**, Waldorf, D.C., self published, 1985.
85. **THE BADMINTON LIBRARY OF SPORTS AND PASTIMES – ARCHERY**, Edited by His Grace, the Duke of Beaufort, KG., Longmans, Green & Co., London 1894 (2).
86. **THE BASIC TECHNIQUE OF INSTINCTIVE FIELD ARCHERY**, National Field Archery Association USA. (undated???1960s)
87. **THE BOOK OF ARCHERY being the COMPLETE HISTORY AND PRACTICE OF THE ART**, Hansard, George Agar, Henry G Bohn, New York and Covent Garden 1841.
88. **THE BOOK OF PRIMITIVE ARCHERY**, Massey, Jay, Bear Paw Publications, 1990.
89. **THE BOW AND ARROW FOR BIG GAME** and **ARCHERY, AN ENGINEERING VIEW**, Nagler, Forrest, (Two titles in the one book), Frank Taylor & Son, Publishers, Albany, Oregon, 1941.
90. **THE BOWYER'S CRAFT**, Massey, Jay, Bear Paw Publications, Alaska 1987.
91. **THE COMPLETE ARCHERY BOOK**, Hochman, Louis, Arco Publishing Co. Inc. New York 1975. ISBN 0-668-00552-1.
92. **THE ELEPHANT PEOPLE**, Holman, Dennis, John Murray pub., 1967.
93. **THE ENCYCLOPEDIA OF ARCHERY**, Hougham, Paul, A.S. Barnes & Company, New York 1958.
94. **THE ESSENTIALS OF ARCHERY**, Stemmler, L. E., Self published, 1942.

95. **THE FLAT BOW**, Hunt, W. Ben, Metz, John J., The Bruce Publishing Co., New York, Milwaukee, Chicago. 1936.
96. **THE GREY GOOSE WING**, Heath, E. G., Osprey Publications Ltd. 1971.
97. **THE GREAT WARBOW**, Strickland, Matthew and Hardy, Robert, Sutton Publishing, 2005, ISBN 0 7509 3167 1.
98. **THE HERITAGE OF THE LONGBOW**, Bickerstaffe, Pip, Self published, 1999.
99. **THE HISTORY OF ARCHERY**, Burke, Edmund, Heineman – London, Melbourne, Toronto, 1957.
100. **THE HISTORY OF ARCHERY**, Burke, Edmund, William Morrow and Co, New York, 1958.
101. **THE LONGBOW**, Loades, Mike, Osprey Publishing Ltd. 2013. ISBN 978 1 78200 085 3.
102. **THE MARY ROSE – The Excavating and Raising of Henry VIII's Flagship**, Rule, Margaret, Conway Maritime Press Limited, 1990 reprint.
103. **THE NEW ARCHERY – HOBBY, SPORT, CRAFT**, Gordon, Paul H., D. Appleton-Century Co., New York, London, 1939.
104. **THE NEW ARCHERY HANDBOOK**, Laycock, George and Bauer, Erwin, Fawcett Publications Inc. 1965.
105. **THE SPORT OF ARCHERY – The Selection and Use of Archery Equipment**, The Archer's Company, Bristol. 1935.
106. **THE TEACHING OF ARCHERY**, Craft, Dave and Cia, A.S. BARNES & Co., New York, 1936.
107. **THE WITCHERY OF ARCHERY**, Thompson, J. Maurice., The Archer's Company, 1928.
108. **TOXOPHILUS 1545**, Ascham, Roger, Simon Archery Foundation, Manchester University, 1987. ISBN 0 9503199 0 9.
109. **TURKISH ARCHERY AND THE COMPOSITE BOW**, Klopsteg, Paul E., Self published, 2nd edition, 1947.
110. **WITH A BENDED BOW – Archery in Mediaeval and Renaissance Europe**, Roth, Erik, Spellmount 2012. ISBN 978-0-7524-6355-1.
111. **YOU CAN MAKE A BOW - HERE'S HOW**, Farrell, Ed., self-published, 1959.

PERIODICALS

112. **NFAA 'ARCHERY' MAGAZINE –**

1945 – January, February, April, May, August, September, October, November, December.

1946 – February, March, April, October, November, December.

1947 – January, February, March, April, May, June, July, August, September, October, November, December.

1948 - February, March, April, May, June, July, August, December.

1949 - January, February, March, April, May, June, July, August, September, October, December.

1950 - January, February, March, April, May, June, July, August, September, October, November, December.

1951 - January, February, March, April, June, July, September, October, November, December.

1952 - January, February, March, April, May, June, July, August, September, October, November, December.

1953 - January, February, March, April, May, June, July, August, September, October, November, December.

1954 - January, February, March, April, May, June, July, August, September, October, November, December.

1955 - January, February, March, April, May, June, July, August, September, October, November, December.

1956 - January, February, March, April, May, June, July, August, September, October, November, December.

1957 - January, February, March, April, May, June, July, August, September, October, November, December.

1958 - January, February, March, April, May, June, July, August, September, October, November, December.

1959 - January, February, March, April, May, June, July, August, September, October, November, December.

1960 - February, March, April, October, November, December.

1961 - January, February, March, April, May, June, July, August, September, October, November, December.

1962 - January, March, April, June, July, August, September, November, December.

1963 - January, February, March, April, May, June, October, December.

1964 - January, February, March, April, May, June, July, August, October, November, December.

1965 - January, February, March, April, May, June, July, August, September, October, November, December.

1966 - January, February, March, June, September, October, November, December.

1967 - January, February, March, April, July, August, September, November, December.

1968 - February, April, May.

1969 - July.

1970 - May, June, August, September.

113. AMERICAN BOWMAN REVIEW –

1942 - August, September.

1943 - February, June, September.

1948 - January.

1950 - February, March, April, May, June, July.

1951 - January.

114. BOWHUNTING –

1960 - January, February, March, April, May, June, July, August, September, October, December.

1961 - March, August.

1962 - February, September.

115. BROADHEAD MAGAZINE –

1959 - June.

116. THE BOWHUNTER –

1953 - February, March, May.

1954 - November.

117. THE EASTERN BOWHUNTER –

1957 - January, May, July, December.

1958 - January, February, March, April, May, June, July, August, September, October, November, December.

118. THE LONGBOW MAGAZINE –

1988 - January, February, March, April, May, June, July, August, September, October, November, December.

1989 - January, February, May, June, July, August, September, October.

119. THE LONGBOW-RECURVE MAGAZINE –

1990 - August.

120. THE NATIONAL BOWHUNTER –

1957 - February.

1960 - November.

1961 - September.

1963 - June, July, August, September.

PDF ARTICLES ON THE BARE-SHAFT TUNING OF ARROWS

121. 3Rivers Bare Shaft Tuning Guide 2011

120. Balbardie Archers' Reference Guide

121. ARCHERY AUSTRALIA - Blank Shaft Arrow Tuning

122. Bow-Tuning-Tests

123. Damage_Target_face_instructions

124. Dynamic Spine Calculator Instructions 7-18-10

125. Easton_Tuning_Guide_1999

126. Easton_Tuning_Guide_2000

127. FITA Recurve Bow Equipment Tuning

- 128. Martin_Compound_Bow_Manual_2001
- 129. The Mechanics of Arrow Flight upon Release
- 130. The Nuts & Bolts of Archery-111510-rev2
- 131. THE MECHANICS OF ARROW FLIGHT UPON RELEASE' by Lieu, D.K., University of California, Berkeley