From:
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Mr. Dale Karch
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P.O. Box 517
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Dear Mr. Karch:

Recently you shipped two longbows to me requesting that I subject them to tests designed to determine their performance. These bows were as follows:

1. A 64-inch Tomahawk Desert Fox (Diamond Series) serial number 9352 with a manufacturer's rating of 60-pounds at 28-inches draw length (ATA)

2. A 58-inch Tomahawk Thunder Storm (Diamond Series) serial number 8698 with a manufacturer's rating of 60-pounds at 28-inches draw length (ATA)

We agreed that the 64-inch Desert Fox would be tested at 26, 28 and 30-inches draw length, allowing it to be rated in line with ASTM Standard 1544-04 as well as my performance profile system. On the other hand, the 58-inch Thunder Storm would be limited to tests at 24. 26 and 28-inches draw length because of its shorter length. It is understood that restricting the tests to a maximum of 28-inches draw length does not permit standardized rating but does allow valid performance comparison to other bows at the shorter draw lengths.

The remainder of this report is divided into two major parts, each part dealing with one of the two bows individually.

1.0 64-INCH TOMAHAWK DESERT FOX –SERIAL NO.9532

While fitting in the generic longbow category the Desert Fox is more precisely described as a reflex-deflex flat bow although the limb cross-section, particularly in the outboard area, tends toward the thicker truncated form more typical of that of the English longbow. The cross-section is composed of five laminations plus the facing and backing clear glass composite. The laminations are disposed symmetrically about the center of the limb, with a tapered cross-laminated maple lamination on either side of a thin parallel carbon composite lamination. This assembly is covered by decorative strips of elective hardwood veneer under the clear facing and backing material. The limb tips are long and slender and are reinforced on the back with overlays of composite material (Micarta) consisting of three layers of contrasting color. Carving for the string groove is smooth and deep, extending through the outer tip reinforcement overlay. The satin finish on the test bow was flawless.

The grip section on this test bow is covered with a section of shrink tubing that apparently conceals a mechanical joint dividing the bow near the vertical center of the grip into two sections, thus making it a two-piece take-down. The Flemish-splice string was made of 18 strands of Brownell's Fast Flight Plus material.

1.1 TEST AT 30-INCHES DRAW LENGTH

Force-draw characteristics are determined with the use of a force-draw machine equipped with a Mark 10 digital force gauge capable of reading to the nearest 0.1 pound. Force readings are taken at one-inch increments from brace height to just beyond the test draw length in order to define the force-draw curve. In this instance force measurements were made to 31-inches draw length to cover a test at 30-inches draw length. The area under the force draw curve is integrated by elemental summation and then converted to foot-pounds to obtain the energy that is stored when the bow is drawn from brace height to full draw. Other pertinent measurements are also taken with the bow at brace height and at full draw. The results of the force-draw measurements are tabulated under the heading "Stored Energy Data" on the first and second pages of the computer print-out for the 30-inches draw length test. A plot of the force-draw and let-down curves is included on Page 5 of the print-out section.

A review of the force-draw curve indicates that this 64-inch Desert Fox has a "sweet spot" that begins at about 26-inches draw length and extends at least to 30-inches draw length. In this area the increase in draw weight per one-inch increase in draw length is approximately 3-pounds, and the rate of change of that incremental increase has a total spread of only 0.5-pounds. Incipient stack is only beginning at 30-inches draw length.

Energy storage for a bow of this type is good, with a ratio of stored energy to peak draw force (S.E./P.D.F.) of 0.965 foot pounds per pound and an energy storage efficiency of 55.47 percent based on the power stroke.

This bow was tested at draw lengths of 30, 28 and 26-inches in that order. Normally when following that test format, I perform one force-draw test and use that test to provide stored energy data for all three dynamic tests. I followed that procedure for the dynamic tests at 30 and 28-inches but noted that I found unusually large string stretch resulting in a total loss of brace height of 5/16-inch after the third test. To correct for this problem I performed a second force-draw test after completing the dynamic test at 26-inches draw length. The difference in stored energy between the two tests equaled 1.10 foot-pounds. The peak draw force and stored energy values for the 28-inch draw length were then adjusted by interpolation. It is my opinion that the "string stretch" is attributable primarily to slippage in the Flemish splice. I did not experience this problem during the test of the Thunder Storm.

Static hysteresis is determined by subtracting the energy subtended by the let-down curve from the energy subtended by the force-draw curve. It is not a particularly significant factor when dealing with longbows or recurves because it is measured under static conditions rather than under dynamic conditions. For the Desert Fox it measured 2.03 foot-pounds or 3.21 percent of stored energy at 30-inches draw length.

Dynamic tests were conducted using a shooting machine and a single-gate chronograph arrangement. The shooting machine is equipped with a double-jawed release that holds a short straight section of the bowstring. This permits precise measurement of draw length. The chronograph, a Custom BowMeter, is located 3 feet down range of the back of the bow. Seven test arrows, ranging in weight from 360 to 654 grains, were each shot a minimum of five times to establish credible average velocity values at the respective arrow weights. The arrow weight and velocity values were used to calculate the kinetic energy of each arrow. With the kinetic energy known, the dynamic or bow efficiency may be computed. Subsequently the experimental values of virtual mass are determined and a curve of theoretical virtual mass is established by linear regression. From this curve it is possible to calculate velocity and dynamic efficiency for any desired arrow weight. A plot of initial arrow velocity versus arrow weight is presented on page 7 of the computer printout.

It is important to note that curve plots included in this report include values of arrow weight as low as 200-grains. The values corresponding to grain weights below 360-grains are a result of automatic extrapolation and are not within the range of actual test arrow weight. They are included in the software program to cover light weight bows that do use arrows in that weight range. They are not applicable to bows of heavier draw weight. **<u>It is recommended that such light weight arrows not be used when shooting this bow.</u>**

Dynamic efficiency is determined by expressing the kinetic energy of the arrow (as it passes through the chronograph) as a percentage of the stored energy of the bow when drawn to the test draw length. Values of initial arrow velocity and dynamic efficiency, as determined from the performance profile of the bow, are found on pages 3 and 4 of the computer printout. A curve of dynamic efficiency plotted versus arrow weight is presented on page 8 of the computer printout. Comparison with similar values for the tests at 28 and 26-inches draw length will show that the dynamic efficiency increased as the draw length was reduced. This can be attributed to the fact that limb travel during recovery was shortened, thus requiring less energy to return the limbs to brace height position.

Kinetic energy of the arrow is a function of the mass of the arrow and the square of its velocity. The penetration potential of the arrow is related to the kinetic energy that it carries. Kinetic energy increases with arrow weight even though the arrow velocity is reduced. This is true within the range of arrow weight that we normally shoot from a given bow. A plot of the kinetic energy versus arrow weight is presented on page 9 of the computer printout.

The Rating Velocity is a parameter developed by ATA to permit comparison of the performance of bows using a standardized procedure. In accordance with ASTM Standard 1544-04, it is expressed as the initial velocities of two arrows, one weighing 360 grains and the second weighing 540 grains, shot from a bow set at 60 pounds peak or maximum draw weight, and 30 inches ATA draw length. ASTM Standard 1544-04 provides a method of correcting the results when the bow being tested differs in draw weight from the 60-pound standard. This procedure produces reasonable accurate values to allow comparison with other bows. Since the test Desert Fox reached 65.3-pounds peak draw force at 30-inches draw length it was necessary to resort to this approach to obtain values for Rating Velocity. The ASTM standard establishes specific methods, tolerances and controls governing the tests. The standard calls for the Rating Velocities to be the average of five shots with the test arrows. The method of determining the Rating Velocity that I have used for these reports consists of determining the initial velocities from the performance profile of the bow. The performance profile is the plot of initial arrow velocity versus arrow weight. It is established from tests of seven arrows and a total of 35 or more shots. This method actually includes the tests prescribed by ASTM Standard 1544-04 so the results of both methods are available. It is my practice to provide values determined by both methods. They seldom differ by as much as one foot per second however, in this instance, the difference is 1.7 feet per second for the 540-grain arrow. I attribute this to the fact that bows cut short of center, such as this longbow, are more sensitive to arrow spine than those that are cut beyond center as are most contemporary compounds. The 540-grain arrow, a 2117 Easton aluminum alloy shaft, was of ideal spine for use with the test bow. The curve of empirical virtual mass versus arrow weight shows that the virtual mass was lower and the arrow more efficient than any of the other test arrows. It was significantly more efficient than the next heavier arrow which was a combination glass and carbon composite shaft. This arrow lost some of its energy during launch resulting in a reduced chronograph velocity. An arrow of this type would be a poor choice for use with this longbow.

ARROW WEIGHT	**RATING VELOCITY**	
	BOW REPORT METHOD	**ASTM 1544-04**
360 grains	222.8 fps	222.4 fps
540 grains	192.9 fps	194.6 fps

1.2 TEST AT 28-INCHES DRAW LENGTH

The Desert Fox longbow was tested at 28-inches (ATA) draw length following the same format as that used for the test at 30-inches. The peak draw force (corrected for string stretch as described earlier) at this draw length was 58.2 pounds. The brace height was 7 1/4-inches. The 1/8-inch reduction in brace height reduced the peak draw force by 0.8-pounds. Stored energy was 51.984 foot-pounds, for a ratio of stored energy to peak draw force of 0.893 foot-pounds per pound.

The computer printout for the test at 28-inches draw length presents the same data on page 3 as that for the 30-inches draw length with respect to stored energy, recovered energy, static hysteresis, and empirical values of initial arrow velocity, initial kinetic energy, dynamic efficiency and virtual mass. Pages 3 and 4 list values of these characteristics calculated from the theoretical curve of virtual mass derived by linear regression. Here the values are provided for 25-grain increments of arrow weight. A plot of empirical virtual mass is presented on page 5. Observe that the effect of varying arrow spine has less effect on dynamic efficiency with the reduction in draw length and corresponding lower peak draw force. Plots of initial arrow velocity, dynamic efficiency and initial kinetic energy are presented on pages 6, 7 and 8 respectively.

Reducing the draw length by 2-inches resulted in a reduction of static hysteresis from 3.21 percent of stored energy at 30-inches draw length to 2.43 percent at 28-inches. Obviously, less overall energy is stored with the shorter draw length and energy storing efficiency suffers. On the other hand, dynamic efficiency with lighter weight arrows is slightly improved with the shorter draw length and changes very little at the heavier weights.

It is not practical to attempt to correct values of Rating Velocity for differences in draw length. Entirely too many variables enter the picture. For that reason tests at draw lengths other than 30-inches (ATA) draw length do not list Rating Velocity values.

1.3 TEST AT 26-INCHES DRAW LENGTH

The third and final test of the Tomahawk Desert Fox was run with the draw length set at 26-inches (ATA) draw length. Again, the same format was followed as for the preceding two tests of this longbow. When the brace height was measured after the test at 28-inches draw length, it was found that the brace height had decreased to 7 1/16-inches. At this point a second force-draw test was performed to eliminate any error introduced by this change in the setup. As detailed previously, the force-draw characteristics for the 28-inches draw length were adjusted to compensate for the string stretch.

At 26-inches draw length and with the brace height at 7 1/16-inches, the peak draw force was 51.7-pounds. The stored energy totaled 42.21-foot-pounds for a ratio of stored energy to peak draw force of 0.817 foot-pounds per pound. Energy storing efficiency based on the power stroke was 57.01 percent. Static hysteresis measured 1.26 percent of stored energy. Considering the seven test arrows, average empirical virtual mass was 147.2-grains, compared to 157.9-grains at 28-inches draw length, and 161.6-grains at 30-inches draw length. Correspondingly, the shortest draw length yielded the highest levels of dynamic efficiency. This is to be expected since less energy is lost to limb recovery due to the shorter distance that the limbs travel during recovery. This allows proportionately more of the stored energy that is available to be transferred to the arrow and that is reflected in increased dynamic efficiency.

Values of initial arrow velocity, initial kinetic energy and dynamic efficiency for 25-grain increments of arrow weight are tabulated on pages 3 and 4 of the computer printout for the test at 26-inches draw length. Page 5 presents the force-draw and let-down curves, and page 6 shows a plot of empirical virtual mass. It can be observed that virtual mass for the Desert Fox, when refined by linear regression, maintains an almost constant value regardless of arrow weight. This is true at all draw lengths tested. This is a characteristic that I have found for most long bows. This does not happen for compounds or recurves.

Pages 7, 8 and 9 present plots of initial arrow velocity, dynamic efficiency and initial kinetic energy respectively for the Desert Fox set at 26-inches draw length.

2.0 TEST OF THE 58-INCH TOMAHAWK THUNDER STORM

The Tomahawk Thunder Storm is in many ways a short one-piece version of the Desert Fox. With a length of 58-inches it is 6-inches shorter than the Desert Fox. The reduced length is accomplished partly in the riser and partly in the limbs. By precise definition it is a reflex-deflex flat bow with a truncated limb cross-section that is wider on the back than on the face or belly. It has 5 core laminations plus glass-fiber reinforced epoxy backing and facing. The outside core laminations are decorative veneers visible through the clear facing and backing. A pair of tapered cross-laminated maple laminations sandwich a thin, parallel, center lamination of carbon composite material. This lamination spans the full length of the bow, passing over the back of the riser insert. The Thunder Storm was fitted with a Flemish-splice string made of 18 strands of Brownell's Fast Flight Plus material.

Considering the short length of the bow, the test program was established to limit testing to a maximum draw length of 28-inches, with additional tests at 26 and 24-inches draw. This does not permit determination of standard Rating Velocities since that requires a 30-inch draw length. It is not practical to adjust for variation in draw length when performing a standard rating test.

2.1 TEST AT 28-INCHES DRAW LENGTH

The static and dynamic tests were conducted in the same manner and with the same equipment as was employed during the tests of the Desert Fox. The results of the static tests are presented on pages 1 and 2 of the respective computer printout. Stored energy at 28-inches draw length amounted to 49.71 foot-pounds for a ratio of stored energy to peak draw force (S.E./P. D. F.) of 0.840 foot-pounds per pound. Energy storing efficiency was 52.69 percent based on the power stroke. Static hysteresis measured 0.94 foot-pounds or 1.90 percent of stored energy.

The same seven test arrows used for the Desert Fox tests were employed for the dynamic tests of the Thunder Storm. The average virtual mass obtained for the seven test arrows was 129.47-grains reflecting a higher level of dynamic efficiency as compared to the longer bow shot at the same 28-inhes draw length. Values of initial arrow velocity, dynamic efficiency and initial kinetic energy for 25-grain increments of arrow weight are tabulated on pages 3 and 4 of the computer printout.

Force-draw and letdown curves are presented on page 5 of the printout. Examination of the force-draw data and curve show that the Thunder Storm has a sweet spot in the draw beginning near 23-inches of draw length, and extending to about 28-inches draw. In this area the increase in draw force per inch of draw is between 2.8 and 3.6-pounds. The spring rate increases at about 0.2-pounds per inch. This level of stacking is hardly perceptible. Beyond 28-inches the degree of stack becomes more pronounced.

Plots of empirical virtual mass, initial arrow velocity, dynamic efficiency and initial kinetic energy versus arrow velocity are presented on pages 6, 7, 8 and 9 of the computer printout.

2.2 TEST AT 26-INCHES DRAW LENGTH

Brace height was measured after the test at 28-inches draw length and was found to have been reduced only 1/16-inch. Consequently I decided that an additional force-draw test prior to the 26-inches test was not necessary. The force-draw data from the previous test could be used with a high level of confidence.

Again, the static and dynamic tests at this draw length were conducted in the same manner and with the same equipment and instrumentation as the preceding tests. The data from the static tests is found on pages 1 and 2 of the computer printout for this draw length. At 26-inches draw the Thunder storm stored 40.44 foot-pounds of energy for an S.E./P.D.F ratio of 0.775 foot pounds per pound. The energy storing efficiency was 54.28 percent based on the power stroke, Static hysteresis measured 0.86-pounds or 2.13 percent of stored energy. The force-draw and letdown curves for 26-inches draw length are presented on page 5 of the printout.

The same seven test arrows were again used at this draw length. The average of the seven test arrows was 130.41-grains showing very little effect for the 2-inch reduction in draw length. Pages 3 and 4 present tabulations of the results of the dynamic tests. Values of initial arrow velocity, dynamic efficiency and initial kinetic energy are listed for 25-grain increments of arrow weight.

A plot of empirical virtual mass for the seven test arrows is shown on page 6 of the printout. Note that the 599-grain XT 19-12 arrow with the fiberglass shaft shows the same poor matching on this bow as it did when used on the Desert Fox bow. Pages 7, 8 and 9 present plots of initial arrow velocity, dynamic efficiency and initial kinetic energy versus arrow weight. These pages are a graphical picture of the data cited earlier.

2.3 TEST AT 24-INCHES DRAW LENGTH.

This draw length is well within the “sweet spot” for the Tomahawk Thunder Storm. The brace height was measured after the test at 26-inches draw and was found to be unchanged. The force draw data already available was deemed satisfactory for this test.

No change was made in the test procedure or equipment from that used for the preceding tests. The data from the static tests at 24-inches draw length are found on pages 1 and 2 of the appropriate computer printout. At 24-inches draw length the Thunder Storm stored 32.26 foot-pounds of energy for an S.E./P.D.F. ratio of 0.701 foot-pounds per pound of peak draw force. This resulted in an energy storing efficiency of 55.65 percent based on the power stroke. Static hysteresis was measured at 0.76 foot-pounds or 2.35 percent of stored energy. The force-draw and letdown curves for 24-inches draw length are presented on page 5 of the printout.

Pages 3 and 4 of the computer printout present tabulations of the results of the dynamic tests. Values of initial arrow velocity, dynamic efficiency and initial kinetic energy are listed for

25-grain increments of arrow weight. The same seven test arrows were again used at this draw length. The average of the seven test arrows was 115.4-grains. This means that this draw length offers the highest dynamic efficiency for this bow with any arrow weight within the range tested. The values of dynamic efficiency tabulated on pages 3 and 4 demonstrate this conclusively, running as high as 84.88 percent for a 650 grain arrow, and extrapolated to 85.79 percent with a 700-grain arrow. With a 400-grain arrow, a weight more likely to be shot at the draw weight obtained at 24-inches draw, the dynamic efficiency would be about 77.7 percent.

Page 6 of the printout is a plot of the empirical virtual mass for the seven test arrows. The poor matching condition of the XT 19-12 arrow is demonstrated one again. Pages 7, 8 and 9 present curves of initial arrow velocity, dynamic efficiency and initial kinetic energy plotted versus arrow weight for the 24-inches draw length condition.

3.0 COMMENTARY

The draw weight of these two bows (essentially 60-pounds at 28-inches) did not permit me to conduct extensive hand shooting tests because 60-pounds is more than I can comfortably draw. I did, however, shoot both bows at reduced draw length to gain some feel for their handling characteristics. The force-draw curve is a far better measure of the draw cycle than any subjective evaluation made by hand. Holding the draw length within the limits of the “sweet spot” on the force-draw curve assures a pleasant feel during the draw. I did not draw either bow beyond 26-inches so my subjective analysis could add nothing to the picture conveyed by the force-draw curves. They are smooth drawing longbows. Hand shock was minimal with the 28-inch 2018 shafts I used.

Sincerely,

Norbert F. Mullaney P.E.