By Larry Wise

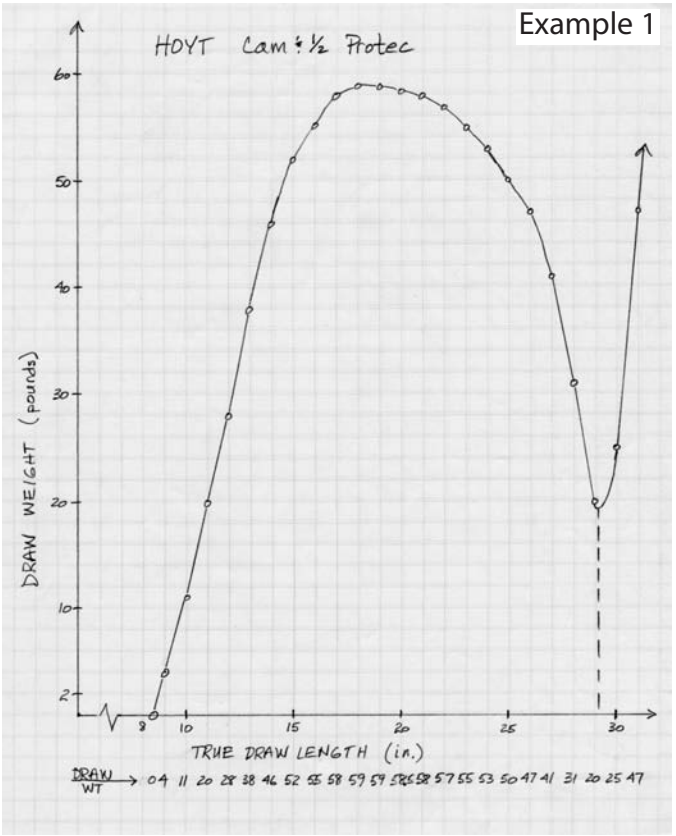
Understanding Force Draw Curves

You see one in almost every archery magazine you pick up. Most have some accompanying charts to help you interpret what you're seeing and to some people they all look alike. With that in mind I'm taking time to educate you on the Force-Draw Curve of a compound bow.

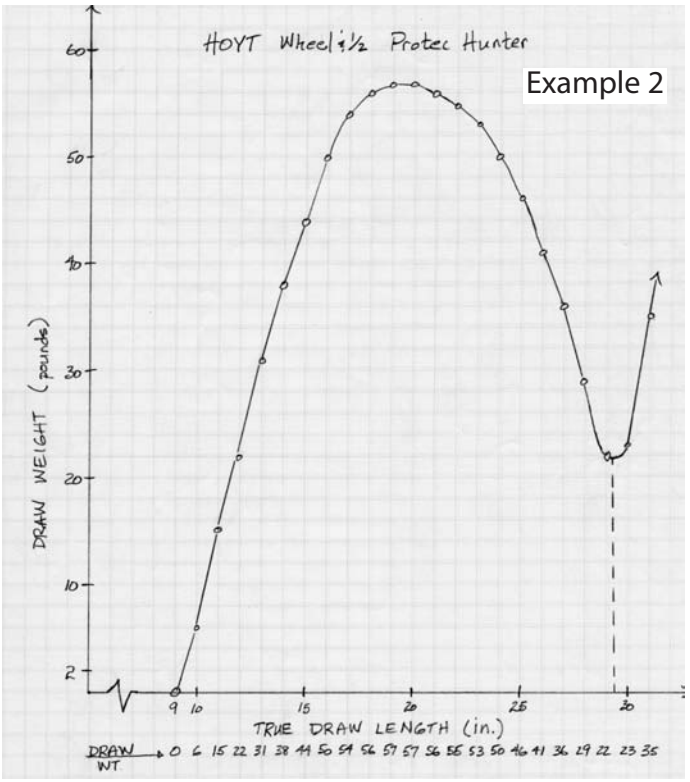
Understanding the features – the ups and downs – of a force-draw curve will help you help your customers. Since you usually know your customers' skill level and purpose for buying a particular bow you need to be well informed about all of your bows' force-draw characteristics in order to point them in the right direction regarding the "feel", speed, shooting and tuning. You need to do your part to get the appropriate bow in their hands so they can better enjoy archery. After that, it's up to them and if they choose otherwise you can rest assured that you've done your part.

DEFINITION: An ARCHERY BOW FORCE-DRAW CURVE is the two-dimensional graph plotting of the bow's draw weight in pounds (#) versus its draw length in inches (“), measured at each inch, for the entire draw stroke of the bow. The pounds of force are plotted on the vertical axis of the graph while the inches of draw length are plotted on the horizontal axis.

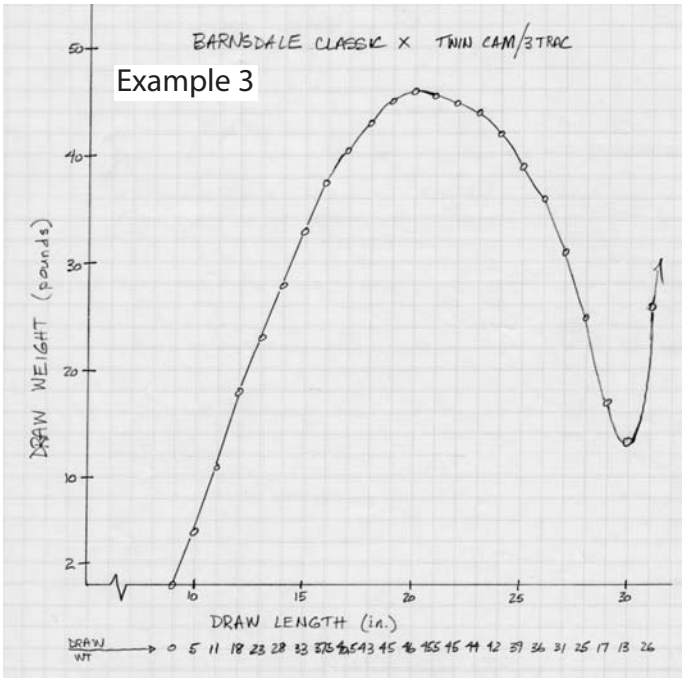
The result, when the data points are connected, is a curve reflecting how the draw weight of the bow increases at the beginning of the draw stroke, reaches a peak weight, dwells there for some distance, and then "lets off" to a lesser holding weight at full draw. Example 1 shows both the data collected and the plotting of the data points for a Hoyt Cam &1/2 Protec bow. Example 2 is my easier-drawing



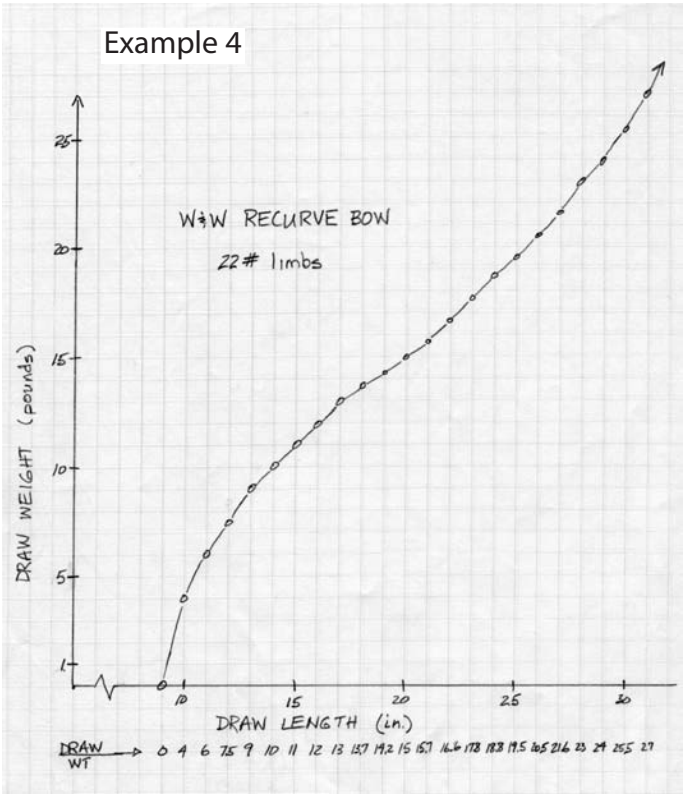
This force-draw curve was made for my Hoyt Cam &1/2 Protec. As you can easily see, the draw weight increases rapidly at the beginning of the draw stroke and stays near peak weight for five or more inches before letting off to the holding weight at 29.25 inches of true draw length (31" AMO draw length). Beyond this point, the weight increases dramatically as the cables hit the cam draw-stops. Notice that the draw weight is scaled vertically in two-pound increments.



I hunt with this Hoyt Wheel & ½ Protec because it's easy to draw when I'm cold but yet provides plenty of energy for the arrow. Notice the rounded-top to the curve indicating that this bow stores a little less energy that a cam bow but is easier to draw over peak weight for us old guys with worn-out shoulders. It also has a softer feeling, rounded valley which I like but most don't.



A Barnsdale twin-cam bow increases to peak weight over a longer distance and drops smoothly into the "valley" or holding weight. Notice the recorded draw weight data along the bottom line of the graph page.



This Win & Win recurve does not have a straight-line draw curve like the long bow would. As the recurve limbs unbend they allow for a less steep weight increase mid-way through the draw stroke. As you draw the recurve further the increase gets steeper which is called "stacking". Note that I used a one pound vertical scale for this light-weight recurve.

Wheel 1/2 model, a Hoyt Protec Hunter. Example 3 above is a Barnsdale Twin-Cam Classic with a shoot-through cable system.

Example 4 above is a Win&Win recurve bow. The recurve bow draw stroke increases continually as far as you can draw it but not in a perfectly straight line as you can see in the example. The "recurve" feature of the limbs provides a less-steep, softer feeling curve near the end of the intended draw stroke that differs slightly from the straight-line longbow graph.

BUILDING THE FORCE-DRAW CURVE:

You can build the force-draw curve for any bow in your shop with a few simple tools or you can buy a commercially available unit. For the do-it-yourself approach, you'll need a bow scale (you probably already have one), a long board (6 foot 2x4), a winch of some sort, 5 feet of rope, a measuring tape, a pencil and a piece of graph paper.

Attach the scale to the top of the 6 foot 2x4 with a hook so it can hang down. Then attach the winch to the bottom of the 2x4 as shown in the illustration on page 83. One end of the rope attaches to the winch reel and the other to the bow handle at the grip. The measuring tape zero-end hooks to the scale so it matches the bowstring nocking point. The other end of the tape (an old carpenter I worked with one summer called this the "smart" end and always gave me the other end to hold) should hang down across the arrow rest.

PROCEDURE:

SET UP: Once the bow is in place on the scale/winch rig I adjust the crank so the bow is near the brace position. In other words, the tape measure is reading the 7 to 9 inches that correspond to the advertised brace height of the bow – or close to it. I use the grip pressure point as reference but you may like using the arrow rest mounting hole instead as these two features are usually close to the same measurement from the nocking point on the string.

PREPARE YOUR GRAPH PAPER: Here's where you have to recall some old skills you may have learned in math class way back in junior high school. Sketch a vertical reference line (called the "Y" axis in math class) and also a horizontal line (called the "X" axis) on the ¼ inch grid graph paper. Label the vertical units in two-pound increments as I find this makes a friendly scale to use. Label the horizontal units in one-inch increments.

COLLECTING DATA: The mass of the bow will cause it to hang down a little putting a slight bend in the bowstring. Ignore that and record 0 pounds at the brace height measurement. I record these weight values on the graph paper directly under the corresponding draw length.

Turn the crank so the bow is drawn into its draw stroke to the next whole inch. In other words, if the brace height was 9 inches then turn the crank to 10 inches at the rest-mounting hole. Record this weight value under the corresponding draw length on the graph paper. Continue doing this for the entire draw stroke of the bow being careful to crank slowly at the end of the draw stroke as the weight goes down very quickly.

Also pay close attention at the very end of the draw

stroke as the cables come to rest against the draw-stop feature on the cams. Once the cables hit these stops the draw weight goes up again at a very high rate of increase so only record the weight for 1 inch of this increase. Terminate the measuring process at this point.

PLOTTING THE DATA: Beginning on the horizontal axis at the brace height measurement, 9-inches in my example, mark a small dot at the zero pounds level. Next mark a small dot above the 10-inch position at the draw weight recorded for that distance. By now you remember doing this in school and find it easy to finish the process for each data pair. Connect the dots into a smooth curve. My sample data is from my Hoyt Protec Wheel &1/2 hunting bow. The graph shows a smooth curve that doesn't stay at peak weight for very long – just what I like drawing on a cold day in my treestand.

DRAW CURVE FEATURES:

FRONT SLOPE: As you begin drawing the compound bow you immediately feel the increase in the force needed to do so. This force continues to increase from zero pounds at brace height up the "front slope" of the curve until you reach peak weight. This slope is much steeper than most of the recurve bows you've drawn and tells you immediately that you're storing more energy with the compound bow. The steeper the front slope the more energy you expend during the first few inches of draw and the more energy the bow can store.

If the front slope is close to vertical the bow becomes very uncomfortable to draw. You have to exert a high amount of energy to get the draw stroke started and the price you pay may not be worth the value returned in added stored energy. My old muscles need a softer start (particularly from the treestand) but many of the younger guys want all the stored energy they can get.

PEAK WEIGHT DWELL: Its obvious to most everyone what the peak weight of the bow is and how to read it from the graph: It's the high point. What you may not pay much attention to is how long the draw weight stays at or near this peak value. I call this the "dwell" and reading it from a graph tells me how smooth the draw stroke is going to be and how much work will need to be done by my drawing shoulder.

The round wheel bows of days past had draw strokes that increased to a peak weight and immediately began letting off to the valley or holding weight; their curve had a nicely rounded top. As faster and faster cams were designed, draw strokes rose quicker to peak and stayed there longer with a dwell of 6 to 8 inches. This meant that you had to draw the peak weight until just 2 to 3 inches from your full-draw-position. The result is a very fast arrow but harder work for your shoulder.

Some dwell at peak will provide plenty of speed but having the let-off begin 3 or 4 inches before full-draw-position makes it a lot friendlier to us old guys. A bow can have all the speed in the world but if I can't efficiently draw it back that speed is no good to me.

THE LETOFF SLOPE: The Genesis Bow that's so great for kids and beginners has no let-off. It stays at a very manageable peak weight for the last three-fourths of its draw stroke so that anyone can use it no matter what their draw length. It serves its intended purpose as a "starter" bow. All the other compound bows have a let-off from peak weight down to a lower holding weight into what is called "the valley".

Most archers want to know what percent the let-off - peak down to valley - is on a given bow before they buy it. Most are in the 65 percent to 75 percent range with a few higher. Back in "the day" when compounds were first made, 25 percent was common. My early 80's Jennings bows had around 40-45 percent let-off and when we got a bow with 50 percent or 60 percent let-off we thought we were in heaven. We sure have gotten spoiled. But those higher let-offs common today are more comfortable for

Shooting a short draw bow at only 40 pounds provides enough kinetic arrow energy to kill a whitetail buck at close range. My son, Todd, shot this eight pointer behind our home his first year of hunting. No, I didn't give him the black eye because he shot a bigger buck than I did that year – he got that playing at a friend's house.

old shoulders like mine!

Reading the steepness of this down-slope will tell you how fast the bow weight drops off of peak. The steeper the slope the faster the drop and the more you'll feel it when the draw weight hits bottom. The fast drop from peak takes some getting used to and may cause you to look away from the target while finishing the draw stroke. Not staying focused on the target is the part I don't like so I prefer a less steep slope on this part of the curve so I can keep my vision focused on the target through the entire draw stroke. Those that want all the speed they can get will opt for the steeper drop from peak.

THE VALLEY: At the end of the let off slope is the "valley" where you reach your full-draw-position. This position is critical to an archer's success because here's where you need the most bio-mechanically efficient posture for you skeleton. This position was presented in my 2006 January Arrow Trade article for establishing correct draw length for your customers. As a reminder, full-draw-position is established when your bow arm is extended with the bones inline and your drawing forearm is inline directly behind the arrow shaft.

The valley or holding weight needs to be matched with your full draw position so the shot can be efficiently and smoothly executed. Most of today's bows have a narrow valley in their force-draw curves with a hard or sudden "stop" built into the cam system at the end of the valley.

I like and need a little cushion in the valley of my bows. That means I look for a valley section on the force-draw curve that is rounded and about one-half to one-inch wide. I know that the conventional wisdom has people looking for that hard wall to pull against but I like shooting lots of arrows into the middle and I can't do that with the hard wall style cams; it builds too much unnecessary tension in my old shoulder muscles. I've come to the conclusion that the hard wall game is for young men and the rest of us need a little softer feeling setup at full-draw-position.

The percent let-off is calculated using the peak weight and the lower holding weight. The formula looks like this:

% LET-OFF = ((PEAK WT – HOLDING WT)/(PEAK WT)) x 100

In words, subtract the holding weight from the larger peak weight to get the let-off amount then divide that let-off amount by the peak weight. This gives a ratio value less than one but greater than zero so multiply by one hundred to get the percent value we're used to seeing and using.

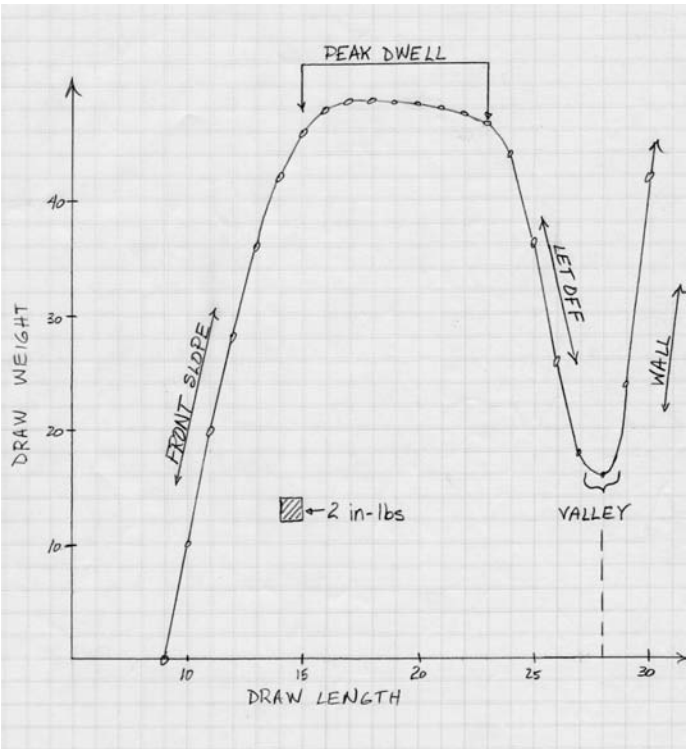
A sample would look like this for a peak weight of 60 pounds and a holding weight of 17 yielding a let-off of 43.

((60-17)/60) x 100 = ((43)/60) x 100 = .717 x 100 = 72% LET-OFF

The bow's power stroke ends at the valley and can be measured by subtracting the brace height from the valley distance. For me that is usually 29.5 inches – 8.5 inches = 21 inches for a bow with an 8.5 inch brace height. Twenty-one inches is a long power stroke and is a real advantage when it comes to storing energy. The longer the power stroke the more energy stored.

THE WALL: A hard "stop" or "wall" is evident in the force-draw curve by a sharp turn upward at the back of the valley. This can be slightly curved or nearly a vertical straight line – like a wall - depending on the design of the "stop" feature in the cable track of the cams. You'll realize this when you collect the data and find a 30 to 40 inch draw weight increase in the first inch beyond the lowest holding weight. The bigger the increase, the steeper the wall and the harder the stop feels.

This "stop" prevents the archer from overdrawing the bow but, if the valley isn't correctly matched to the archer's draw length, it also adds tension build-up into the aiming process. Aiming with too much tension build-up leads to premature muscle fatigue and inconsistent performance – loading and shooting with your arms instead of your body's skeleton and back



The features of a force-draw curve have some common labels that I've shown here. The "front slope" is steep and the "dwell" is long for many cam bows in order to store more energy. The let-off is also steep for many cams. Cams and wheels with "stops" built into the cable track will cause a steep increase in draw weight at the back end of the "valley". The area under the curve from brace height to valley represents the stored energy of the bow. Here each square represents 2 inch-pounds.

muscles inhibits your best aiming and wears down most people. Getting the valley to match an archer's draw length is the most important issue a dealer has to deal with. Get it right and the bow feels good and the archer shoots well – get it wrong and the opposite occurs.

I've noticed over the last two years that well over 50 percent of the archers that come to me for coaching have bows that are too short for them. That makes adjusting the bow's draw length our first task. When we get that right my students can begin using their body correctly and efficiently at full draw. That's when they can get better.

READING STORED ENERGY: Simply stated, the area under the force-draw curve represents the stored energy value of the bow. This energy must be labeled in inch-pounds since our vertical graph axis is labeled in inches and the horizontal axis is labeled in pounds. To be more specific, each of our graph squares represents 2 inch-pounds of stored energy since our scale is 2-pounds per vertical unit and 1 inch per horizontal unit.

If you count the squares, including an estimate for the partial squares, under the force-draw curve and multiply by two you'll determine the approximate stored energy of the bow. You'd have to count all the squares from the brace height measurement, usually 7 to 9 Inches, to the lowest holding weight, which is about 29.25 inches of true draw for me. My Mathew's Apex example shows a total count of about 365 squares or about 730 inch-pounds of stored energy. If you divide by 12 inches per one foot you get about 61 ft-lbs of stored energy.

If you don't like counting all those squares, there's an easier way – add the recorded weight values. To get an accurate stored energy value that compensates for all the partial squares start by adding only half of the first non-zero weight value recorded beyond brace height; that's 13/2 for my Apex example. Then add all of the weight values up to and including the lowest holding weight. This sum will be close to your counting result if you care to check. I get the following for my example:

STORED ENERGY SUM =
.5+20+26+32+37+41+43+45+44+44+44+44+45+45+44+
42.5+40 +36+ 30+22+14 = 745
TOTAL STORED ENERGY = 745 inch-pounds
745 in-lbs divided by 12 in/ft = 62.1 ft-lbs of stored energy.

Mathematically this is a very good estimator for the stored energy and an easy method for most readers to use. You don't need the graph to get this S.E. value, just add the recorded weight values.

ARROW KINETIC ENERGY: Now that you know the stored energy what do you do with it? Alone it can be an indicator for the probable penetrating power that you might get from the arrow. Understand that no machine is 100 percent efficient and so, in the case of compound archery bows, 25 percent to 30 percent of the energy available gets used to operate the machine leaving 70 percent to 75 percent available for transfer to the arrow. That means that the arrow in my example has about 45 ft-lbs of kinetic energy as it leaves the bow and that's plenty to penetrate through the rib cage of a whitetail deer.

Obviously, a bow with much more stored energy, say 80 ft-lbs, will transfer about 60 ft-lbs to the arrow. That's a 33 percent increase to the arrow's kinetic energy and will do more in the way of penetrating a game animal. As a 12-year-old, my son used a 40 pound, 23 inch draw Xi Prodigy bow to completely penetrate a large eight-point buck at a distance of 18 yards. His arrow, I'm sure, had only 35 ft-lbs of energy and that's enough at close range - - - the deer fell only 35 yards away.

If you want to measure the Kinetic Energy of an arrow you need two easy to collect pieces of data, the weight of the arrow in grains and the speed of the arrow in feet per second. The Phantom Carbon arrows I shoot out of my Hoyt Protec Wheel &1/2 hunting bow weigh 340 grains and have a speed of 265 ft/sec. Therefore, they have a kinetic energy of 53 ft-lbs.

Here's how to calculate K. E. with the grain weight and feet-per-second measures.

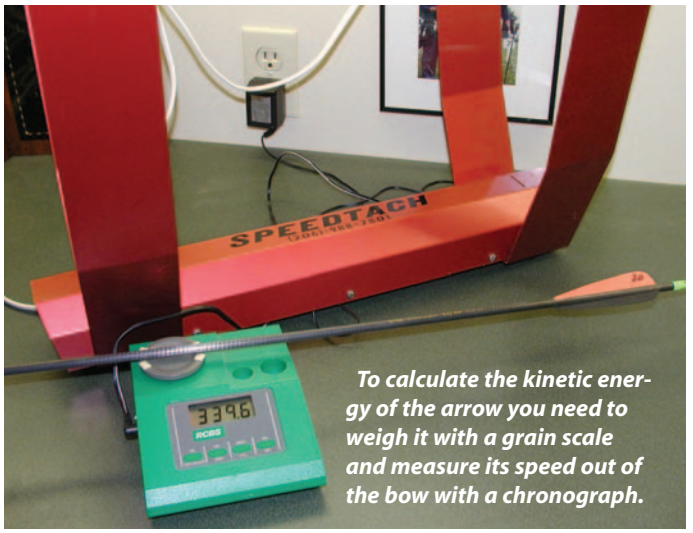
K. E. = (arrow wt) x (arrow speed) x (arrow speed)/ 450,240

In words, multiply the arrow weight by the speed, multiply the result by the speed again and then divide by the measuring-units-conversion-factor of 450,240. The result will be the arrow's kinetic energy in foot-pounds; in my case it's 53 ft-lbs.

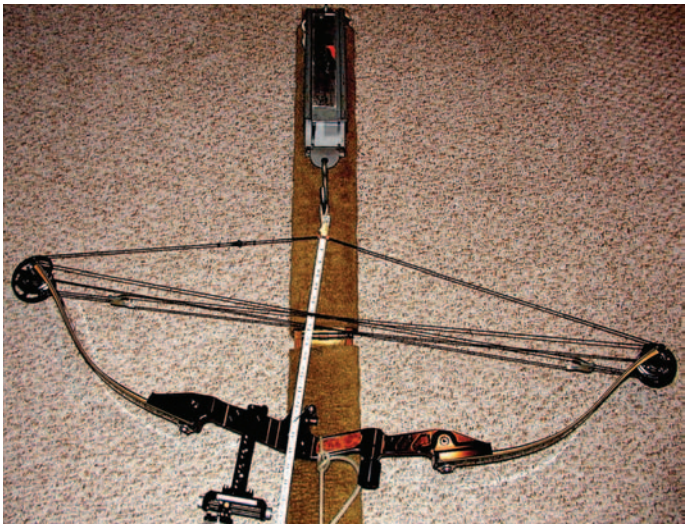
KE = 340 X 265 X 265 /450,240 = 23,876,500/450,240 = 53.03 ft-lbs

With this value your customers will know for sure what kind of energy they're able to deliver in a hunting situation. Most bow hunters have an inflated idea of just what their bow and arrow set is doing. They think their bow is set heavier than it is and/or that their arrow is flying much faster than it is. In either case they think that their arrow can penetrate the shoulder bone of a deer almost like a rifle can. And then they take shots way beyond their effective range.

If we arm them with the "real" truth about their setup



To calculate the kinetic energy of the arrow you need to weigh it with a grain scale and measure its speed out of the bow with a chronograph.



To collect the data for a force-draw curve you could built the device shown here. A spring-scale is attached to the top of a six-foot 2x4 and a winch at the other end. The bow is hooked to the scale by the bowstring and a rope is used to hook the riser to the winch. As the winch is turned a tape measure indicates how far the bow is being drawn. Recording the weights at each inch of draw length is all you need to build a graph.

Easton has a complete kit to make stored energy calculation easy. The Mapper Kit contains a hand held digital scale unit, a chronograph and a printer unit. Draw the bow with the digital scale and it records the draw weight data that you can download into the printer. This great kit provides the chronograph to measure arrow speed data but you'll have to have your own grain scale to weigh the arrow.

maybe they will choose to be more patient and selective in their shot taking. Consider that a 150-grain bullet traveling at 2000 ft/sec will have 1332 ft-lbs of kinetic energy. That's 25 times the energy of my hunting arrow. Bow hunters have to know this and use their weapon in a manner that takes advantage of the cutting edges on the broadhead – aim for the lungs and make a good shot at close range! Our weapon is lethal because of its cutting ability not its "shocking" power.

BOW EFFICIENCY: To measure the efficiency of a bow you need only do a simple division. Divide the Kinetic Energy of the arrow by the Stored Energy of the bow. My hunting bow stores about 68 ft-lbs of energy and has an efficiency of 53/68 = .77 = 77 percent. That means that my bow is transferring 77 percent of its stored energy to the arrow and that's really good for a machine.

THE EASTON FORCE-DRAW MAPPER KIT:

If you missed seeing it at the January 2005 ATA Show you missed the neatest product there. The Easton Bow Force Mapper utilizes a hand-held device to draw and record the force data from any bow. This data can then be downloaded into a smal printer included with the kit to obtain a paper record of the bow information and a graph of the force-draw curve.

The Bow Force Mapper comes with its own chronograph, hand-held digital bow scale, portable printer and directions. The software package enables you to print the force-draw curve along with the relative information like peak weight, holding weight, length of power stroke and the bow's stored energy. It also prints a list of various shaft sizes that will most likely work for the given force dynamics of the bow being tested.

All you need to do to operate the Mapper is to attach the hand-held bow scale to the bow string and draw the bow through a full power stroke and let down. The scale does the rest by recording the draw weights at various distances through the stroke. Next, use the included cords to download the information into the printer unit. It's simple and very effective.

CONCLUSION:

Collecting information about a bow takes a little time, I'll agree, but with good information you will be better able to point people in the right direction. Yeah, some people don't want to know any more and are content to head to the woods with unrealistic expectations. We must do our part to educate them anyway. I like to think that we educate them so they stay in this sport, do it right and enjoy it as much as we do. And they will use their weapon most effectively by making appropriate shot selection.

Keep well, shoot straight. *Larry*

Editor's Note: Larry Wise's first book, "Tuning Your Compound Bow," has been updated with a new chapter on hybrid cams plus other new information. His latest, "Core Archery" details correct form in a step-by-step format, defines back tension and how to execute it, and presents a plan for the high performance mental game. Get either though his web site www.larrywise.com, or by phone at (717) 436-9168. They are also available from Target Communications, 7626 W. Donges Bay Road, Mequon, WI 53079.

Larry Wise is available to conduct one-day and two-day shooting schools at your facility. This is a great way to jump start a league program, to grow participation among your customer base in competitive archery and to help position your pro shop as the place where people learn to shoot better. Contact Larry Wise at the address or phone number above for more details.