The Mechanics of Fly Casting 3

By Bob Bolton

In the first and second articles we learned something about rod and line dynamics and the laws of Physics and about fly lines. Now we can look at the single piece of equipment, other than the fly itself, that has the most mystery surrounding it. To say a fly rod is just a stick to throw line with is like saying a golf club is just a fancy croquette mallet, a stick with a weight on the end. “Oh my God! Blasphemy!” How many fly casters have told you they liked a certain kind or rod and when you asked them why they replied, “It just feels good. “ or “It is smooth and progressive.” How would you like it if your wife told you to go down to the store and buy her a pair of shoes. “What kind?” then “I don’t know, just ones that look good.” You would be in serious trouble. So what if you told a new fly caster to go down to the store and buy a rod that “feels good” or “loads smoothly and progressively.” Or you could go to an expert fly casting instructor, if you know one, and have him pick out one for you. So here is all I know about rods, and it isn’t much. You probably would be better off with the casting instructor.

But you know there is something to the “feel” of a rod. You know because in the dark of night you can still cast. You can feel the rod load on the back cast and you can feel the line accelerate. You can feel the rod load at the terminal extension. All of this in the dead of night. So you know there is something going on in the handle of that rod that tells you what the rest of the system is doing. But, at the end of the day, all you can really feel is the forces and torques on that rod handle. No rod shaft, no line, no fly – all of that exists only in your imagination. All you are really feeling is that rod handle.

And even in the daylight, when you can see the whole system, there are things you like to feel and things you don’t. Try taking a stiff graphite rod and loading it with a line that’s a couple of sizes too small. The rod will still cast the line but you won’t like it. There is something about how the line loads the rod and transmits this back to your hand that is uncomfortable. Try putting a very heavy line on a very light rod. You won’t like that either. And it does not take an expert to know the difference. If you compare any line properly weighted for the rod against on that is all out of whack, you will instantly know. But why?

Metrics

A little story, off the subject, might be a good way to introduce the term “Metrics’, or

more specifically, “Handle Metrics” into the field. This story relates to something most of us do, that is drive an automobile. When I was an engineer in the auto industry, we struggled for a number of years with a subject which was to later become called “Peddle Metrics.” This came about because as we made the transition from cars with big engines running on fuel at $.20 a gallon to smaller engines running leaner air fuel mixtures and steeper rear axle ratio ratios to keep engine speed low, people started complaining about how the cars “felt.” Complaints came about how the car was “stretchy.” You could push and push on the throttle and nothing would happen until the transmission downshifts and the vehicle would take off like a jack rabbit. When fuel injection came along and the throttle body was no longer required to meter fuel, the number of throttle bores went from four or two down to one and people started to complain about jack rabbit starts from a traffic light. “You just touch the gas and the car jumps ahead. You can’t even park it right,” they would say. Attempts were made to adjust this feeling with cams and cables in the throttle linkage but with limited success. Clearly, people wanted a specific response from the car for what they did at the gas peddle. With experimental electronic throttles available to adjust the actual throttle at the engine to a specific driver input at the peddle, we could run experiments with a select group of people (clinic – in car talk) and determine what they really wanted to feel the car do when they pushed on the gas peddle. So the term “Peddle Metrics” was born to describe in measurable parameters what people were feeling “in the seat of their pants.” As it turns out, people wanted to feel a particular acceleration when they pushed a little on the throttle, and a little more each time they pressed a little more. What they were feeling was actually the rate of change of acceleration rather than the acceleration itself, but suffice it to say they wanted to feel a change. And we could put actual, measurable numbers on what people wanted. Do the terms “smooth” and “progressive” seem to apply here? In truth, you like to feel that you are in control and that the input you are giving has an effect, and that effect is something you can control in a smooth, progressive, and predictable manner.

Handle Metrics

If the rod were just a stick and all you felt was the line at the end, the line weight compared to the rod stiffness would matter not. So it must be in the rod deflection that you feel the difference. But if the line and rod were loaded in the middle of a cast, all you would feel is the load of the line and the rod would be invisible because the load would not be changing. This leaves us with only one thing left to “feel.” It must be the load/motion curve we are feeling. That is, the faster we move the rod, the more we feel it in the handle as forces and

moments. This happens as a function of things like rod length, and beam stiffness, and line weight. Time to have fun with Engineering Mechanics.

A mathematical model of a fly rod is a very complex endeavor. There have been a number of attempts, and successful ones, to model the actual process but we can discover some characteristics of a rod with some basement experimentation.

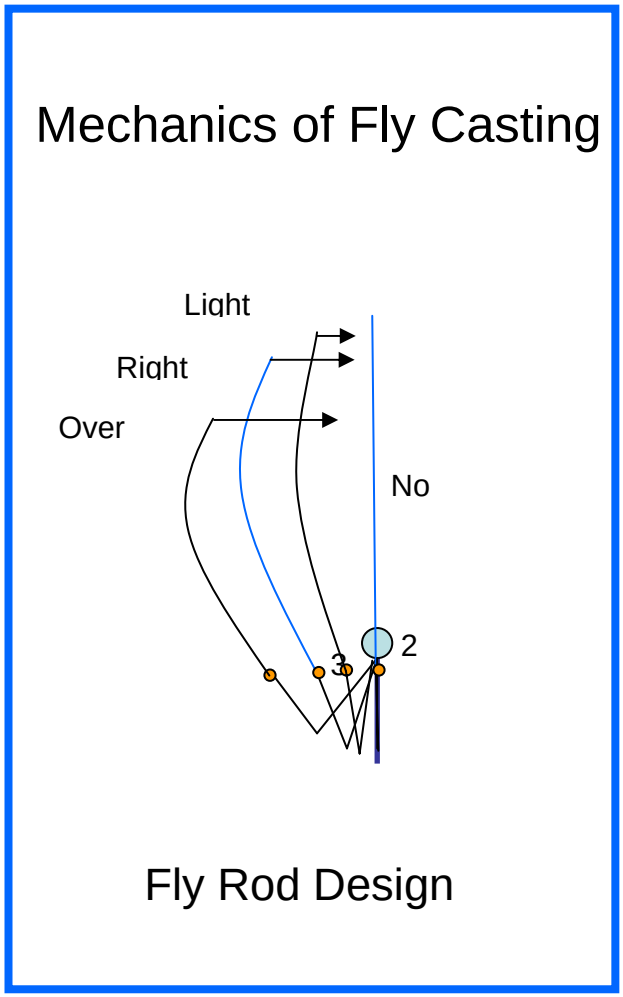

Figure I.

Let's go back and look a figure from the first article. We'll call it Figure I. here. It says there is a correct load for any given rod. This is only approximately true. There is actually a range of loads that is "comfortable" for a given rod. The fact that loads on either side of this range would be considered uncomfortable by most, is true. But the comfort range varies somewhat.

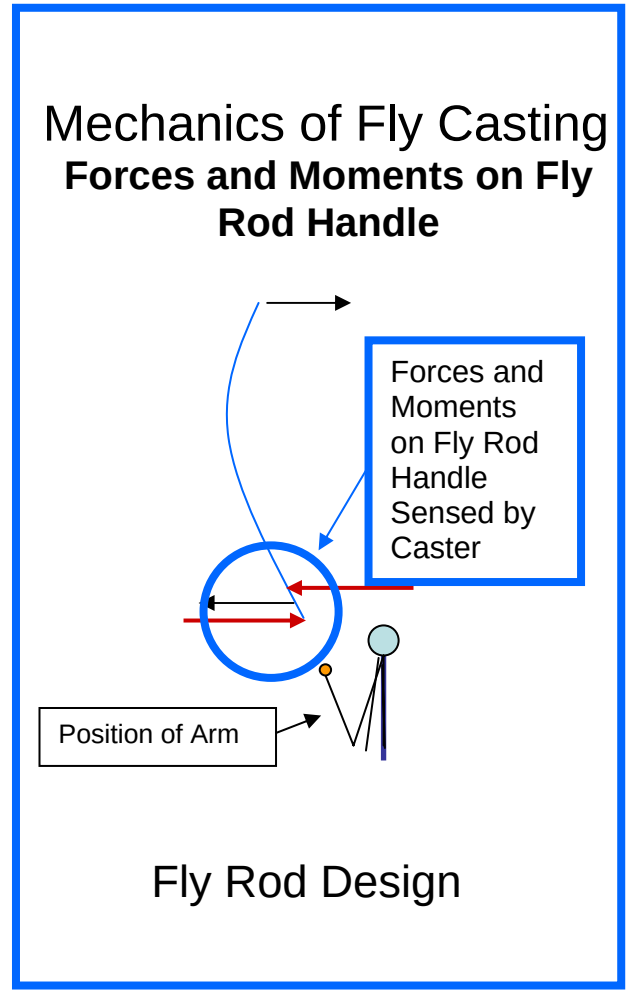

Figure II.

Figure II. shows a free body diagram of just the rod. The only thing the caster feels is the forces and moments on the handle. As a static free body, these forces and moments tell him nothing about what is happening to the line. It might as well be in China. But he also knows

instinctively where his arm is. If you close your eyes and move your arm, you will know where it is. And by adding dynamics, if the caster changes position of his arm, or more accurately, changes the rate of change of position of his arm, he can sense what is going on at the top of the rod where the line is attached. But he can only sense it if there is a rate of change associated with it. In other words, if he changes the rate with which he is accelerating the rod handle, he can sense what is happening with the forces and ergo, the acceleration at the top end. And if that rate is progressive with increasing change of rate, he will be able to control it and will call it "smooth and progressive." Wow! Take a hit of single malt and go back and read that again.

Now suppose we get a bunch of one ounce fishing weights, grab the single malt, go down in the basement, clamp the rod horizontal, and measure the rod tip deflection as we add weight. The process would look like Figure III. Performing this little experiment on a 6 weight medium flex graphite rod, the results look like Figure IV. Actually there are several rods on this plot but we will only talk about the mid flex 6 weight for now.

You can see that with this 6 weight rod, 3 ounces of weight puts about a 2 foot bend in the rod. I took this rod and video taped several casts with different lengths of line out and found out that I didn't like the feel of the rod with more than 2 feet of deflection on the cast. It felt "stretchy." I also didn't like the feel if there was only enough line for a shorter cast that was less than 1 foot of deflection. It felt "jerky and unresponsive." But when I had enough line out

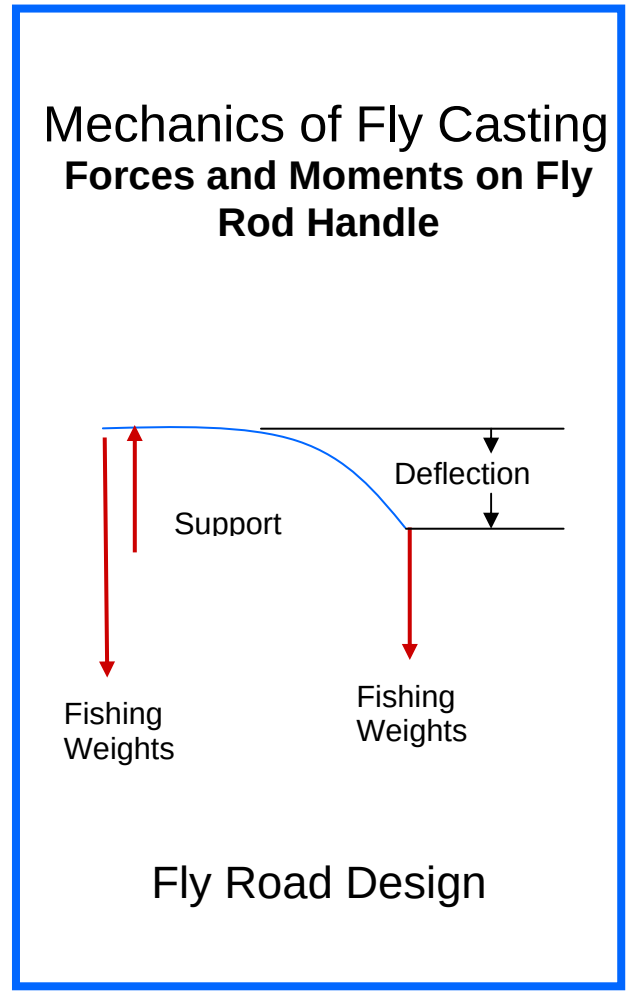

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Figure III.

that the bend was between one and two feet, the rod felt "smooth and progressive." I could feel the rod load and during the acceleration (constant force) part of the cast, I could increase and decrease the rate of acceleration and feel a predictable change in the feeling at the handle.

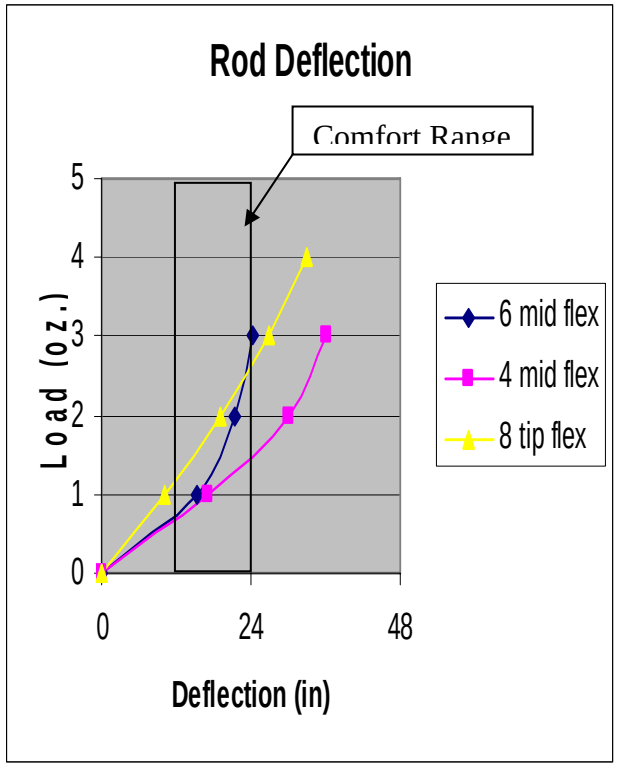

Figure IV.

So for me, this is the comfort range of this rod. It may not be the same for you, but there will be a range that if you load the rod higher or lower, it will not feel likeable. This is not to say that you can't make a cast outside of your "comfort range." It just means you will not like it as well.

Back to Figure IV., in the case of the 6 weight rod, this deflection translates to a load between .7 ounces and 3 ounces as shown by the intersection of the rod load curve with the sides of the yellow box. "So what!" is probably your response to this bit of information? "Well, I'll tell you what," my father-in-law talking again. But first we have to learn about work and kinetic energy. If you get bored here, just skip to the conclusions.

Work

Here we need to learn about another term in engineering mechanics called "work." This is not the same as the work you go to or the work that the farmer does in the field. This is work in an engineering sense and it is defined as:

Work = Force X Distance

In other words, if a 1 pound box were sitting on the floor and you pushed on it with enough force to overcome friction and move it 10 feet across the floor and that force was a half a pound, the work done would be .5 lb. X 10 feet or 5 foot-pounds. So looking at Figure IV. We only see part of the story. This plot shows the force applied by a particular rod in a particular comfort range but it is missing the other all important part. That is, over what distance is that force applied? Back in Part I we showed the following plot show below as Figure V.

Assuming an arc of about 70 degrees, the distance traveled by the tip of the fly rod is about 10.5 feet. 1.3 ounces over 10.5 feet is .85 Fy-Lb of work. The actual work done in this period, allowing for flexing and decelerating the rod, is about .72 Lb-Ft. The point of all this technical junk is to show that the rod is a device to do work in the engineering sense and that both the deflected load and the fly rod length are the relevant terms of the equation.

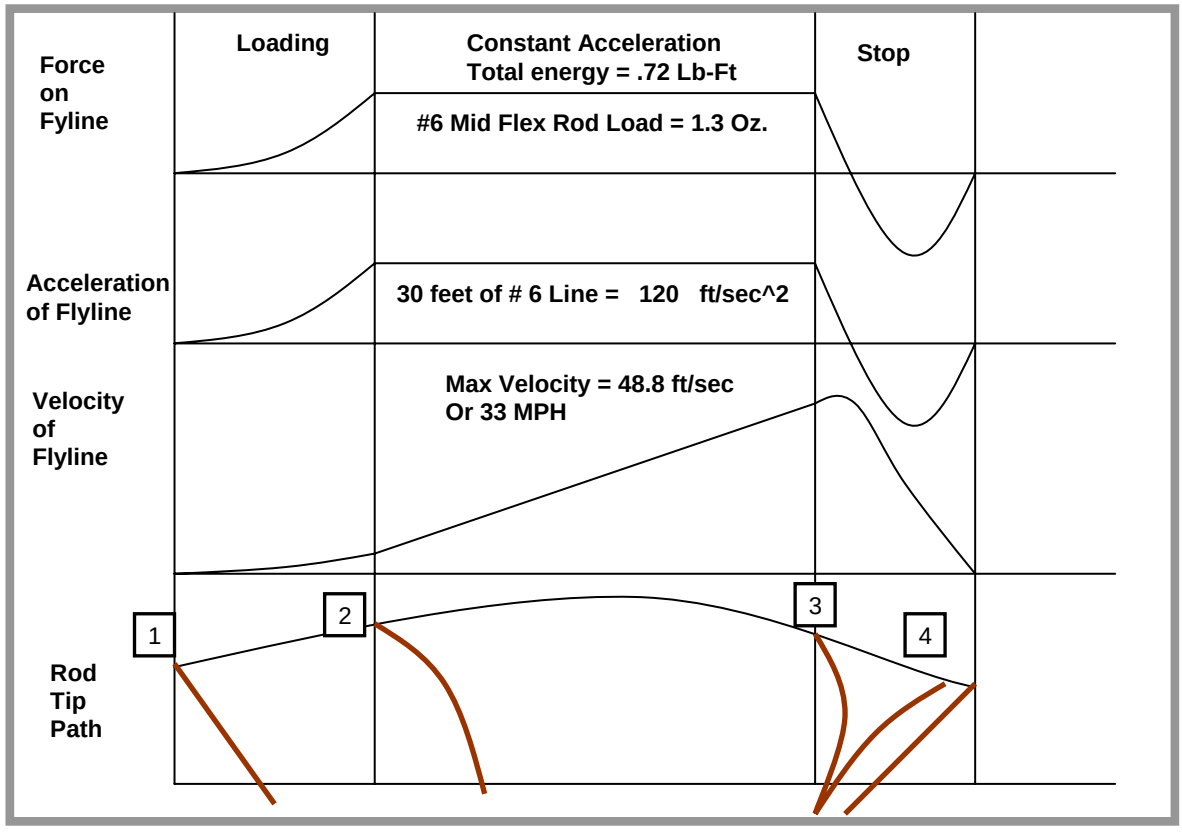

Figure V.

"I already knew that rod length and stiffness affected fly casting," you say. Of course you did. But I bet you never thought of a rod as something to do work on a fly line. Of course you didn't. Why would you ever think of it that way? A little more single malt and read on.

Kinetic Energy

Kinetic energy is the energy of motion. It is possessed by any body with mass and velocity. The greater the mass the higher the energy. The greater the velocity, the higher the kinetic energy. Hunters are familiar with this term. They are concerned about the amount of kinetic energy possessed by a bullet and how to convert this energy to force on an impact. Kinetic energy is defined as:

$$KE = \tfrac{1}{2} M X V^2$$

where M is the mass and V is the velocity. It has the units of Ft-Lb's. A fly line has kinetic energy at the beginning of the cast. The mass is the weight of the fly line required to reach a given distance in a cast and the velocity is that required to get it there before gravity pulls it down or air resistance slows it down. So why should we care. Turns out that the kinetic energy required to make a certain distance cast with a

certain weight fly line is exactly the same as the work done on the fly line by the rod. So we can compare them directly. Now we can compare the energy required by given distance cast with a given weight fly line to the comfort level of the fly rod selected to do the work.

If we know the approximate velocity the line will need to go a given distance and we know the mass of the line required to reach that distance we can calculate the kinetic energy required. This will be an approximation because the exact velocity will vary greatly depending on many factors such as fly weight and wind resistance, wind speed and direction, direction of the actual cast (from the horizontal), line type, any double hauling or shooting of the line, and many many others. Also, we lack the sophisticated tools that would be required to run and experiment. But we can get in the ball park just for the sake of explanation of the theories. And the ball park would look like Figure VI for a normal floating line with a normal size dry fly. As you would expect, heavier lines require more energy, longer casts require more energy, and double taper lines require more energy than wt taper lines past 30 feet where the back taper comes into play. Also note that the energy required to cast longer distances goes up exponentially as you might expect. Not shown here is the effect of wind resistance being a larger factor on the kenitic energy required on lighter lines because of the proportionally greater effect of the fly wind resistance and their lower sectional density.

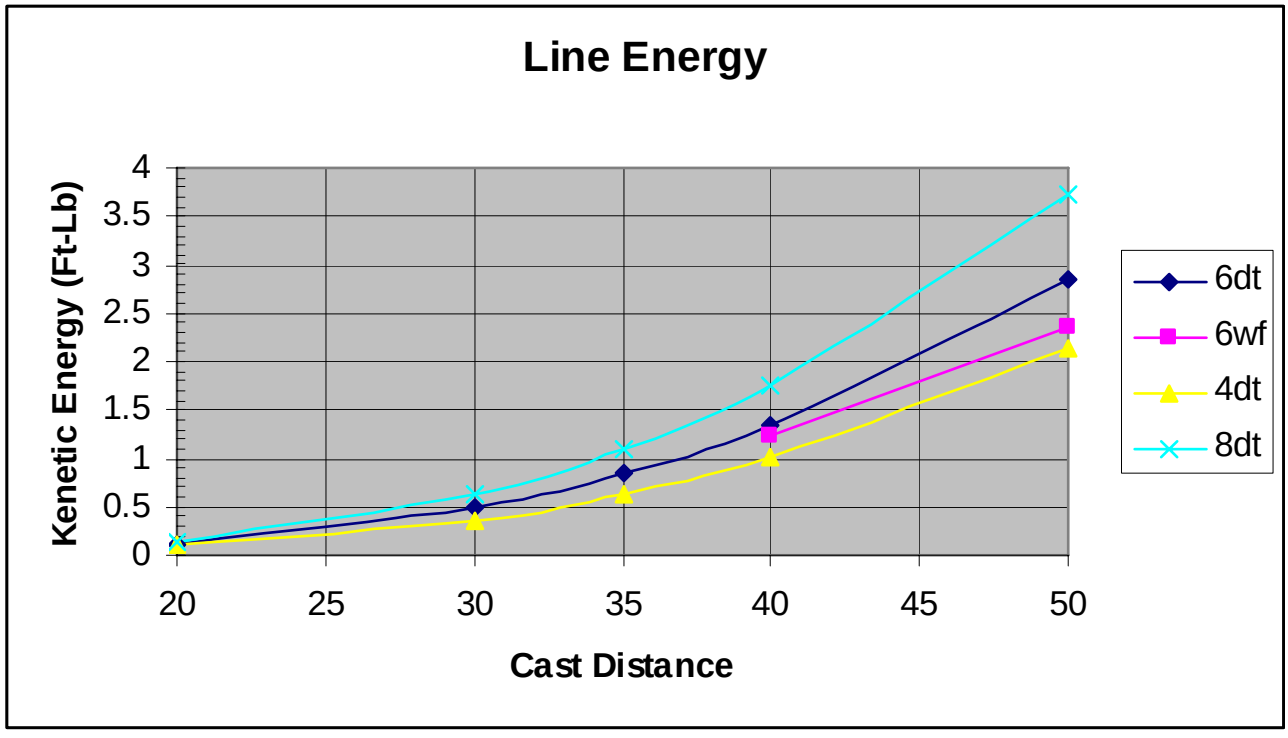

Figure VI.

But all that will come when (if) I get smarter. This will do for now to make our point.

And the point is this. If we superimpose the work that each rod in Figure IV., based on it's comfortable loading and casting stroke length, we get Figure VII. Gollee, what a super plot! You can see that a 4 weight rod will not throw an eight weight line very far. But you already knew that. You can see that an eight weight rod is for throwing big lines a long ways. But you already knew that.

If you learn anything from this plot that you didn't already know it is this. It is very obvious that you need to size your equipment for the type of casting you will be doing the most of. But you already knew that. But now you know something of the science behind it.

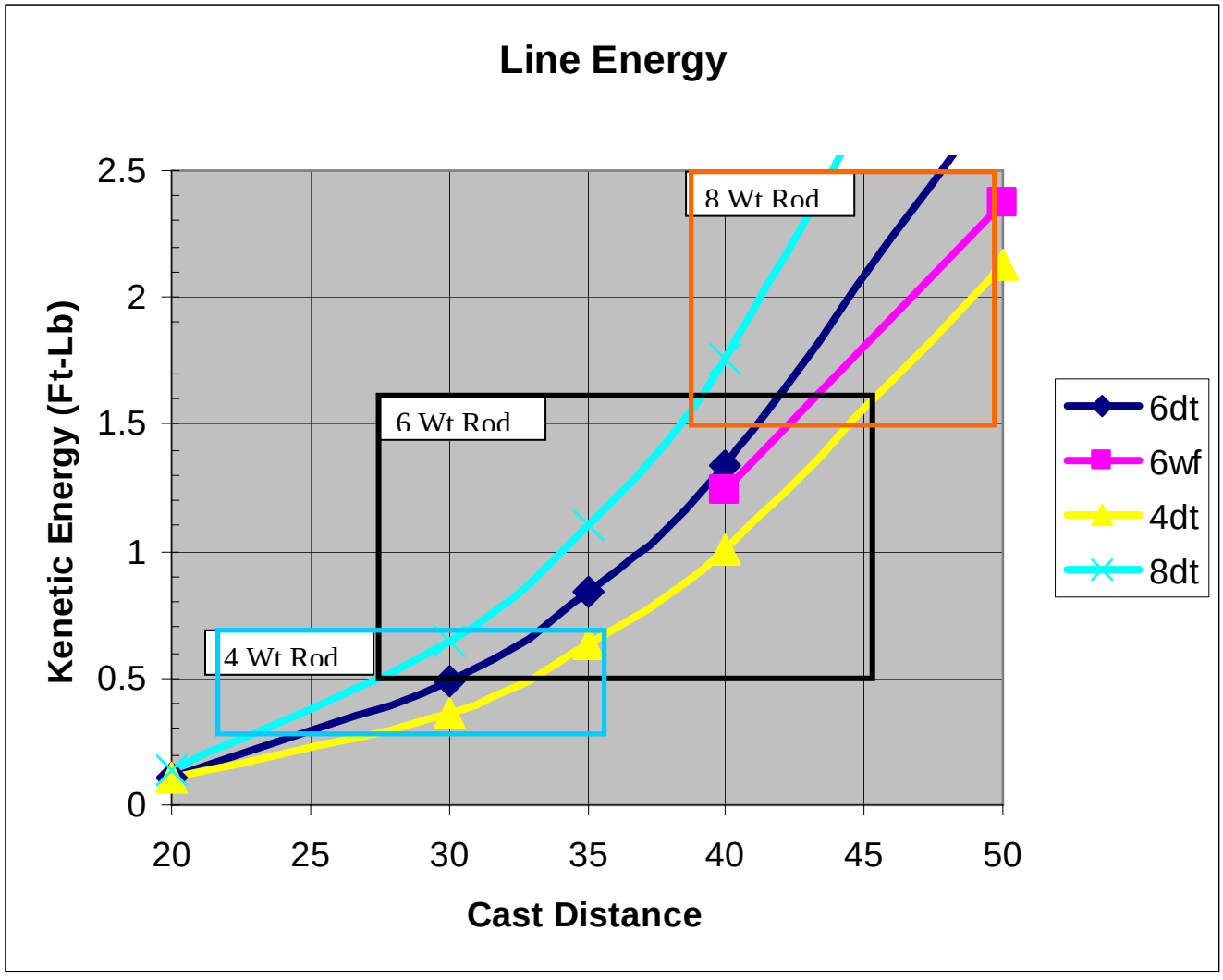

Figure VII.

Conclusions

The purpose of this dissertation is not to present an exact table for you to go select equipment from. It is not how to teach you how to cast. It is not how to become a better caster. It is not how to solve all your casting problems. It is merely to help you understand some of the science behind the sport and maybe to increase you enjoyment knowing what is really happening.

You still need to decide what type of casting you will be doing the most of and select your equipment accordingly. No one rod or line will suffice for all situations. You may be able to make them work but the casting experience will be exactly that – work.

You should go to a reputable dealer and cast the actual equipment you are thinking about buying. And cast it at the distances you will be predominately fishing. And cast it with the line you will be fishing with. Sinking lines with big bass stuff do not cast the same as dry fly stuff shown here.

You still need to get someone to show you how. You may be able to read enough and get by but nothing beats a good lesson. You can also have someone video tape you and you can critique yourself. Taking a spare rod tip from a 2 piece rod and tying a 10 foot piece of swanandaze to it is a useful tool to look at rod tip path and acceleration and see its effect on line travel. Just hold the rod tip out horizontally and observe loop formation. Then go do the same with your overhead cast.

Bob Bolton is a retired mechanical engineer. He spent 35 years designing engines for a major automobile manufacturer and now writes technical design manuals on consignment to his own consulting company. In his spare time he hunts birds, fly fishes fresh and salt water, and works on finding fishing sites for handicapped anglers (www.HATofMichigan.org). He has written one book, You Can't Make a Living Tying Flies, in which writes of fishing and hunting in Michigan.