The Mechanics of Fly Casting

By Bob Bolton

Most of us learned fly casting by watching, reading and practicing. We wandered in and out of problems and bad habits, thinking that it was just a learned art and if we just kept doing it, everything would work out. Rarely did we ever think about what was really happening with a cast. But by applying a little high school physics, we can understand the process better. A better understanding will help correct those bothersome times when something just isn't going right. So let's go back to school.

Force, Mass, and Acceleration

Remember your physics instructor in high school. Remember how he used to harp at you, "velocity and acceleration are not the same!" Well, he was right. The first equation of motion that we learned was:

$$F = M * A$$

that is, Force equals mass times acceleration.

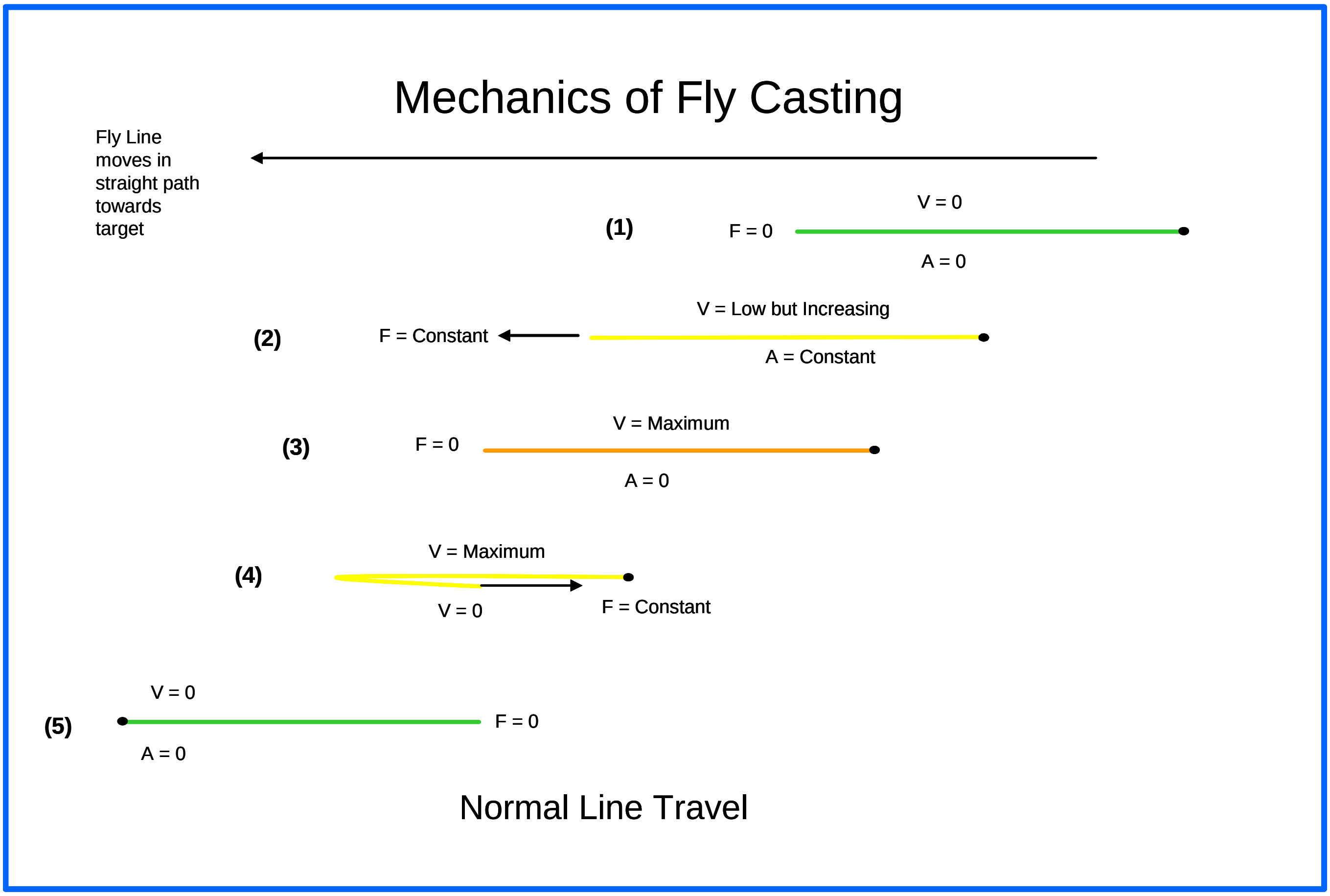

Figure I.

Now he also used to say, "mass is not the same as weight." But for our purpose here, and since we are not on the moon, we can assume it is the same. So how does all this apply to fly casting?

Line Travel

Looking at Figure I., think about a fly line sitting somewhere in mid air behind you at rest (diagram 1). Alright, alright, that could never happen because gravity would cause it to fall to the ground. Maybe we're in outer space or something. Just cut me some slack for now and I'll give you back gravity in a second.

Now what we want to do is get the line into the position of the line in diagram (5) with the fly (little circle) on the target. Remembering that we don't have the line all neatly stacked on a reel with a brick with hooks on the end like a bait caster, we must figure out how to get this flexible string from (1) over to (5) and reversed. The fly on the end has negligible mass (weight) and a lot of wind resistance so it is of little help at all if not a actually a hindrance. So whats a body to do? Well, let's start by making the string have some mass (weight). We can make it thick woven silk and linseed oil it down good as in the old days or we can make it out of some flexible space age plastic with super slick coatings – no matter. Now we have something we can work with.

What happens if we apply a force to the non-fly end in the direction of our target. Let's not worry about how we apply the force and let's assume the force is constant. In physics, or in its big brother, engineering mechanics, we call this a "free body diagram." This is where we break down a system and just look at its reaction to the situation around it. Fancy, huh!

Back to our line. We applied a force and lo and behold, F=M*A. Since the mass of the line is constant, the constant force will produce a constant acceleration. So the line velocity (speed for us locals) will start to increase and will continue to increase as long as the force is applied. Noting the "free body diagrams" in Figure I. we are moving through (2) till we reach (3) where we run smack out of force and quit applying it.

Two points are noteworthy here. First, we used a constant force and let the velocity increase in a smooth progression. It will become obvious later why we did this when we add the rod. But second, and important right now to note is the fact that the line is moving in a <u>straight</u> line directly at the target. Think about an arrow. True, it is important to have the pointy end going toward the deer, but it is also important that the arrow is going along nicely with the back directly in line with the front. Fancy ballistics people would refer to "sectional density" where the cross section of the arrow is the section and the mass relates to the density. Sd =

mass/section. The larger the sectional density, the more energy is used making the arrow go a long way and the less is used to fight the wind to get there. Arrows don't fly well sideways – sectional density goes to pot. Well guess what! Fly lines are just like arrows in the respect they like a straight line. If the fly line gets catywmpus to the direction you want to go, the wind will grab it and it will drop like a rock. This is because the entire side of the line becomes the section and the sectional density just went south. Just like an arrow going sideways. Sometimes this is good like in a dump cast, but not usually. So if you take nothing else away from this article, remember this! **STRAIGHT LINE!** That way the back of the line is just carrying itself and not out there fighting the wind.

So at point (3) we have the line moving along nicely with maximum velocity and directly at the target but oops, it's backward. What to do, what to do! Let's apply a force quick backward on the end of the line closest to the target by briskly stopping the rod. That end stops and the back end keeps going. So a loop forms and the line turns over in a spot that moves down the length of the line until the fly hits directly on the target and at (5) we remove the stopping force and bingo, a perfect cast.

The Fishing Rod

True or False, a fly rod is just a stick. There is no fly fisherman who, in my opinion, would ever answer "true" to that statement. The fly rod, after the fly itself, is unquestionably the signature of the craft to almost anyone for a myriad of aesthetic and personal reasons. But there are a number of mechanical attributes to each individual rod that are important. We can start by creating a free body diagram of just the rod itself. While this approach will, in no way, go to explain the incredible diversity and art in fly rod design, it will at least simplify what we are trying to accomplish with the rod. At the end of the day, all we are doing is throwing a piece of fly line with a fly attached, right? Any old stick will work for that. Right?

Going to Figure II, remember back when we were talking about applying a constant force to the fly line? We may have said it better if, in addition to constant, we had added the words controllable and smooth. In Figure II we show an unloaded rod, a lightly loaded rod, a properly loaded rod, and an over loaded rod. This figure was included to show that every rod has an optimum loading. Loaded too lightly, the rod requires very precise movements. While it is okay to under-load a rod for certain close in, light casts with a given rig, it is unreasonable to expect to do this accurately all day.

This is also true of the over loaded rod. The extreme bend in the rod and the decreasing effective rod length caused by the excessive bend will make repeated casts difficult to control with any consistency. This will not be desirable for extended fishing. You will fatigue and accuracy and distance will suffer.

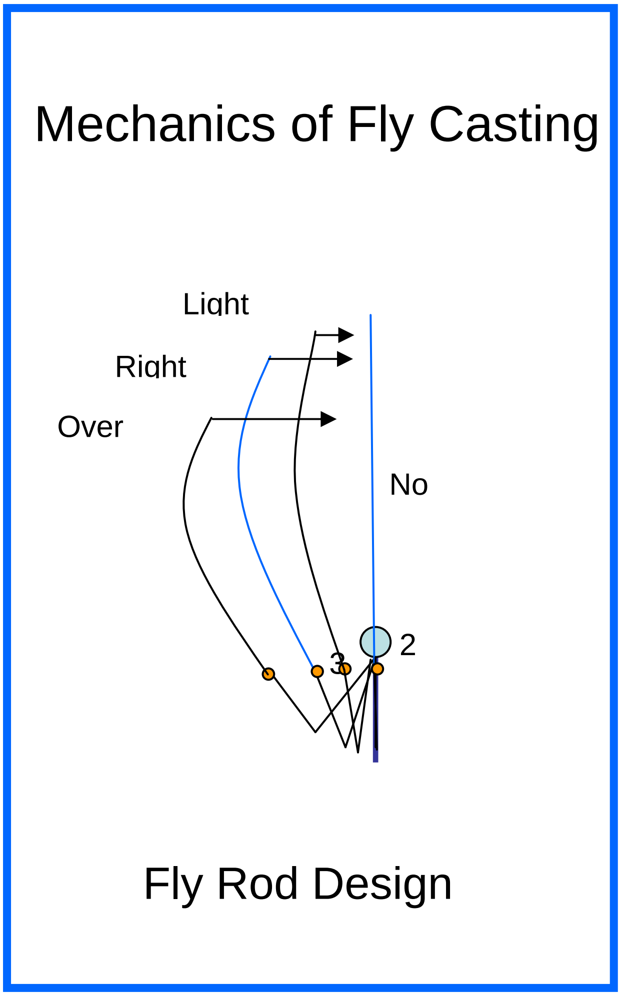

Figure II.

Finding the right rod for the job requires a fair degree of experience and a lot of trial. There are many parameters to rod design such as design weight, material modulus, length, and taper which must be matched up with other equipment parameters such as line weight and taper which must be matched up with fishing type and desired casting distance. All rods have a "sweet spot" where the loading is comfortable and maximum accuracy and repeatability will occur. Long, high modulus rods are intended for throwing heavy line long distances while short supple rods with their associated lighter loading are meant for light lines in small streams.

A classic example of extremes would be you can't expect to cast a 9 weight fly line 70 feet with a seven foot 4 weight fly rod.

So, what was this all about? The point you want to take away from this is that the proper rod for a good cast will be able to apply a constant force to a fly line and accelerate it smoothly and comfortably without excessive bend or without requiring superfine touch.

Remember, what I said was constant force. Do not confuse constant force (begets constant acceleration) with constant velocity. The movement you start your cast with will be mush slower than what you finish with because the velocity of the line is increasing.

Putting it Together

We now get to the part where we try to take some of the magic and hocus pocus out of fly casting and put in a little science. Not much mind you. We wouldn't want to taint any of that mystique that separates up from those who attach a brick studded with hooks to the end of a garden hose reel and sling it at some unsuspecting critter sleeping in a weed bed. This critter, bass I think they call them, would basically hit anything in the water just out of spite, that is, if the brick doesn't bonk him on the

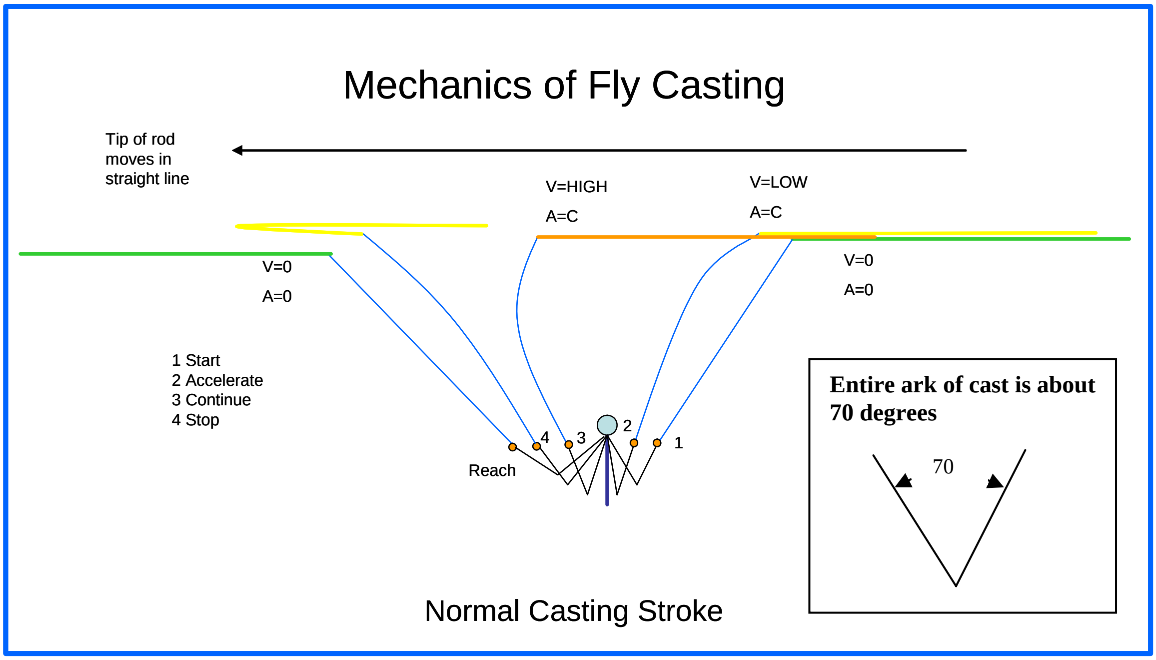

Figure III.

head. Not much danger of that with a dry fly.

But on to fly casting. Looking at Figure III. We've added the fly caster to the rod and line. All of the same lessons we have learned in Figures I. and II. are here. Starting at (1), the rod and the line are both at rest. Moving to (2) our stick man applies a force to the end of the fly line by moving and rotating the rod to bend and load it. Notice that his stick wrist does not bend. This is for two reasons. First, it effectively adds length to the rod. Second, it prevents too much arc in the movement of the rod tip. We will show you later why too much arc will open the loop and ruin the line of the cast.

This loading and initial movement starts slowly but increases in velocity as the velocity of the moving fly line increases. Moving on to (3), the application of load has reached it's practical limit and the stick guy quickly slows the rod stopping it at (4). Note that at (3) the rod is moving rather rapidly so that the force from the deflected on the fly line can be maintained on the rapidly moving fly line. When the rod stops at (4), the rod deflects forward as it applies a reverse force on the rod end of the fly line. Note also that the fly line will form a tight loop as it rolls over forward. All this is accomplished because the path of the **TIP** of the rod travels in a **STRAIGHT LINE** towards the target. If the rod tip travels in a straight line, so will the line. So as you cast, visualize in your mind the **TIP** of your rod moving in a straight line towards the target. When you start to think of casting in this way, you technique will immediately improve.

Now what happened to (5) from the previous diagrams? Well, here we call it reach.

Here's why. Notice that at (4) the rod is bent forward. If the stick guy just stands there and don't do nothing, the line will straighten out and the rod will recover, pulling the line backwards. You know what that is. The line stops out there in space and your fly comes back towards you just enough so that when it drops to the water (I gave you gravity back) it lands in a pile with your leader scaring the beegeebies out of any poor trout in the general area. So here's what. How about you put a little reach right at the end to unload the tight rod and line. The fly then drops on the water with the leader stretched out nice and the trout grabs it just out of respect for a good cast. Well done!

Now there are other ways to get that jumble out of the leader at the end of the cast. You can tilt the plane of the whole cast effectively driving the fly down to the water before any rebound. The rebound will then help straighten your leader because it is already in the water. You can also shoot a little line right at the end of the cast. Do this by just releasing the line in your non-rod hand and letting the inertia of the cast pull out that last little bit of line. Works fine if you planned for it and don't end up on the bank.

Now back casts are the same rules as a front cast except you are usually picking the line off the water. The line is usually in some disorder and can be difficult to get straightened out enough for that initial acceleration into a back cast. Never underestimate the importance of the back cast. Without proper line position at the end of the back cast, disaster and other bad things can happen on the forward cast. Many anglers will flip a little roll cast while the line is on the water to help straighten it and lift it out of the water in preparation for the back cast. Others will strip in line to maintain a relatively straight line then shoot the stripped line back out on the forward cast. Lots of tricks, huh.

More Science

So you say to yourself, " That straight . line stuff. Nobody can move the tip in a straight line when your wrist is straight and your arm is connected to your body." Well, you're right. When I say, " think of it as a straight line," I am cheating a bit. Turns out it is not really quite a straight line. But if you look down in the right corner of Figure III., you will see a little caveat. The entire casting stroke happens in about a 70 degree total ark. That's about a little before 11:00 to just after 1:00 to you clock people. The travel of the rod tip in this segment with rod deflection considered in, is about straight. Enough so that the line doesn't know the difference. The total length of this ark for an 8 foot rod considering the center of rotation is somewhere around your elbow, is about 10 feet. This gives you about 2 feet to deflect (load) the rod, about 6 feet of constant force, and a couple of feet to decelerate and stop the rod.

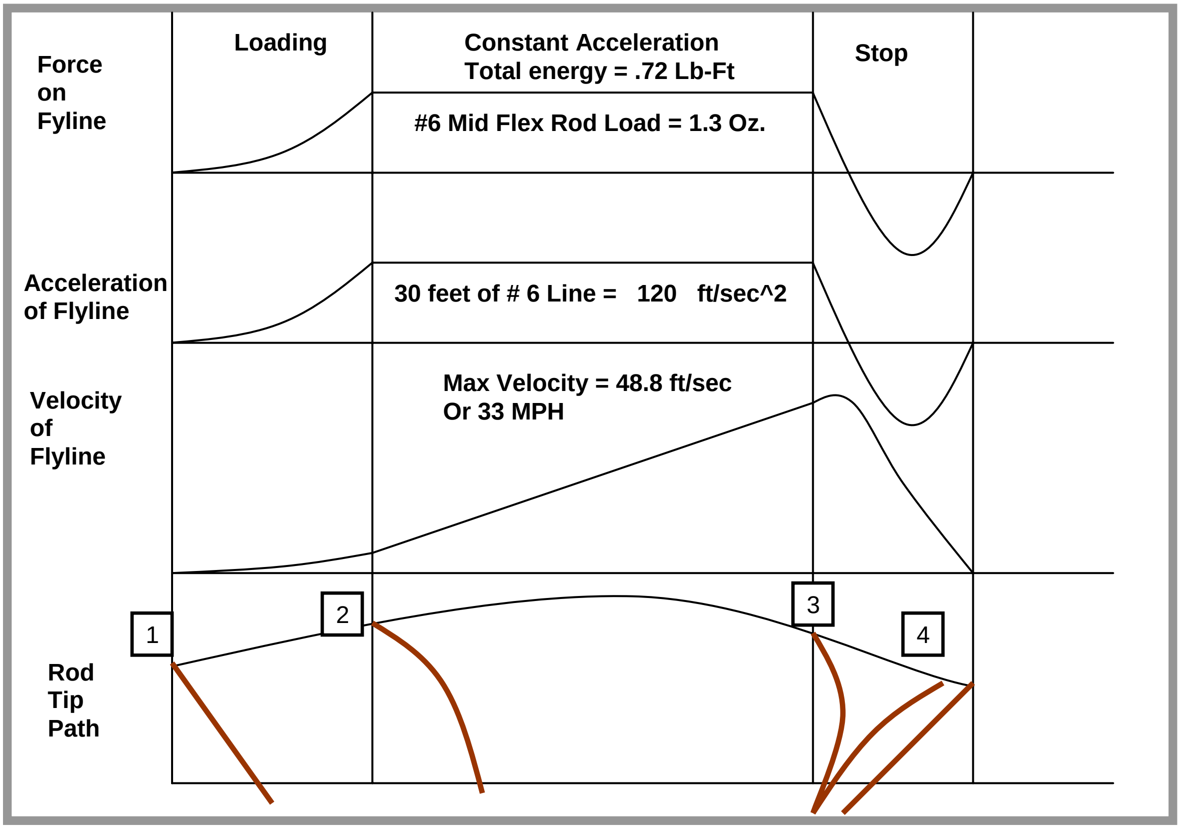

Figure IV.

All this fancy stuff can be seen in Figure IV. The first 2 feet or so from “1” to “2” (see also Figure I.) is spent loading or bending the rod. The next 6 feet or so from “2” to “3” is a section or constant force and therefore, constant acceleration. Then from “3” to “4” the rod is stopped brusquely. The example is for a 6 weight rod with 30 feet of 6 weight line. All this hoky-poke will result in a nice tight loop and a pretty 30 foot cast. Unless…..

Bad Things Happen

Okay, I realize that I haven’t even begun to cover all the stuff. There’s lots more on why fly lines are tapered, why double taper lines cast better short and WF cast better long, why sinking lines seem hard to cast, how a roll cast works, and much more, all that have scientific reasons that are interesting and may even be of use. I’ll try to write more articles when I get smarter but since I am already 61, I think I am going down hill in the smarts department.

But here are some reasons for bad things that happen. First and foremost, what happens when you put too much arc in your cast. Remember the arrow analogy? Look at Figure V. In position (4) the line is like an arrow going sideways. All the energy is being used up fighting the wind and the line ends up in a pile in front of you.

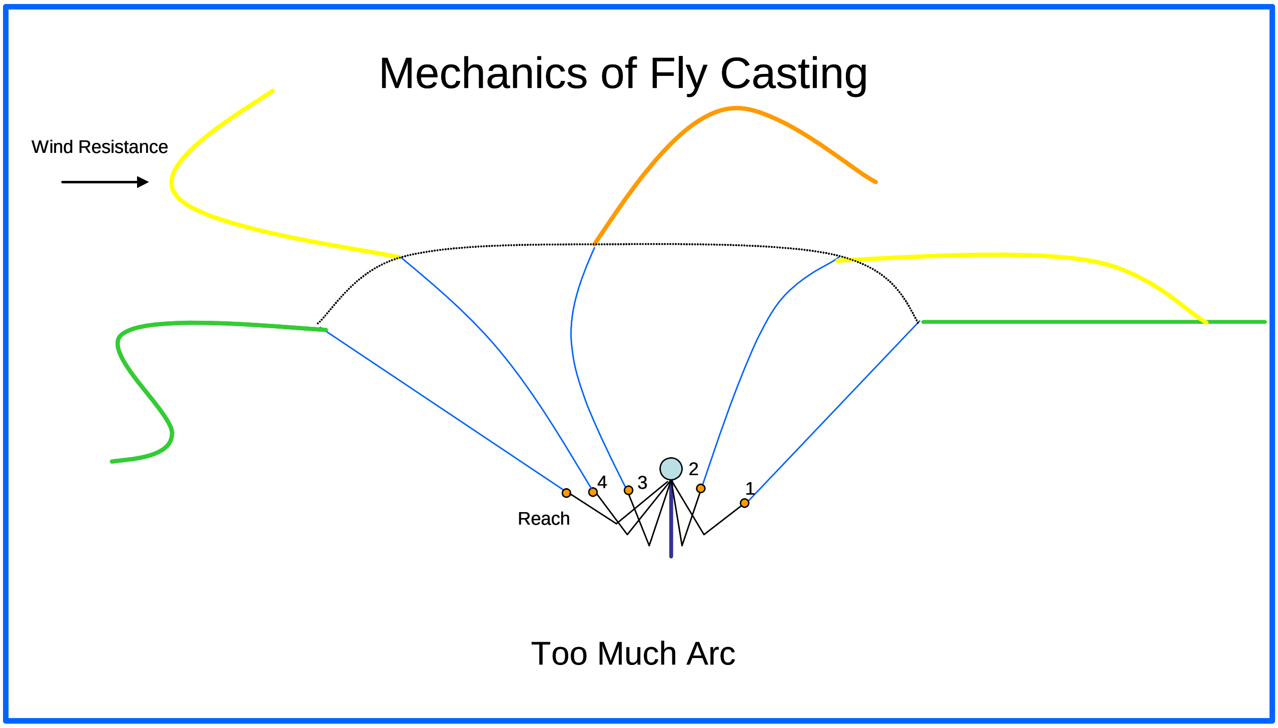

Figure V.

The entire problem started in the position of the line and the rod at the beginning of the front cast. The front part of the line was accelerated out of line with the casting direction and the loop opened up. Disaster, unless you wanted to do it. Sometimes this type of cast is used when casting downstream. Then the pile of line creates slack so you can get a downstream drag free float. When done intentionally, its called a dump cast. Done unintentionally people will just say, "What a pity."

Another problem I have heard even accomplished casters complain about is a tailing loop. The symptom is that even though the fly line is cast correctly, the fly comes by the caster too low sometimes even catching soft parts of his body with the hook. This is when you will really appreciate barbless hooks, or pain in the barbed situation. Even though most accomplished anglers will never admit to it, this is most often caused by starting the front cast before the line is completely straightened out in the back cast and then finishing with a weak stop on the front cast. Often times this happens when there is structure behind you and you are goosey about getting hung up in it. Got that problem? Look at Figure VI. and have a friend watch your back cast and watch your front cast stop. See if this is it.

You can see the premature front cast will cause the line to turn over rapidly behind you. Converting this large does of angular momentum to linear momentum and, sometimes preceded by an audible snap, the fly will drop low carrying the fly hopefully just pass your face. This will be especially true if you follow your ambitious casting start with a lazy finish.

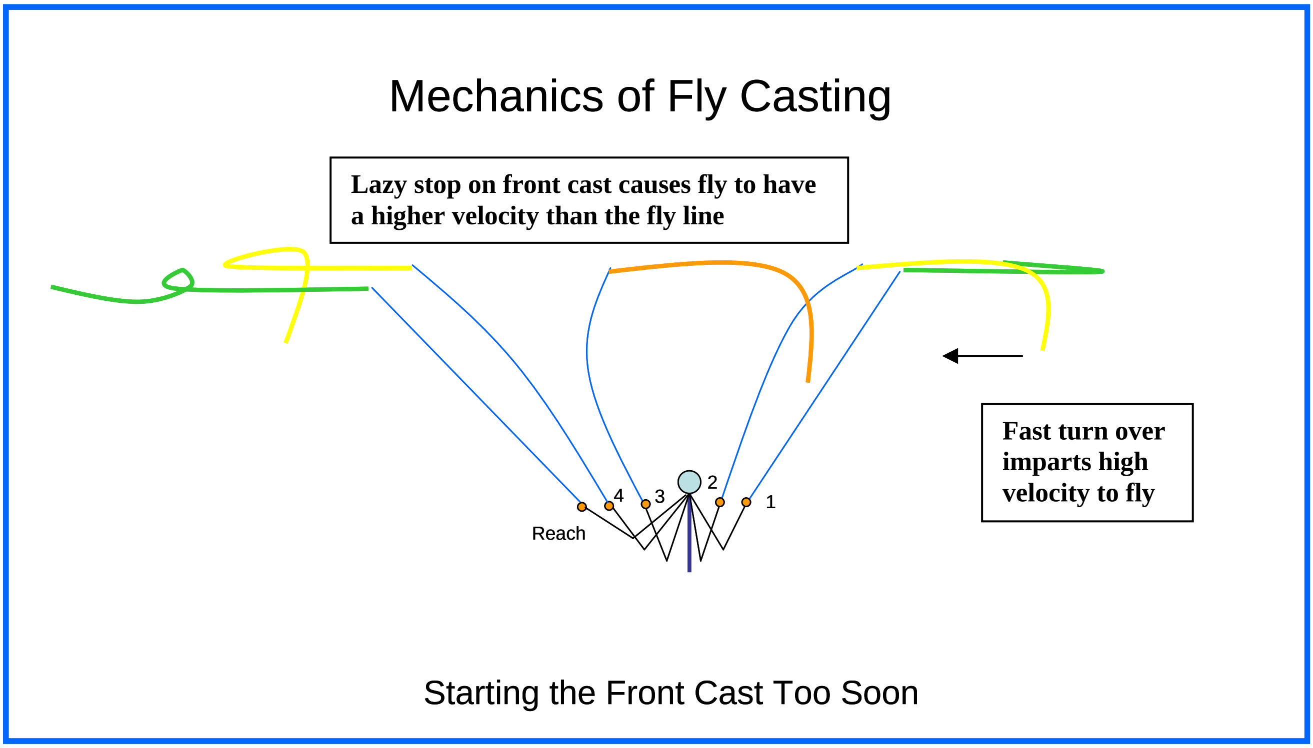

Figure VI.

Now this is not to say that trailing loops cannot be formed in other ways. The same result can be accomplished with an open loop in the back cast and a lazy stop on the front cast, but it is not nearly as much fun.

Nuff science yet? Let's do more later. There is so much more to play with. And maybe we can fix something in the process.

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, <u>You Can't Make a Living Tying Flies</u>, in which writes of fishing and hunting in Michigan.