Some Simple Physics and Dimensions for High Starts

On his now-extinct WACO web site, Frank Weston presented an interesting discussion of the physics of high starts. Recently, some messages on RCSE and measurements of the elastic properties or surgical rubber tubing by Rich Hollyday and Jeff Reid have prompted me to update and revise earlier discussions on the physics of high starts.

Representative measurements of high-start rubber are presented at:

http://www.hollyday.com/www/rubberdata.htm

Jeff Reid has measured samples of amber and red rubber tubing and has obtained a range of elastic parameters that fall in the general range of those measured by Rich Hollyday.

The following table is a reproduction of that on the Hollyday web site with one addition, the inclusion of the weight of a typical glider suited to a particular tubing size. In each case, the peak tension (assumed to be at 300% elongation) is 5 times the nominal weight of the glider. Warning: The typical descriptions for different sizes of tubing vary from one high start supplier to another.

	Hand Launch	**Two Meter**	**Standard**	**Heavy Duty**
Inside Diameter (in)	1/16	1/8	1/8	1/8
Outside Diameter (in)	3/16	1/4	3/8	7/16
Wall Thickness (in)	1/16	1/16	1/8	5/32
Cross-sectional area (sq in)	0.024	0.037	0.098	0.138
Tension at 300% elongation (lbs)	4.2	6.5	17	24
Nominal Glider Weight (oz)	13	21	54	77

The tension per unit area at 4:1 stretch or 300% elongation (e.g., a 100-foot length of tubing stretched by 300 feet to a total of 400 feet) is assumed to be the same (175 lbs. per sq. in.) for all sizes of tubing meaning that they are all stressed the same amount. A point to note is that the important measure is the cross-sectional area of the tubing (unstretched), not the diameter or the wall thickness separately. In order to know if a particular high start matches your application, you need to know (or calculate) the cross-sectional area. At 300% elongation, the tension is 5 times the weight of the glider in all cases listed in the table. This gives a robust launch. For reference, I launch my 26-oz. Dove with 10 lbs. of tension or 6.1 times its weight. It really zooms up! My 36-oz. Spirit is also launched with 10 lbs. of peak tension, 4.4 times its weight. If you are a little aggressive, the tubing can be stretched to give some more launch tension and a higher launch. However beyond 300% elongation, most latex tubing gets stiff and provides little added launch height.

Having picked the appropriate tubing size, the next step is to choose the length. The height to which a glider can be launched is limited only by the size of your field and your pocket book. A typical rule of thumb is to choose a length of rubber that is 13% of the length of the field. Attach to this a length of tow line which is about 45% of the length of the field. For this choice, the length of tow line is about 3.5 times the length of the rubber. This is a good compromise between dimensions appropriate for launching in still air and in a wind. For still air, you want more rubber and less tow line. The opposite is true for launching in a wind.

Some physics (probably more than you wanted to know):

The basic physics says that the potential energy gained in rising to launch height is no more (in still air) than the energy stored in the rubber. This energy is given by

(average tension) x (distance that the rubber is pulled back)

Tension data from Jeff Reid and Rich Hollyday show that the tension rises steeply at small elongations and then rises more slowly out to about 300% elongation. Beyond 300% elongation, the force may begin to rise faster as the rubber gets stretched beyond its recommended range of use. The force is definitely not linear as would be the case for a simple Hooke's Law material. For 300% elongation, the average of the two data sets predicts that the stored energy is given by

0.64 x (peak tension) x (distance that the rubber is pulled back)

If we assume that peak tension = 5W, where W is the weight of the plane, then the stored energy is given by

3.2 x W x (distance that the rubber is pulled back)

This energy must be degraded by some efficiency factor to estimate the energy converted to launch height. The energy at launch height (if we ignore the kinetic energy of the glider) is given by

W x (launch height)

Note: If we give the glider a good toss at launch time, the extra kinetic energy at the start of the launch will be about the same as that at the end of the launch. Combining these equations yields the simple relation (for still air):

launch height = 3.2 x (efficiency factor) x (distance that the rubber is pulled back)

At 300% elongation, the rubber is pulled back by 3 x L where L is the unstretched length of the rubber. This yields the simple relation:

launch height = 9.6 x (efficiency factor) x (unstretched length of the rubber)

In practice, launch height in still air (with a peak tension around 5W) is about four times the unstretched length of the rubber. This implies that the efficiency factor is around 40%, a not unreasonable value. Most of the rest of the energy is lost to air drag on the plane and tow line as well as to hysteresis in the rubber. Gliders designed for high efficiency and low drag at high speed may yield a higher efficiency factor and a higher launch.

These energy considerations alone would imply that to achieve maximum launch height, you want the longest piece of tubing that will fit into your field when stretched out. However, some tow line must be added to the rubber for several reasons. The most important reason is that you don't want the rubber pulling down on the glider at any time during the launch (except for a possible zoom launch which usually isn't very effective off a high start). Since the rubber is capable of storing enough energy to launch the glider to about four times the unstretched length of the rubber, you want a towline that is at least three times as long as the rubber. If you allow for the bowing of the line due to air drag and for release some distance before the glider gets over the stake, then the tow line should be closer to four times the length of the rubber. This shorter rubber has some side benefits including the fact that less of the heavy rubber is being pulled into the air and the impact on your pocketbook is reduced.

If you launch into a head wind, the kite action of the glider in the wind will lift the glider considerably higher than the height obtained in still air. With a head wind, a longer towline and shorter rubber are desirable.