Apogee Components

PEAK OF FLIGHT

NEWSLETTER

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Cover Photo: The Madcow Super DX-3 painted in red, white, and blue. Get your kit at: www.ApogeeRockets.com/Rocket_Kits/Skill_Level_3_Kits/Super_DX3_4.0in_Payload_Rocket_Kit

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Drag of Tube Fins

By Allison Van Milligan

{Editor's Note: In Peak-of-Flight Newsletter #345 (www.ApogeeRockets.com/Education/Downloads/Newsletter345.pdf), I wrote about how to borrow time in a research wind tunnel. In this issue, we'll share some of the data that was collected by my daughter Allison. She is 13 years old, and this is a snippet of her R&D project that she presented at NARAM-55 in Aurora, Ohio. The full version can be found on the Apogee web site at: www.ApogeeRockets.com/Tech/RD_Projects_from_the_NAR}

The Objectives Of the Work

My objective was to find the drag of a tube fin rocket vs. a regular finned rocket, and try to predict drag of other tube-fin rockets.

The Approach Taken

Step 1: I built all the rockets the same except for the fins. I built one rocket with just a nose cone and a body tube. I did this so that I could find the drag of the nose cone and body tube, and subtract it from the overall drag of the rockets with tube fins. I wanted to get the drag of just the tube fins, and not the overall rocket itself. Next, I built a normal rocket with 2x2 squared fins. I did this to compare it to the tube finned rockets. The leading and trailing edges of the 1/16" fins were just rounded. The surface was finished with two coats of CyA glue, and sanded smooth.

Picture 1: Attaching the fins to the body tube using the Guillotine fin jig (www.ApogeeRockets.com/Building_Supplies/Tools/Guillotine_Fin_Jig).

The next rocket was with 2in long BT-70 fins. Then I built one with 2in long BT-60 tube fins. Then I built one with 6in long BT-50 tube fins. For this rocket I scored the 6in long tubes at 5in, 4in, 3in, 2in, 1in, and 1/2in. I did this so it would be easy to cut the tube for the next test when I got to the Air Force Acedemy. I did the same thing for BT-20 rocket.

Picture 2: The rockets prior to wind tunnel testing. The long tubes were scored at 1-inch intervals. These were cut and shortened between wind tunnel tests.

Step 2: The next thing I did was go to the Air Force Academy to find out how we were going to mount the rocket in the wind tunnel, and which wind tunnel I was going to use. I would have loved to use the Subsonic wind tunnel, but it cost $10,000 per week to use it.

We ended up using 1 foot x 1 foot classroom wind tunnel. The Air Force Academy calls this the "Low Speed Wind Tunnel."

Step 3: The next thing I did when we went back to the Air Force Acadamy was do the tests. I put each of my models in the test section with help from Katarina McGuire, who is an intern at the Academy in the summer.

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Picture 3: Katrina helped me mount the rockets in the wind tunnel and acquire the initial data.

Picture 4: Leveling the rocket to make sure it was pointed straight in the tunnel.

We had to make sure the model was level. That way we knew that the model was pointed straight into the wind of the tunnel.

We started with an "air off" test to make sure the system was measuring data.

Then we did a 10hz test, a 20hz, a 30hz, a 40hz, and a 50hz test. This was how the wind speed in the tunnel was adjusted. For example, 40 hz corresponded to a wind speed of approximately 32 mph, and 50 hz corresponded to almost 40 mph.

As a side note, the wind tunnel had a speed range of 20 - 150 ft/sec (13.6 mph - 102 mph). For my test, they only allowed it to go to around 40 mph, because they were afraid that some part would break off my model, and get stuck in the fan that sucked air through the tunnel. I wished I could have gone at a higher speed.

Each test lasted a couple of minutes. This happened because we had to wait for the air to stabilize, and to save the data file to the computer hard drive. I did this for every model.

Step 4: I collected and read all the data.

Picture 5: Tightening the mount to hold the rocket securely.

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www.ApogeeRockets.com/Newsletter/Newsletter_Guidelines

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Picture 6: Data collection was the most important part of the process.

I didn't do any data reduction at the Air Force Academy. This was done when I got back home.

To find the wind speed: I opened the Excel files for each rocket configuration. It didn't give speed directly. It measured pressure difference in the tunnel. The wind tunnel measurement system took 20 air samples (once every two seconds) at each wind speed. I had to average out those to get the average pressure difference. By averaging the samples, any turbulence would be smoothed out in the results.

This pressure measurement (the average found above)

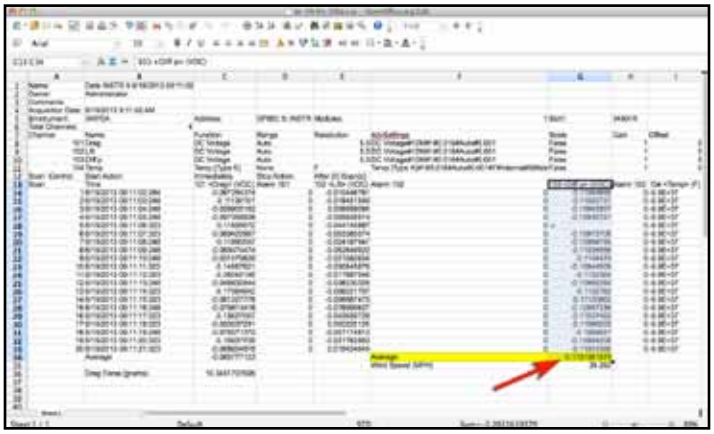

Chart 1: This is a sample of the raw data that was output by the computer at the Air Force Academy. Everything below line 33 is what I had to do. The first step: in the data spreadsheet for the test run, I had to average the 20 readings of pressure (shown by the arrow). This was to even out any turbulence in the wind tunnel. This data sheet was from the test of the rocket with the 6 inch long, BT-50 size tubes, and was run at the speed when the tunnel was turn on to the 50 hz setting.

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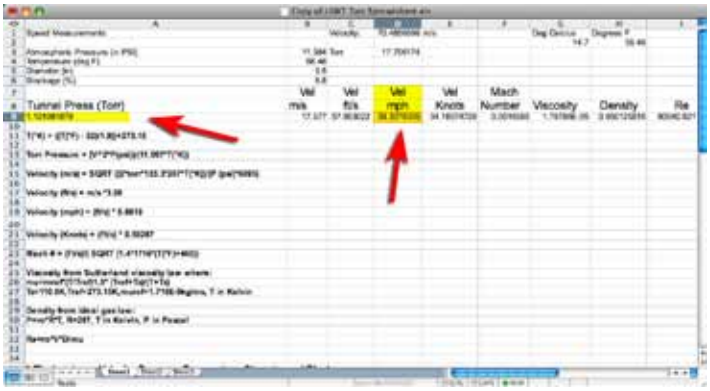


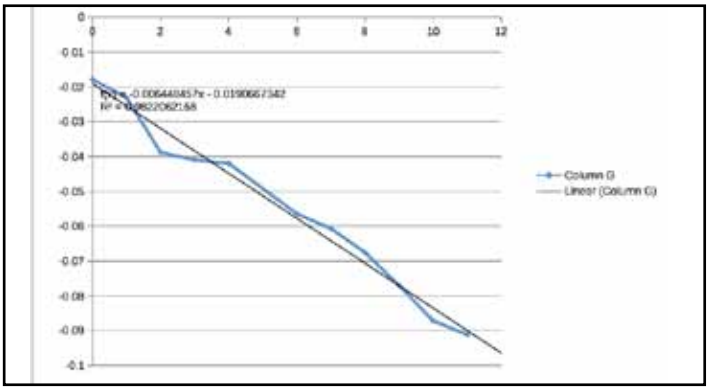
Chart 2:The Air Force Academy gave me this spreadsheet that determines the wind speed in the tunnel based on the pressure reading. The pressure reading (from the chart on the previous page) had the decimal point in the wrong spot, so I had to multiply it by 10 before I typed it into cell A9 (left side). From that pressure, the spreadsheet calculated the velocity of the air in the tunnel.

was multiplied by 10. The reason was the Air Force Academy's data sheet had an error in it. They gave me a spreadsheet called the "LSWT Torr Spread Sheet," which finds the airspeed based on the pressure measurement system. The wind speed, this spreadsheet was calculating, was around 12 mph, instead of 40 mph. By talking with the Air Force, they finally figured that the decimal was in the wrong place. It was off by a factor of 10. They told us to multiply the pressure measurement by 10, and the spreadsheet would calculate the correct wind speed.

I took this speed and wrote it down in my data sheet (see the "Data Collected /Results Obtained" section of this report). The max wind speed was a little over 39mph. It varied slightly from test to test because pressure outside the room changed (the door to outside was open, to prevent turbulence inside the room from the air hitting the wall behind the wind tunnel).

To find the drag:

Prior to my arrival at the Air Force Academy, Katrina McGuire and Ken Ostasiewski calibrated the measurement system with precise gram weights that I couldn't touch, because the oil on your skin can change the mass of the



Graph 1: This is the calibration graph that was created prior to wind tunnel testing. It was used to find the drag on each rocket.

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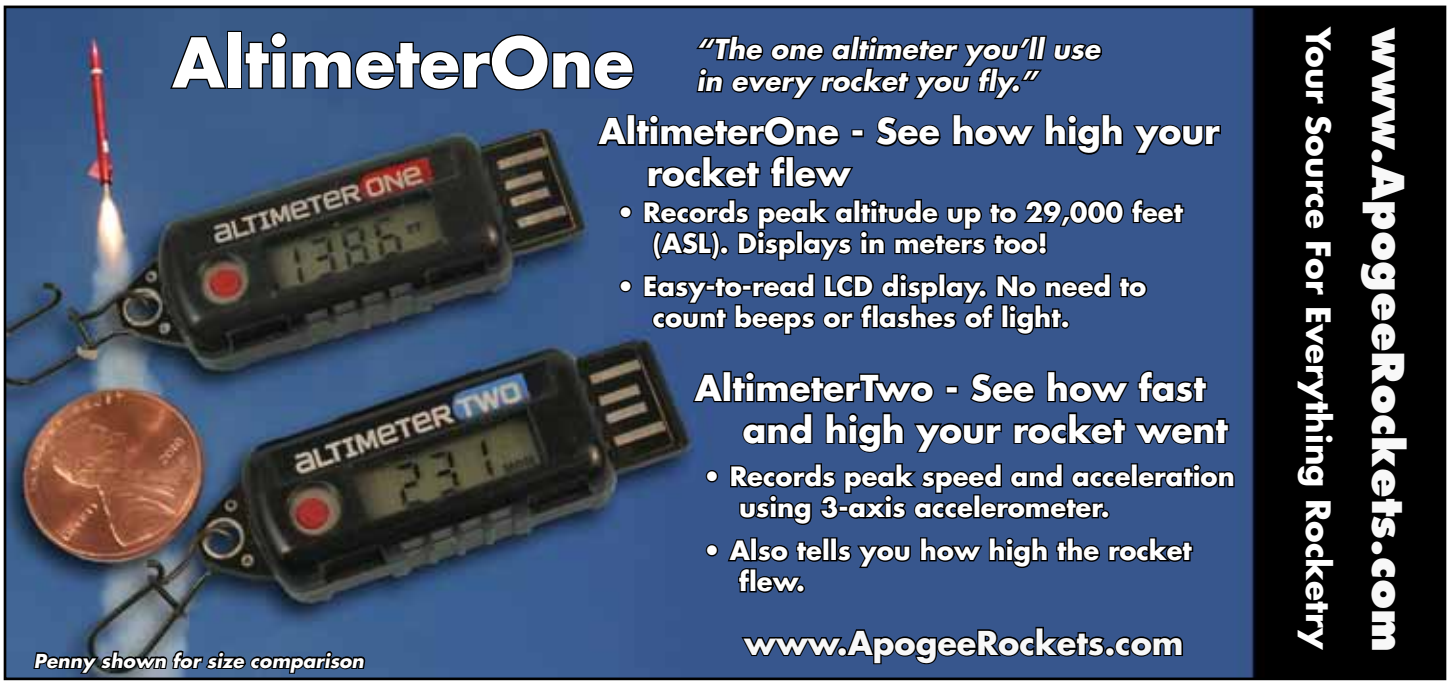

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weights.

They created a graph (shown in Graph 1 on the previous page) and equation that calculates the force at each voltage value. I would use this equation to find the drag of each configuration.

The equation used to find the force was found by rearranging the equation on the calibration chart and solving for the variable "x". The equation was:

Weight = (voltage reading + 0.0190667343)/ 0.006448457

When the data system took measurements, it actually takes voltage readings. Like for wind speed, it took 20 voltage measurements (once every two seconds) that had to be averaged.

I took the average voltage measurement and put that number into the calibration formula. That formula gave me the force in grams that created the voltage.

Once I had the drag I put it into my chart. I had to do this for 17 rocket configurations and three tests; one for the stand and two without fins.

After the chart was made I organized it by putting it into graphs. I used a feature in Microsoft Excel to put trend lines on the graph, and calculate the equation of the trend line.

Data Collected/ Results Obtained

The Results that I obtained are as follows:

1. As the tube length increases the drag goes up.

Rocket Configuration	Tube Size	Tube Diameter	Tube Length	Length/Dia. Ratio	Wind Speed (mph)	Total Drag Force	Tube Fin Drag (g)	Temp
Base	No fins	No Fins	No Fins	No Fins	31.81	2.150		72°F
Base	No fins	No Fins	No Fins	No Fins	39.29	6.958	0.000	72°F
1	BT-20	0.736	6	8.152	39.34	8.479	1.521	72°F
2	BT-20	0.736	5	6.793	39.21	8.765	1.807	72°F
3	BT-20	0.736	4	5.435	39.21	6.598	-0.360	72°F
4	BT-20	0.736	3	4.076	39.23	7.663	0.705	72°F
5	BT-20	0.736	2	2.717	39.26	6.326	-0.632	72°F
6	BT-20	0.736	1	1.359	39.31	6.272	-0.686	72°F
7	BT-20	0.736	0.5	0.679	39.20	6.522	-0.436	72°F
8	BT-50	0.976	6	6.148	39.31	10.345	3.387	72°F
9	BT-50	0.976	5	5.123	39.34	8.116	1.158	72°F
10	BT-50	0.976	4	4.098	39.05	9.096	2.138	72°F
11	BT-50	0.976	3	3.074	38.97	9.338	2.380	72°F
12	BT-50	0.976	2	2.049	39.28	6.550	-0.408	72°F
13	BT-50	0.976	1	1.025	39.47	8.592	1.634	72°F
14	BT-50	0.976	0.5	0.512	39.18	7.155	0.197	72°F
15	BT-60	1.637	2	1.222	39.23	11.862	4.904	72°F
16	BT-70	2.217	2	0.902	39.25	12.275	5.317	72°F
17	2x2	N/A	2x2	N/A	39.32	7.597	0.639	72°F
18	Stand	N/A	N/A	N/A	39.28	3.805	N/A	72°F

Table 1: This is the reduced data of the 17 different rocket configurations that were tested.

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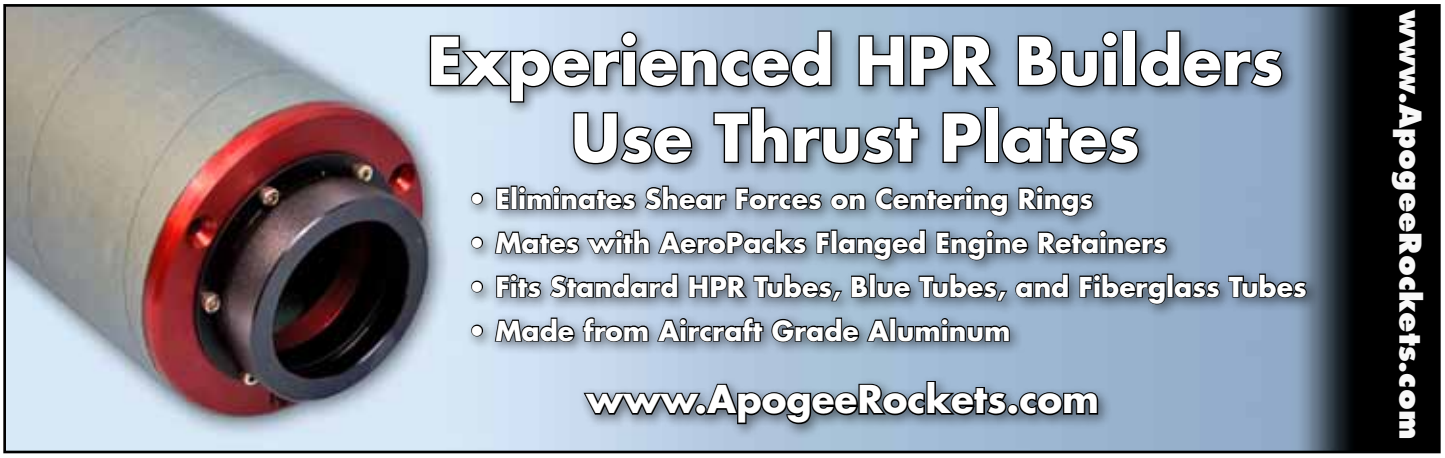

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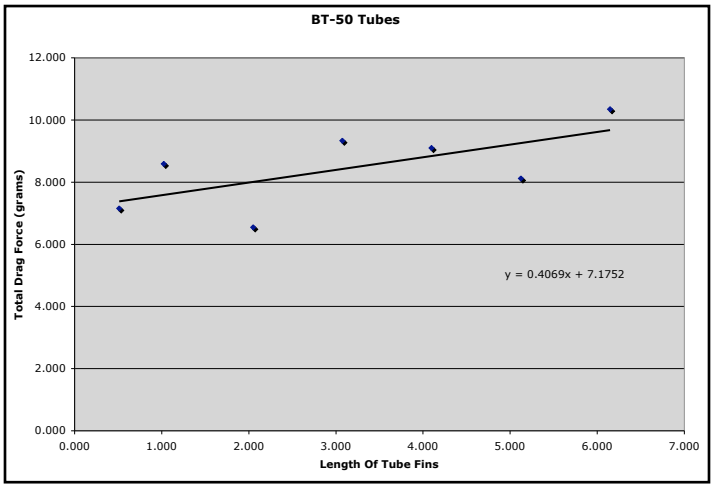
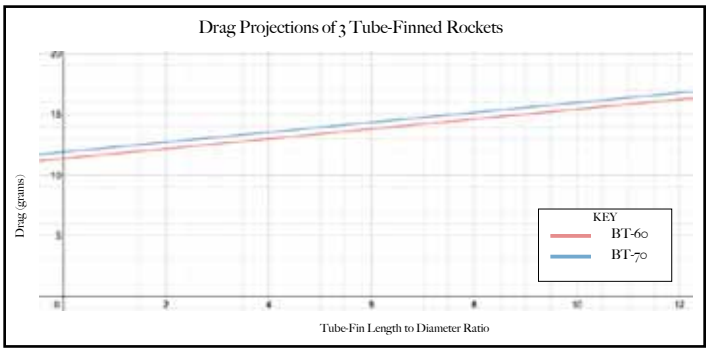


Graph 2: A typical graph of tube-fin drag. This one is for BT-50 size tubes. As the length of the tube increases, the drag also increases.

2. Also the slope in the BT-50 and BT-20 slopes are very close. This says that a person can predict the drag will be about the same slope for a BT-60 and BT-70.

Here is the graph I made to predict the drag:



Graph 3: My BT-60 and BT-70 drag predictions based on the slope of the smaller tubes that I tested in the wind tunnel.

3. I also realized that when I tested the base rocket the drag was too high. See the chart for the second "Base" configuration at 39.29 mph wind speed. That configuration had a force of 6.958 grams, where the same configuration at 31.81 mph had a much lower drag force of 2.150 grams. I don't know why it was too high, except that maybe it wasn't aligned in the wind tunnel perfectly straight. That is why some of the numbers for "Tube Fin Drag" are negative. Other than that, I believe that all my numbers are accurate because I had the help of the Air Force Academy to make these measurements.

4. Tube-Finned rockets have about the same amount of drag as regular finned rockets. If you had a tube finned rocket with the same surface as a regular finned rocket you would find that the drag is about the same.

Here's how I figured this out. If the surface area of the regular finned rocket is 2" x 2", that is equivalent to a tube fin rocket having a 2 inch long X 0.6366 inch diameter. To figure this out, refer to graph 3 on page 15 of the online report. When you extend a line up from 0.63 inches diameter, you'll find the drag to be a little over 7 grams. That is real close to the drag of a 2" X 2" fin which had a drag of 7.597 grams. But tube fin rockets are less stable than regular flat fin rockets, (see reference #1) so you'd need bigger tubes to make up the difference. That would mean when comparing rockets of equal stability, the tube fin rocket would have more drag, because it needs larger tubes.

References on Subject

1. *Stability of tube fins* by Seth Avecilla.

2. *The Effect of Model Rocket Tube Fin Characteristics on the Location of the Center on Pressure* by Andrew Polashenski 11th grade science fair project.

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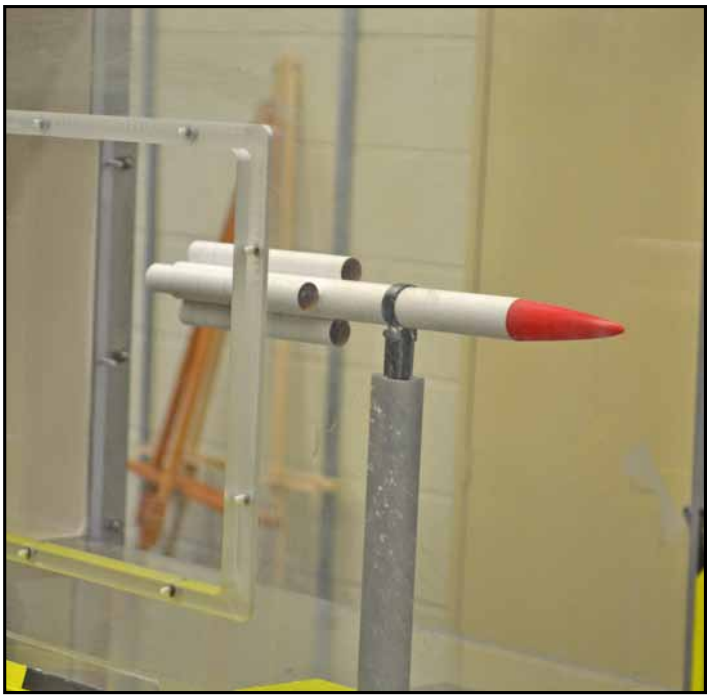
4. Larry Brand, "Tube Fin Rocket Aerodynamics Revisited Part 2", *Sport Rocketry* magazine, March-April 2008

5. Larry Brand, "Tube Fin Rockets - Seven Beats Six Part 3", *Sport Rocketry* magazine, March-April 2010

6. Larry Brands Tube Fin Construction Articles: http://www.rocketreviews.com/larry-brand-page.html

7. United States Air Force Academy Department of Aeronautics - *Laboratory Facilities Handbook*.



Picture 7: Tube fins made with BT-60 tubes. The long tubes were trimmed down at pre-marked intervals from the front. This allowed fewer rockets to be built for the experiment.

Picture 8: A model with BT-50 size tube fins. This is at the 1 inch long length. The shortest length tested was 1/2 inch.

Picture 9: Close-up view of the mount used to hold the rockets steady in the tunnel.