PEAK OF FLIGHT

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A Comparison Of Piston Launcher Technology

By Tim Van Milligan

Piston launchers are used to give an extra kick to a rocket at liftoff. They are primarily used on small competition rockets where you need every percent of efficiency in order to do well. No place is this more important than in international competition where the level of craftsmanship is at its highest. In this article, I thought I'd tear apart a piston from Bulgaria and another from Ukraine, and compare them against the pistons that we use here in America.

In Peak-of-Flight Newsletter 374 (https://www.apogeerockets.com/education/downloads/Newsletter374.pdf) Chan Stevens presented the basic plans for the style of piston launcher that is breaking records here in the United States at NAR competitions. It is typically called an internally wired, zero-volume, floating-head piston launcher. Check out those plans before reading on, as what follows may not make sense to you.

For the World SpaceModeling Championships that my girls competed at in August, we used a variation of Chan's design. Essentially it was made smaller to accommodate the 10.2mm diameter motors that are used in international competition. My version uses a 0.25 inch diameter by 39 inch long hollow graphite rod as the inner support through which to supply power to the igniter in the head.

The bottom three inches of the rod are split in half. This allows the wires to exit out the tube, while still allowing the tube to be shoved into the ground to keep the piston vertical (**Figures 1 & 2**).

A piston launcher enables the 1/4A boost glider to be launched successfully. Because 1/4A motors only come with a very long 3 second delay, the model really needs the extra kick provided by the piston launcher to get it high enough to deploy properly.

Figure 1: The base of a hollow graphite rod is split in half so the wires can exit while the rod can be shoved into the ground.

Figure 2: Here the internal graphite rod is shoved into the ground, and the rocket is being placed on top of the piston tube.

The second slight modification I made to Chan Stevens' original design was to protect the wiring at the connector end a bit more. I used heat shrink tubing over the connector and the graphite rod to give it some stiffness as well as protection (**See Page 3, Figure 3**).

The biggest modification I made to the design for international competition was to substitute a fiberglass tube for the launcher in place of the paper tube. A paper tube normally works just fine, but during the team practice session in Muskegon, Michigan in June, my girls had some problems plugging the motor into the top of the tube because the humidity swelled the paper. The fit of the motor into the tube is a

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critical aspect of the function of the piston launcher, so I wanted to reduce the variability of the design because of weather conditions.

Figure 3: The connector is held to the top of the internal graphite shaft by heat shrink tubing. The orange piston head plugs into the connector.

The tube I made consisted of two layers of cloth. The inner layer was a Kevlar® veil (a mesh-like material). Over the top of that was a layer of very lightly woven fiberglass cloth. The Kevlar® gave the piston much needed durability, and the fiberglass was used to seal any pinholes in the tube so that it would hold pressure.

I also made a slight modification to the piston head too. In 2014 when we flew at the World SpaceModeling Championships in Bulgaria, I made piston heads from laser-cut plywood (**See "A" Figure 4**). They worked OK, but the edges of the part were rough. I worried that we were losing a little bit of performance due to gases leaking around the edges of the piston head.

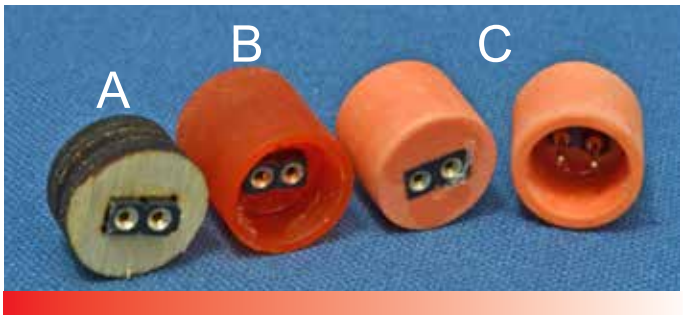

Figure 4: The progression of the piston heads (L to R): Laser cut plywood, 3D printed. The final piston heads were made from cast urethane resin (Top and bottom shown).

This summer, after I got my 3D printer, I thought it would be interesting to print the piston head. I made the part longer so that it would hopefully seal better inside the piston. This is the dark orange part in (**"B" Figure 4**).

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Figure 5: A rubber mold was created so that multiple piston heads could be quickly produced.

The one issue with the 3D parts that come out of my printer is that they are very brittle. They shatter when they are dropped or subject to high stress. In the case of a piston launcher, when the piston head would hit the stop (a coupler) in the bottom of the tube, they would break.

Because of this issue, I came up with a design that was easy to produce using a simple silicone rubber mold and urethane casting resin (**Figure 5**). These new parts are very strong and durable, and I haven't broken one yet in actual testing.

I made them orange with use of a pigment that was added into the casting resin because I wanted to be able to find them easily if they got dropped in the grass on the launch field. So these were the piston heads that my girls used during the launch in Ukraine this summer.

In **"C" Figure 4, Page 3**, the two parts on the far right show the top and bottom sides of the resin casted piston heads.

The connector in the piston head is plugged into the connector at the top of the internal graphite rod and the igniter for the rocket engine is plugged into the top of the piston head. (**Figure 6**).

Figure 6: With the piston head attached to the connector, the fiberglass tube slides up over the entire assembly.

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Once that is completed, the rocket motor is placed on the igniter and the fiberglass piston tube is slid up over the bottom end of the motor (**Figure 7**). As mentioned previously, the critical part is the amount of friction between the rocket motor and the tube. It needs to be snug but not too tight.

Image 7: The igniter is slid into the nozzle of the rocket engine, and the tube is slid over the rear of the engine. The friction holding the tube on should be fairly tight.

Matt Steele came up with a solution to measure the force of friction of the motor into the tube. Basically, he hooks up a spring scale (the kind used to measure the weight of airline luggage) to the motor and gives a tug on it. I'm not sure what force he suggests, but it is a great way to get a consistent amount of friction between launches. If the fit is too loose, some mylar tape is added over the rear end of the motor so it has a tighter fit in the tube. If the fit is too tight, then tape is removed.

In operation, the rocket engine fills the outer tube with gas. It expands and slides upward. In essence, the piston head slides down to the rear of the tube. When it reaches the stop in the base of the tube, the wire connectors on the piston separate from the internal shaft. The tube and piston are then carried up with the rocket as it takes off. Meanwhile, the internal pressure inside the tube is still increasing as the motor is firing into the tube.

Only when the internal pressure is sufficient does the model separate from the tube. Meanwhile the internal shaft with the wires stays on the ground. When the rocket takes off, it carries the tube up with it. Sometimes the rocket will be 10 feet in the air before the piston tube detaches. You know you've got a good piston effect when you see the piston flying high in the air (**Figure 8**).

The advantage of the floating head style of piston launcher is that the rocket doesn't lose a lot of momentum when the rocket detaches from the tube.

Figure 8: The piston tube flies high into the air when the rocket takes off.

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The European Style of Piston Launchers

The main difference between the zero-volume, floating head piston launchers that are typical in the USA compared to the European piston launchers is that they don't use a floating piston head. Their piston head stays attached to the internal shaft where the igniter wires are located. Therefore the rocket comes to a complete stop before the rocket separates from the top of the outer tube.

Figure 9: A Bulgarian piston launcher with a rocket ready for launch.

Because the piston stays anchored to the ground, it is more robust than the design that I built. The Europeans use a lot of turned aluminum components to make up their piston launchers (**See Figure 10**) which has both an advantage and disadvantage.

What I liked best about the Bulgarian piston launcher is the motor receptacle on the top end. It has a little slotted cup with a compression fitting that squeezes it snuggly down around the base of the rocket engine (**See Figure 11**). So you don't have to add tape to the motor to get the friction just right. However it is possible to over tighten the compression fitting and squeeze it too tight on the rocket engine.

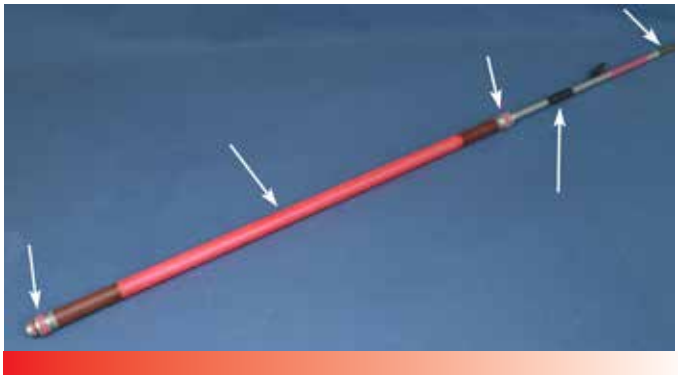

Figure 10: Bulgarian piston launcher. From left to right: motor receptacle, fiberglass piston tube, piston stop, internal shaft, post to stake the unit into the ground.

Image 11: the front end of the Bulgarian piston launcher.

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Figure 12: The piston launcher disassembled.

When you disassemble the Bulgarian piston launcher, you'll see how much machining was done to create the unit. The outer fiberglass tube is a work of art. It is a single layer of fiberglass cloth except for the ends, which appear to have a layer of carbon veil for extra stiffness. The ends take a lot of abuse during launch, so they have to be made a little stronger than the middle.

There is an identical threaded aluminum connector bonded to each end of the fiberglass tube that allows the end caps to be attached to the tube. Since the ends are identical, it doesn't matter which end of the fiberglass tube is the top. In fact, they are often flipped over between one flight to the next because they get discolored from the heat of the launch.

The piston head, which is the slug looking piece in **Figure 12**, is screwed onto the top of the internal shaft (the rightmost component with the spring shown in **Figure 12**). Fully assembled, it looks like the bottom assembly in **Figure 13.**

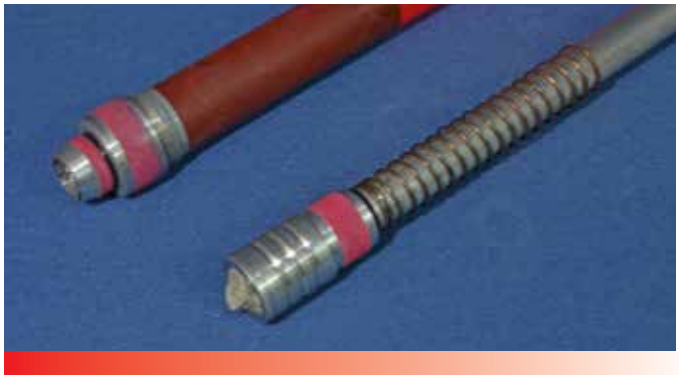

Figure 13: The piston head is screwed onto the internal shaft (lower component). The fiberglass tube (top) is slid over the top of the piston head and tube.

The spring below the piston head is to dampen the piston tube when it expands and slams the piston stop into the piston head at launch. Without the spring, the fiberglass tube would easily break at launch.

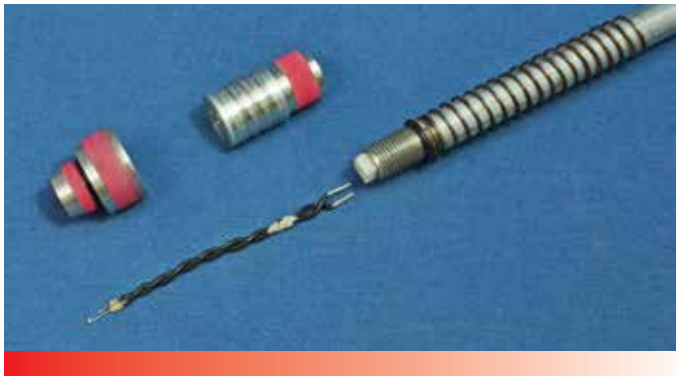

Figure 14: The igniter is inserted into the receptacle inside the internal shaft.

The igniter that the Bulgarians recommend is a simple nichrome wire soldered onto a twisted pair of solid core bell wire. It is stiff, because it has to support the weight of the rocket when it is inserted onto the piston assembly. They like to leave a little gap between the bottom of the rocket engine and the top of the piston head.

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I like that they found a way to seal off the little hole where the twisted wires come out of the piston head (**Figure 15**). They use a soft putty -- the kind used for window glazing -- to seal it. They tell me that even though the putty gets a lot of soot on it, it is completely reusable between launches.

Figure 15: The igniter installed into the piston head. It uses a bare piece of nichrome to ignite the motor. They use a window-glazing putty to seal off the hole around the twisted wires so that the exhaust gasses of the motor do not get into the connector in the internal shaft.

Ukrainian Piston Launcher

The other piston launcher that I saw from a distance was the one used by the Ukrainians. Like the Bulgarian design, it uses a fixed head, so the tube doesn't leave the ground (**See Figure 16**).

Essentially, the Ukrainian design is built similarly to the Bulgarian piston launcher, except the

Figure 16: The Ukrainian piston launcher.

fittings on the ends of the fiberglass tube look a little different.

Instead of using the threaded compression fitting on the end of the fiberglass tube to hold the bottom of the motor, the Ukrainian design uses a simple cup that is machined to the outside diameter of the rocket motor. So like the piston launchers used here in North

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America, the Ukrainians have to put tape on the back end of the rocket motor to adjust the friction fit of the motor into the little cup.

Internally, the differences are a little more striking. First, the piston head isn't aluminum like the Bulgarians. It uses a plastic piston head (probably machined Teflon) so that it has less friction as it slides inside the fiberglass piston tube (**"A" Figure 17**).

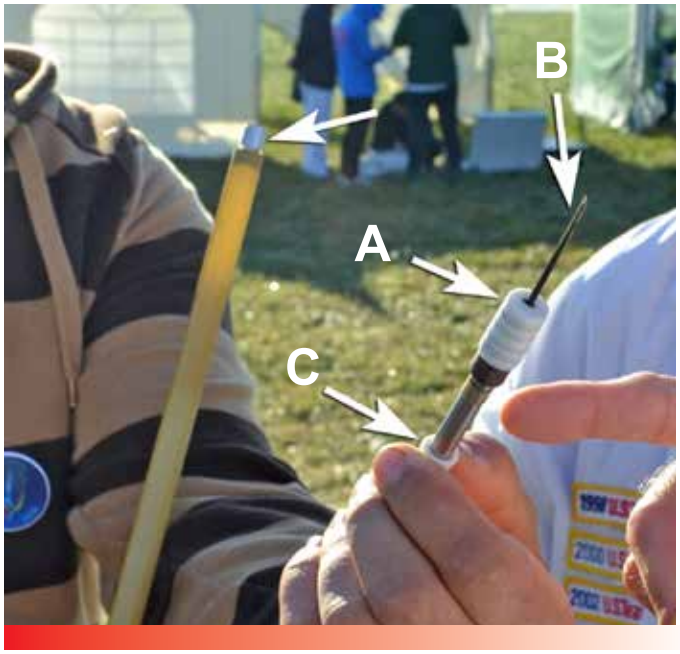

Figure 17: Close up of the internal components of the Ukrainian piston launcher.

Projecting out the top of the plastic piston head is the contacts for the igniter (**"B" Figure 17**). Where the Bulgarians use a socket so igniter wires can be plugged in, the Ukranians use two stiff pieces of metal as contacts. The igniter would be similar to the old Aerotech Copperhead igniters that have two strips of metal sandwiching the insulator that keeps the metal strips apart. **See Page 7 of Peak-of-Flight Newsletter 165** for more information on how Copperheads work: https://www.apogeerockets.com/education/downloads/Newsletter165.pdf.

Their igniter is a lot stiffer than the Aerotech Copperhead, as it is made from a piece of printed circuit board. But essentially, the igniter is inserted between the stiff contacts on the piston. Each of the contacts only touches one side of the igniter.

The final difference is the lack of a spring to dampen the speed of the piston tube as the piston stop moves upward to the base of the piston head. What the Ukrainian design uses is a little plastic split cylinder (covered by the fingers, **"C" Figure 17**). The piston stop at the base of the fiberglass tube engages the cylinder and slides it along the internal shaft. To prevent it from sliding too fast and breaking the fiberglass tube, they wrap tape around the split cylinder. The tighter the tape, the tighter the friction of the cylinder along the shaft. So it limits the speed at which the piston tube moves and therefore the piston stop glued into the base of the fiberglass tube can't slam too hard against the base of the piston head.

They also position the split cylinder halfway along the internal shaft. So the piston tube starts out moving fast, and then it engages the split cylinder and slows down.

Conclusion

It was interesting to compare piston launcher technology from two other countries. They all had some unique aspects that show what is most important to the designers of the pistons. Here in North America, we prefer the floating-head design to limit the amount of momentum that is lost when the rocket reaches the end of the piston. We also like our piston tubes to be a bit longer in length. The ones that my daughters used had a stroke of 35 inches, compared to the 23 inches that the Bulgarians use on their pistons. Finally, we like our designs to be lightweight and inexpensive. There are no machined parts on the design that I built.

But then… the Europeans swear their piston launchers are better. They

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certainly are better looking and are machined out of aluminum.

Additional References:

https://www.apogeerockets.com/education/downloads/Newsletter47.pdf - The theory behind piston launchers.

https://www.youtube.com/watch?v=LZBj8C-SUalQ - Shows the operation of a simple piston launcher.

https://www.apogeerockets.com/Launch_Accessories/Piston_Launchers - Piston launchers available from Apogee Components.

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Tim Van Milligan (a.k.a. "Mr. Rocket") is a real rocket scientist who likes helping out other rocketeers. He is an avid rocketry competitor and is Level 3 high power certified. He is often asked what is the biggest rocket he's ever launched. His answer is that before he started writing articles and books about rocketry, he worked on the Delta II rocket that launched satellites into orbit. He has a B.S. in Aeronautical Engineering from Embry-Riddle Aeronautical University in Daytona Beach, Florida, and has worked toward an M.S. in Space Technology from the Florida Institute of Technology in Melbourne, Florida. Currently, he is the owner of Apogee Components (ApogeeRockets.com) and also the author of the books: "Model Rocket Design and Construction," "69 Simple Science Fair Projects with Model Rockets: Aeronautics" and publisher of the "Peak-of-Flight" newsletter, a FREE e-zine newsletter about model rockets. You can email him by using the contact form at ApogeeRockets.com/Contact.