PEAK OF FLIGHT

NEWSLETTER

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Making Fiberglass Body Tubes for FAI Rockets - Part 2

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Making Fiberglass Body Tubes for FAI Rockets - Part 2

By Tim Van Milligan

This article picks up where we left off in the last issue (http://www.ApogeeRockets.com/education/downloads/newsletter430.pdf) where I've been documenting the development of my FAI style of fiberglass tubes. The ultimate goal is to make a lightweight fiberglass tube that is colorful so it will be easier to find after drifting a long way, and doesn't require a lot of post production work, like sanding to make the surface smooth.

What I determined up to this point was that in order to get a smooth tube, one needed to put it inside a smooth sleeve that was molded to the shape of the aluminum mandrel that the fiberglass cloth was wrapped around. So I molded a silicone rubber sleeve to fit over the mandrel.

Unfortunately, there were some air bubbles trapped against the surface of the transition portion, ruining a nice fiberglass tube. What I should have known, and it took me a while to discover, was that if you squeezed the silicone mold against the mandrel while the epoxy was curing, it would squeeze out the air bubbles.

At first, I tried wrapping rubber bands around the silicone mold. I noticed that it helped a little bit, but not enough. It also left the part with some zebra stripes where the mold was tighter and therefore the epoxy was thinner.

It seemed to me that I needed a more uniform way to squeeze the silicone mold tight against the mandrel.

As mentioned in the last newsletter, I was making smaller parts and had a painter's pressure pot that I could place the molds inside while they cured. These parts turned out nearly perfect. I only needed to have a bigger pressure pot that could hold the longer mandrels of the competition models.

What I really wanted was an autoclave. It would apply both pressure and heat to the mold at the time. Since they are very expensive, I decided to try to make my own out of commonly available PVC pipe from a hardware store.

Figure 1 shows the basic 4" PVC pipe and the fittings. They cost around $28 for what you see here.

Figure 1: PVC pipe and fittings to make a pressure tank.

I glued it all together using PVC pipe glue, and then went to Harbor Freight to get some pressure fittings and a regulator so that I could pump air into it. That added another $28 to the cost of the pressure tank. **Figure 2** shows what the tank looked like when I was done with it.

Figure 2: The completed pressure tank made from PVC pipe and some simple pressure fittings.

WARNING: Everyone will tell you this, and I need you to add my voice

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to the chorus. Pressurizing PVC pipe with air is dangerous. The warnings on the pipe are explicit.

I looked up the pressure ratings for the pipe (http://www.engineeringtoolbox.com/pvc-cpvc-pipes-pressures-d_796.html), and it said that 4-inch pipe has a maximum operating pressure of 133 psi. I don't trust this number, so I determined that I would use 20 psi when making my tubes. I put a pressure relief valve on the tank that would automatically release if the pressure got to 40 psi, just in case I forgot to adjust the pressure regulator on the air compressor. I couldn't find this valve at Harbor Freight, but I did find it on e-bay for under $5.

Having the new tank set up, I laid up a new fiberglass tube on the mandrel, shoved it into the silicone rubber sleeve, and pressurized it overnight at 20 psi. When I pulled it out, I was very pleased to see that it worked. There were no air bubbles along the surface of the transition, where there was previously. Adding air pressure worked great!

However, it wasn't perfect, and I'll talk about this later. But it was good enough that I felt that I had made a significant step forward toward the goal of the ultimate fiberglass tube. Having made progress, I felt that it was time to tackle another nagging problem I was having with my fiberglass tubes.

Removing the Tubes From The Mandrel

Getting the thin, very fragile tubes off the mandrel after the epoxy has cured is a major chore. I've ruined more tubes trying to slide them off the mandrel than anything else in the process.

At this point in my research, I was still painting the fiberglass between the two coats of epoxy. I think I mentioned this in Part 1 of this series.

The process at this time was this:

1. Cut the fiberglass cloth patterns
2. Spray the mandrel with a mold release wax (aerosol can). Let it harden for about 20 minutes.
3. Lay the fiberglass cloth patterns on the mandrel, and then apply a thin coat of epoxy.
4. Squeegee off and blot up the excess epoxy with paper towels. Allow this epoxy to start curing for about an hour.
5. Spray paint the mandrel with a bright fluorescent color. Allow the paint to dry for 10 minutes
6. Apply a second coat of epoxy onto the mandrel, and while it was still liquid, slide the mandrel into the silicone rubber sleeve.
7. Put the sleeve and mandrel into the pressure pot overnight at 20 psi.
8. Pull the silicone rubber sleeve off the mandrel.
9. The result was a nice part shown in **Figure 3.**

Figure 3: The spray painted parts as they came out of the pressure pot.

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Getting the parts off the mandrel is the next step. The traditional way is to heat the mandrel up, which melts the wax mold release. The liquid wax now allows you to slide the fiberglass tube off the mandrel. In theory at least…

There are two ways to heat the mandrel. The first is to throw it into a tube of hot water. The second is to heat it with an electric heat gun, as shown in **Figure 4**.

Figure 4: Heating up the mandrel with a heat gun in order to melt the wax mold release under the fiberglass tube.

There are a bunch of problems here that I fought with. First, to get the wax to melt, the mandrel had to get really hot. So hot, that it was hard to hold with your bare hands. I had to wear thick leather gloves just to hold it for more than a couple seconds.

Second, there are always little tiny pinholes in the fiberglass tube where the melted wax oozes its way up to the surface. The issue is that this has to be cleaned off later, creating a secondary process. Ever tried gluing fins to a waxy tube? They don't stick, do they? Additionally, you also have to get the wax out of the inside of the tube too, or you can't glue in any centering rings.

The third problem is that as you start sliding the tube off the mandrel, you create a vacuum inside the tube in the transition portion of the tube. You have to slide the tube slowly, so that air can make its way under the tube or through the tiny pin holes so that you don't deform the tube as you are sliding it off the hot mandrel.

While you're waiting for the air to get in and reduce the vacuum inside the tube, the mandrel is cooling off and the wax is starting to thicken. So you often have to apply more heat to the tube. This is why I started to use a heat gun instead of the hot water bath method for melting the wax.

The final big problem was that by heating the tube, you are also softening the epoxy in the

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tube. Soft epoxy deforms. I was getting tubes off the mandrel, but then they were no longer nice and circular, being deformed by the heat, as shown in **Figure 5**.

Figure 5: The tubes are warped because the heat softened the epoxy. When it cooled, it permanently took the shape it was in.

When I used the heat gun method, I discovered that the walls of the tube were so thin, that you could easily apply too much heat where it wasn't needed, and you'd bubble up the epoxy, like shown in **Figure 6**.

My thought was that I should stop heating up the mandrel after the epoxy had cured. But then, how do you get the wax to melt in order to slide the fiberglass tube off the mandrel?

So I experimented with different types of mold releases. It was a long and laborious process, and I ruined many tubes. **Figure 7** shows what happened when I used carnauba wax. This is a paste type wax used for cars. You apply it to the mandrel, and then buff off the excess when it hardens. On your car, it is great. On a mandel… not so much.

Figure 6: Too much heat from the heat gun near the tip caused the epoxy to bubble up and ruin the part.

Figure 7: The result of the wrong type of mold release. The part stuck so well to the mandrel that it had to be chipped off with a knife.

I also discovered that the solvents in the paint were removing the mold release from the mandrel, and this was also making it impossible to remove the fiberglass from the mandrel. So I stopped painting the fiberglass once

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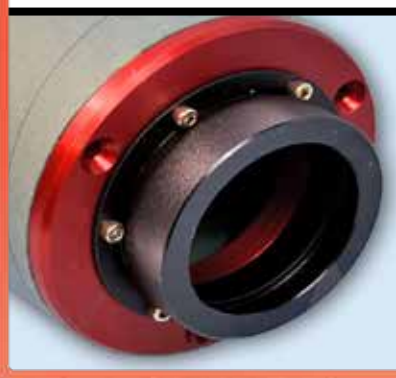

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it was applied over the mandrel (Step #5 in my process listed previously).

To get the color back, I tried adding colored pigment to the epoxy before I applied it to the cloth. Unfortunately, the result was very translucent. There is so little epoxy in the finished tubes that the color looked very weak. Compared to a spray painted model, there was no contest. It just looked sickly.

After carnauba wax, I tried a bunch of others. The one that showed promise was called "Challenge #95" from company called BJB Enterprises (**Figure 8**).

Figure 8: A brush-on type wax mold release.

The Challenge #95 release is a liquid wax that you apply onto the mandrel with a paint brush. When the wax dries, you buff it off, similar to the carnauba wax. It puts a very thin barrier on the mandrel that the fiberglass doesn't stick to.

Since the fiberglass is squeezed down tight to the mandrel during the pressurization process, it looks like it is impossible to remove. But I found that you could get a thin piece of metal under the fiberglass as shown in **Figure 9**.

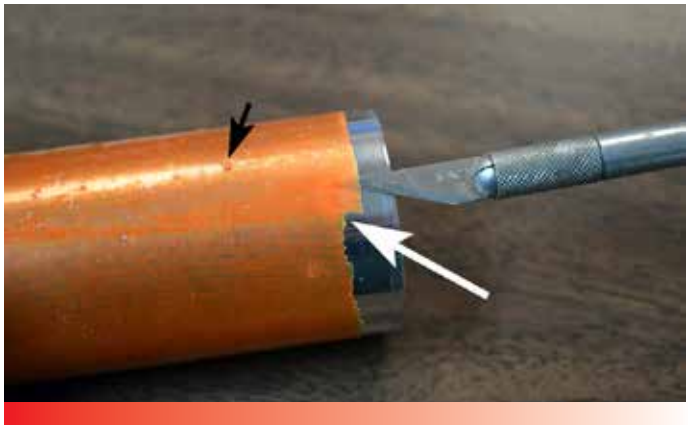

Figure 9: With the right type of mold release applied to the mandrel, you can lift up an edge of the fiberglass and allow some air underneath to break the seal.

Note: The Challenge 95 isn't the final mold release that I settled on, but it was the first one that worked well enough to get the tubes off the mandrel without having to use the spray-on wax and heating up the mandrel after the epoxy was cured.

Essentially with the right mold release, if you can get air under the part, you can slide the whole fiberglass tube off the mandrel. And that is what I wanted to do, to break the seal of the fiberglass against the aluminum mandrel.

See that little air bubble next to the tip of the blade in **Figure 9**, that tells me that the fiberglass is starting to lift off the surface of the mandrel?

You have to be careful here not to scratch the mandrel with the hobby knife. If you do, the next time you apply epoxy to the

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mandrel, it will have a scratch to flow into. It is exactly like scuffing up the surface of a part to make glue stick better. In this case, we don't want any scratches on the mandrel, so that the epoxy won't stick well to it and the fiberglass tube is easier to remove.

While we're looking at **Figure 9** (Page 6), see the little bumps of epoxy on the surface of the fiberglass? I mentioned previously that the surface wasn't perfect, and it was these little bumps that I had me concerned. They were small enough that they could be sanded off without ruining the tube. But the process of sanding would otherwise scuff up the surface and ruin the high gloss finish of the tube as it came out of the silicone rubber sleeve. In a future article, I'll tell you how I fixed this issue too.

Getting back to the air bubble, the trick to getting the fiberglass off the mandrel is to work the air bubble along the entire surface, breaking the surface tension of the tube on the mandrel.

Figure 10: Once the air bubble was started, it was worked along the entire surface of the tube by thumb pressure.

I did this by running the tip of the hobby knife around the entire edge perimeter of the fiberglass tube. Once the edge was up, I worked the air bubble further along the tube by using thumb pressure (**Figure 10**). You grip the mandrel and push the bubble with your thumb.

Essentially, you're creating a wave with the fiberglass, which lifts it off the mandrel as you push it forward. It isn't a fast process, but it can be done in about ten minutes. The straight portion of the tube is the hardest. When you get the bubble to the tapered part of the mandrel, the process goes a lot quicker. I always felt that if I didn't ruin the fiberglass along the straight section by the tapered part, then I

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was assured of getting a usable tube in the end.

You'll always hear a tiny little pop sound when you get to the end of the tube, meaning that the surface tension of the entire tube has been broken.

At this point, once the air is under the entire tube, you can easily slide the whole tube right off the mandrel.

Other than having a sore thumb from the friction pressure of pushing the air bubble along the tube, the result is a usable tube. And since no heat is needed, the tube has a true circular shell without any deformities of shape (**Figure 11**). Plus, the added benefit was that there was no waxy film on the finished part, and you could attach the fins to the surface without having to go back and remove any wax on either the outside or the inside of the tube.

Figure 11: A finished tube after it was removed from the mandrel.

With the Challenge 95 release, I found that I could get better results if I buffed off the excess wax before it was fully dried. Doing so would leave a haze of wax on the mandrel instead of being fully polished off.

By having a haze on the mandrel, I could physically tell if there were any gaps in the mold release. If you miss a spot with the release, you can be assured that the epoxy will stick permanently to the mandrel and you'll have to chip it off later.

But the haze on mandrel made it a little bit harder to push the bubble along the tube during the removal process. It was a game of give and take in order to get the tube off.

As mentioned above, it is still possible to ruin the tube getting it off the mandrel. I ruined a lot of tubes. Too many. There is a technique involved that is hard to describe when pushing the air bubble under the surface of the fiberglass. You're creating a wave with the thin fiberglass shell by pushing and sometimes twisting. The thing is, you can never allow the wave to "crest." To "crest" means that the fiberglass has folded over itself. As soon as it folds over itself, it immediately cracks because it is so brittle. It takes a lot of patience to push the bubble along the tube. When you get impatient is when bad

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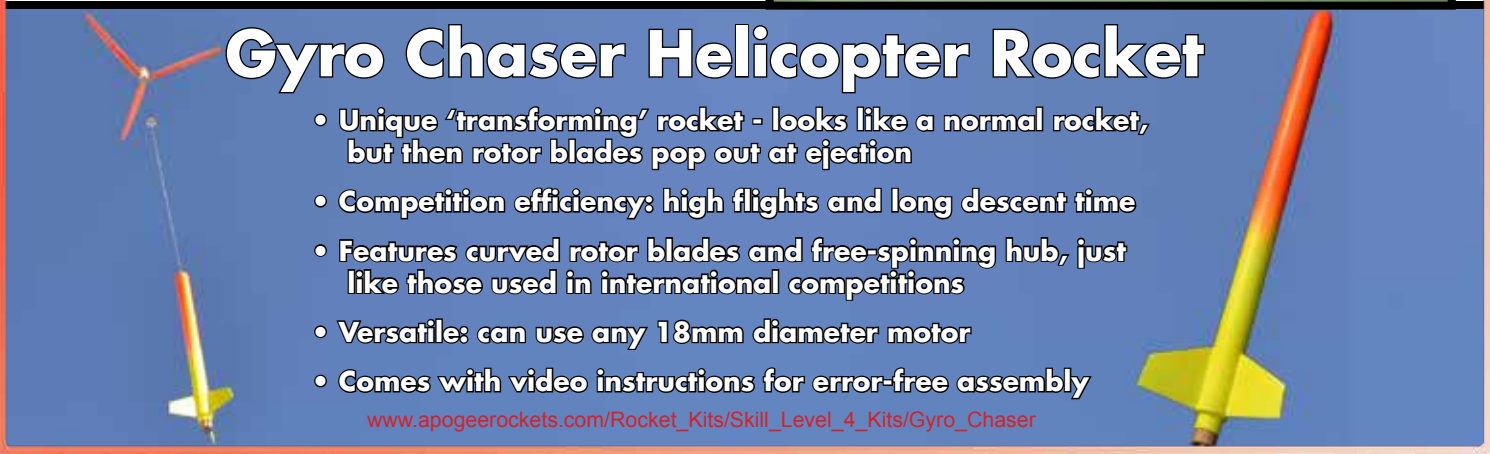

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things happen and you ruin a whole day's worth of work. Remember, it took a day for the epoxy to cure to get to this point. And you can ruin it in just a second when you get too impatient.

Because of that, I continued to experiment with different types of mold releases, and techniques of applying the mold release to the mandrel.

Getting Colorful Tubes

I was still working on a way to get colorful tubes at the same time I was working on getting the tubes off the aluminum mandrel. As mentioned, I found out that spray painted tubes looked much better than trying to add color pigments to the epoxy resin. But I couldn't spray the cloth between coats of epoxy, and I didn't want to spray them after the tubes were off the mandrel. Spraying the rocket with flourescent paint after the tube is done completely ruins the shiny surface finish of the tube. You know this, right? Fluorescent paint is always dull. A dull finish has a higher skin friction surface drag than a polished finish, so the rocket won't go as high. Since these tubes were for international competition, it was imperative that they had a shiny finish so the drag would be lower.

It is possible to shine up fluorescent paint by buffing it with a scotch-brite scrubbing pad. But you can't get it to "super shiny" surface finish like the fiberglass tube that I wanted. Remember, my goal was that I didn't want to do any post production work on the tube other than trimming it to length.

What I did was to paint the fiberglass cloth prior to putting it on the mandrel. In **Figure 12**, you can see that I took the fiberglass cloth patterns that I cut out, and laid them on a piece of cardboard to be painted.

Figure 12: The fiberglass cloth patterns were laid on a piece of cardboard and painted with fluorescent paint.

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The cool thing is that because the cloth is so porous, when you pull it off the cardboard after the paint has dried, you find out that there is very little paint on the cloth. In other words, you saved a lot of weight in paint. But it still looks just as good, as seen in **Figure 13**.

Figure 13: The fiberglass cloth is still just as bright even though it has less paint.

The other really cool benefit of pre-painting the cloth is that it is stiffer and easier to work with. If you've ever handled raw fiberglass cloth, you know how easily the edges fray and distort just by moving it around. Having it painted almost completely solves this issue. The painted cloth is almost like handling a piece of paper. However, and this is the good part, it is still a little bit flexible so you can still shift the fibers around if you need it to conform over a curved surface, like shown in **Figure 14**.

Figure 14: The compound curvature of this transition is only possible because the fibers are shifted around within the weave of the cloth.

You'd never be able to make a compound curve like shown in **Figure 14** with a flat sheet of paper. It would fold over itself as it tried to lay flat on the curved surface. Only fiberglass can lay flat on the curvature because the individual fibers in the weave are shifting around to match the surface underneath.

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Removing Epoxy

Since painting the fiberglass prior to putting it on the tube helped save weight, the next thing I tried was to put epoxy on the fiberglass cloth prior to putting it on the mandrel. In **Figure 15**, you can see that I laid the cloth on a flat surface (a sheet of glass) and then spread some liquid epoxy over the pattern.

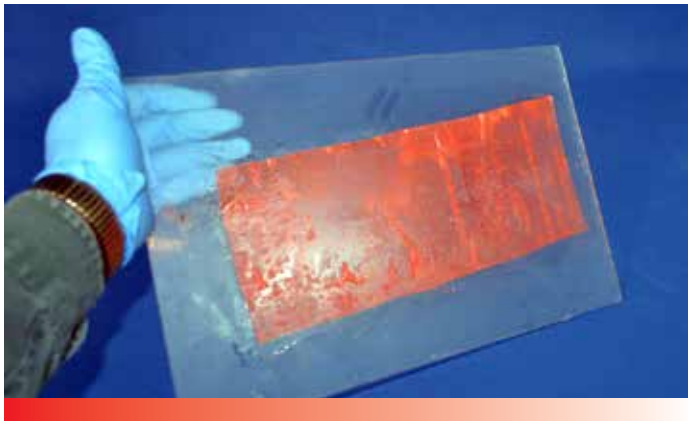

Figure 15: Applying the epoxy to the cloth before laying it on the mandrel.

When the cloth is pulled off the surface, the excess drops through the holes in the weave and stays on the surface of the glass. What remains on the fiberglass cloth is very miniscule.

The cloth was then wrapped over the mandrel, as shown in **Figure 16**.

The advantage of this, I thought, was that there would be very little epoxy on the cloth, and it would make a lighter weight tube.

However, I was still coming back later and putting a second layer of epoxy on the mandrel prior to shoving it into the silicone rubber sleeve. So I really wasn't saving a lot of weight by doing it this way.

By this point in my experiments, I was making some progress towards my goal of a colorful light-weight tube with a great surface finish. But there were a couple of issues I still wasn't pleased with, namely the surface finish having some dimples of epoxy on it that had to be sanded off, and that the tubes were still too hard to remove from the mandrel after the epoxy was cured.

Figure 16: The soaked fiberglass cloth is wrapped around the mandrel.

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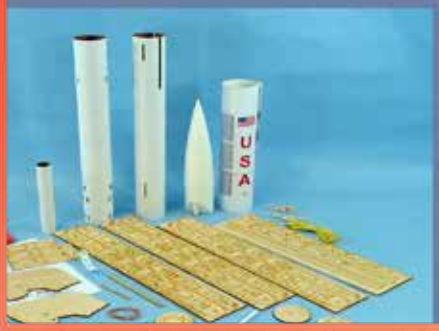

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Figure 17: Parts were coming off the mandrel looking really shiny by this point in my research.

If you have been following along, the step-by-step of the process of making a fiberglass tube has changed.

Here is a summary of what I did at this junction:

1. Cut out the fiberglass cloth patterns to fit the mandrel.
2. Spray paint the patterns using fluorescent paint on a sheet of cardboard and let them dry.
3. Paint on the Challenge 95 mold release onto the mandrel. Let it 'partially' dry. While the wax is still malleable, buff off the excess. It should leave a slight haze of wax on the surface.
4. Lay the fiberglass on a smooth surface, and spread around the liquid epoxy.
5. Lay the epoxy-soaked fiberglass cloth patterns on the mandrel. Let the epoxy cure for about an hour so that it is stuck well to the mandrel and can't shift around.
6. Apply a second coat of epoxy onto the mandrel, and while it is still liquid, slide the mandrel into the silicone rubber sleeve.
7. Put the sleeve and mandrel into the pressure pot overnight at 20 psi to fully cure.
8. Remove from the pressure pot and pull the silicone rubber sleeve off the mandrel.
9. Using a hobby knife, carefully lift up the front edge of the hardened fiberglass shell. Work around the entire perimeter.
10. Using thumb pressure, work the air bubble along the entire surface of the mandrel. When the seal is broken, you'll hear a small pop sound, and the entire shell can rotate freely around the mandrel.
11. Sand down the little epoxy dimples on the surface of the tube. Be careful not to sand too far, or you'll create a hole in the tube.
12. Slowly slide the hollow tube off the mandrel.
13. Trim the tube to length.

Note: More to come. This isn't the final process yet. It gets easier and the tubes get better later on.

About The Author:

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 a M.S. in Space Technology from the Florida Institute of Technology in Melbourne, Florida. Currently, he is the owner of Apogee Components (http://www.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: https://www.apogeerockets.com/Contact.

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