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PEAK OF FLIGHT

NEWSLETTER

Feature Article

Make Your Own Transition Sections



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Make Your Own Transitions

By Tim Van Milligan

An essential skill when designing and building your own rockets is the ability to make paper transition sections. Once you've mastered the procedure, you'll be able to make all kinds of rockets. For example, the figure below shows how the overall look of the rocket changes dramatically once you start varying the diameter of the body.

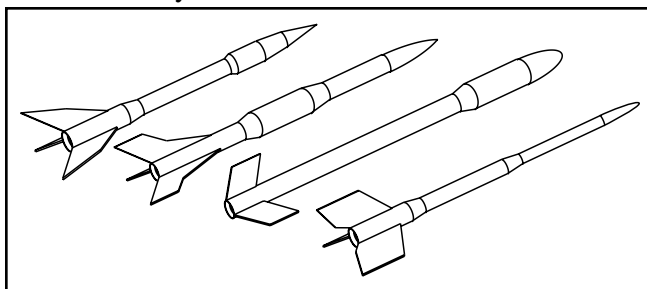


Figure 1: Body tube size variation can greatly enhance the rocket's appearance.

The key component in all these designs is the transition piece. It allows a smooth transition between the different diameter tubes. Many of the model rocket manufacturers offer pre-made transition sections which you can purchase. These can be either plastic or balsa and are designed to fit selected size body tubes. If you need a transition section with a different size, the cheapest alternative is to make one yourself out of a piece of thin cardboard. Transition sections made of thin cardboard are sometimes called shrouds. This is what I hope to show you in this article.

Transitions are given special names corresponding to their orientation. Where the smaller tube is toward

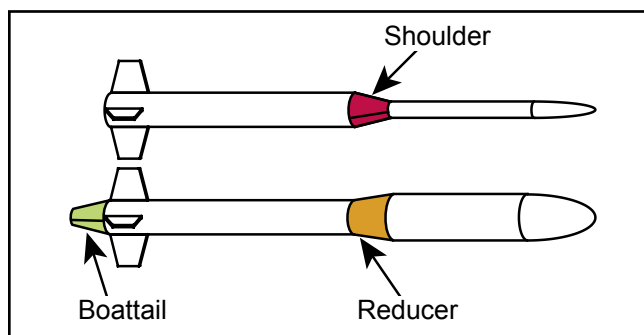


Figure 2: Nomenclature of "transitions."

the front of the model the adapter is called a shoulder; transition where the smaller tube is to the rear are called boattails, or reducers. See figure 2 above.

Designing a Transition Pattern Sheet

A good transition starts with the paper that you use. There is one type of paper is better suited to rolled cones and transitions. It is called Bristol Board. You can find Bristol Board in varying thicknesses at the better artist supply stores. What makes it unique is that it is made up of two or more layers of paper where the grain of individual layers is placed perpendicular to each other. What this does is to make it strong in nearly all directions, and it doesn't crease as easily. So for rolled conic sections, which is what a home-made transition is, you'll get a "better looking" part which is very strong. But if you don't have Bristol Board, don't worry too much. You can make them using any stiff paper or light-

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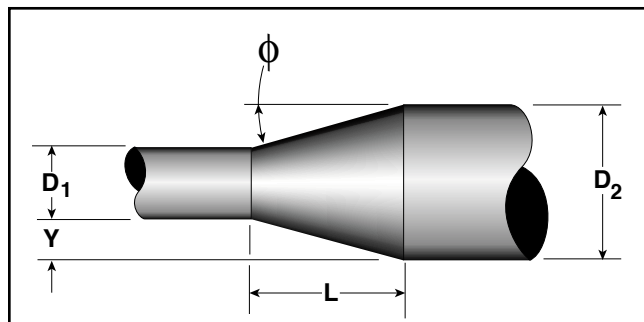
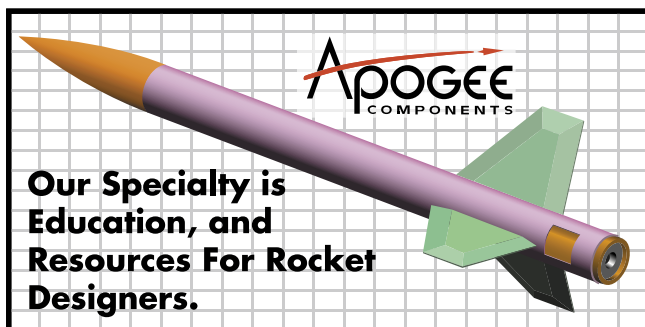


Figure 3: The diameters of the tubes, and the length of the transition need to be measured before a paper transition can be constructed.

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weight card stock.

Begin the construction by researching the actual diameters of the two tubes being connected (See Figure 3). You can find the information in a catalog from a rocket manufacturer, or you may have to measure them with a caliper. Take several measurements to be sure you have it measured accurately. You'll also need to know the length of the transition. This is determined by the rocket designer.

You will need the following equations and Figures 3 and 4 to make your own cardboard transition shrouds. The same equations can be used to make paper cones, too. If you want to make a cone, set the diameter of the smaller tube to zero.

$$Y = \frac{D_2 - D_1}{2} \quad \sin \phi = \frac{1}{\sqrt{\left(\frac{L}{Y}\right)^2 + 1}}$$

$$\theta = 360 \sin \phi$$

$$r_1 = \frac{d_1}{2 \sin \phi} \quad r_2 = \frac{d_2}{2 \sin \phi}$$

Explanation of Symbols

D_2 = Large tube diameter

D_1 = Smaller tube diameter

L = Length of transition

Y = 1/2 difference between tube diameters

ϕ = Taper angle of the transition

θ = Angle to draw transition

r_1 = Radius of inner edge of transition

r_2 = Radius of outer edge of transition

Is there an easier way to make the pattern sheet? Yes!

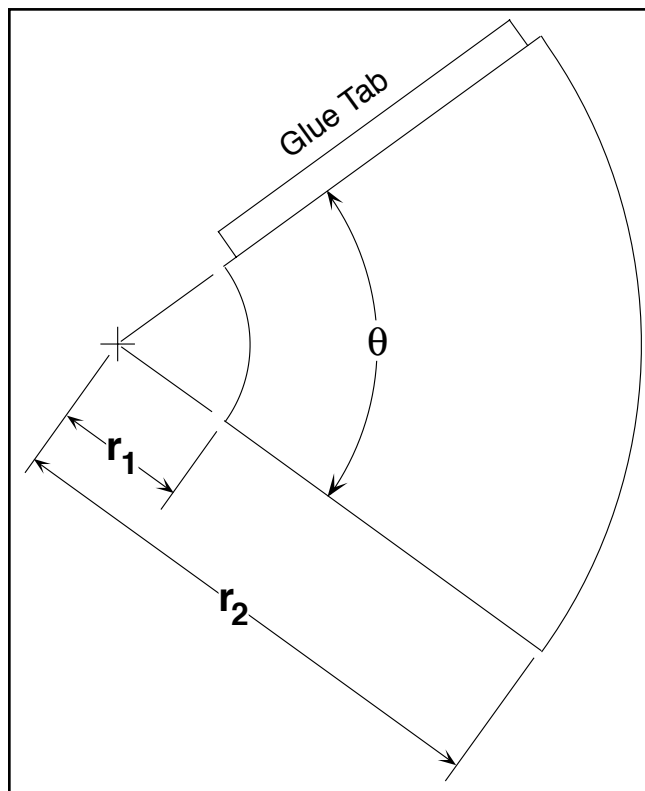


Figure 4: This is the paper pattern you'll be making, which then becomes the transition piece.

You can use the RockSim software (v7.04 or later), which you can get at: www.ApogeeRockets.com/rocksim.asp. It will automatically print out transition templates like the one shown above.

Constructing The Cone

Curling the paper to make the shroud can be done over the edge of a table. The technique is similar to making curly ribbons for wrapping Christmas presents; pull down hard, and fast (See figure 5 on page 4). The fibers will stretch slightly giving the desired curl. For smaller curls, carefully wrap the

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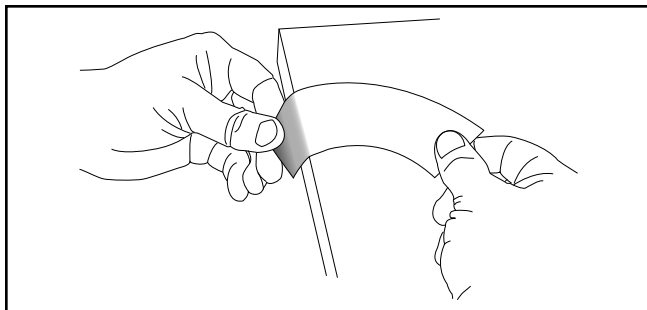


Figure 5: Pre-curl the pattern by drawing it over the edge of a table. Be careful not to crease it.

paper around the handle of a hobby knife. For really tight curls, use a 1/8 inch diameter wood dowel as a curling tool.

In my book *Model Rocket Design and Construction* (www.ApogeeRockets.com/design_book.asp), I recommended that the shroud be assembled using wood glue. I've changed my mind. Don't use wood glue to make transitions. It shrinks as it dries, and will leave slightly indented pucker marks on the surface of the paper.

The glue you want to start with is RUBBER CEMENT. It is flexible, and so the seam will match the curvature of the rest of the transition. If you try to use wood glue, the seam where the edges are joined together will be raised up like a hump. It is ugly.

In the *Peak of Flight e-zine newsletter #125*, I showed you how to make a nozzle, which is similar to a transition. But I want to make one major modification to those

Cut the glue tab free, and position it on the inside of the transition, over the seam.

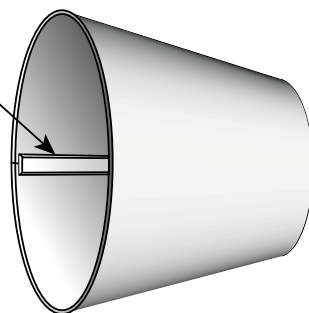


Figure 6: Use the glue tab on the inside for a perfect joint. Use only rubber cement.

instructions that will help you make a perfect transition. That modification is cutting off the glue tab, and gluing it on the inside of the seam, as shown in figure 6. This way you can really butt the edges together to hide the seam.

I also make the tab a little shorter, and center it in the middle of the joint line. So there is a little bit of seam on each end of the transition that aren't reinforced by the

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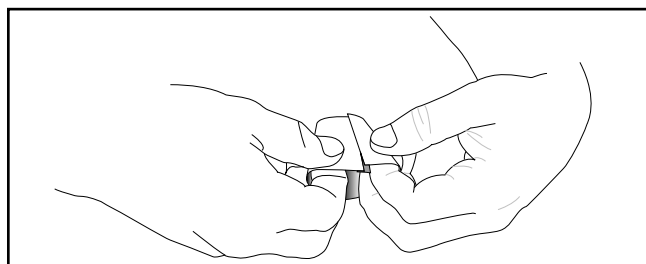
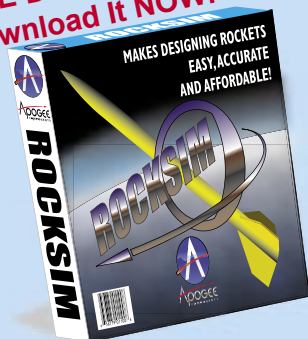


Figure 7: The rubber cement grabs instantly, so line up the edges before letting the paper touch.

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glue tab. That is OK. We'll fix this later.

Using rubber cement is a bit different from other types of adhesives. You need to apply it to both parts being joined, and you need to let it dry completely before bringing the parts together. In this case, you'll completely coat one side of the glue tab, and both the edges of the transition. When the rubber cement is dry, attach the glue tab to one side of the transition. It has to overlap the seam, so only half is attached at this time.

Since the rubber cement grabs instantly (meaning you can't reposition by sliding the paper back-and-forth like you can with wood glue), you'll have to hover the pieces over each other, and then bring them down perfectly. When attaching the other edge of the transition, you have to bring the edge in at a slight angle to get the edges to line up. I know this doesn't make sense

in print, so I've made a Quicktime™ video of the process. You can find it on the Apogee Components web site at: http://www.apogeerockets.com/saturn_instructions_movie.asp.

Once you have the shroud assembled, you can remove the excess rubber cement by rubbing the adhesive with your fingers. It will ball up, and come off easily.

A lot of people (me included) like to come back and saturate the fibers of the paper shroud with water-thin CyA glue. But I'd wait on this until you finish putting on the shroud on the rocket itself. Once you put the CyA glue on, you can't curl the transition anymore because it will be stiff and hard. You'll want to curl it later to make that seam disappear.

Joining the Tubes Together

I wish it were as simple as gluing the shroud on the big tube and then attaching the smaller tube to the top. If you tried to do that, the two tubes will end up crooked (been there, done that...).

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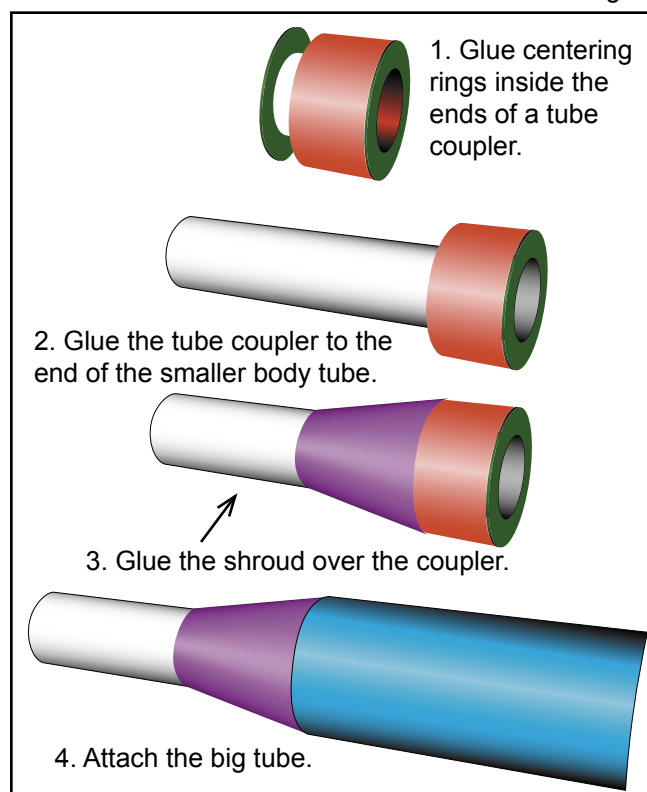


Figure 8: The basic steps to creating the internal structure to align the tubes.

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You'll need to make a structure underneath the transition to align the tubes. Figure 8 on the previous page shows the basic construction steps.

Essentially, you'll need three extra items: two cardboard centering rings that fit inside a tube coupler. (For information on how to make centering rings, see [Peak of Flight e-zine newsletter #126](#)). You'll also need to make the smaller tube a little bit longer, so as to account for the length of the tube inside the transition and inside the coupler.

Start by gluing the rings inside the ends of the coupler. While I recommend Rubber Cement for the transition shroud, I would use wood glue for this step because it is much stronger.

When the glue on the coupler is dry, glue the assembly on the end of the smaller body tube. Allow this to dry before putting the shroud over the top of it.

When the glue is dry on the coupler/tube assembly, I like to chamfer the edges of the coupler slightly. Doing the back allows the coupler to slide easier into the big tube, and chamfering the front edge makes it easier to slide the paper shroud over the coupler. I just use a piece of medium grit sandpaper and a sanding block to chamfer (round off) the edges of the coupler.

Now comes the tricky part — sliding the paper shroud over the tube on onto the coupler. The first worry is getting it over the smaller tube.

Because we used rubber cement to hold the shroud together, it will pull apart if the fit is too tight. We DON'T want this to happen. That is why we're going to test fit this slowly as we push it over the tube.

If it does begin to separate along the seam, you have two choices. Start by sanding the edge of the smaller end of the shroud. What you're doing is shortening the transition slightly so the front diameter is bigger to slide over the tube.

The other alternative is to make a new paper transition. This time, you'll need to make it slightly larger. This obviously takes longer, but in many cases it is worth the extra effort. You want a perfect looking transition, don't you?

Once you get the shroud over the tube without separating the seam, your next worry is getting it over the lip of the tube coupler. This is why I chamfered the front edge of the coupler. It is also why I don't want the glue tube (on the inside of the shroud) to go all the way to the ends of the transition. If it did, it would make it harder to get the shroud over the edge of the coupler, plus it would make it bulge a little bit at the seam line.

I found that rotating the shroud while sliding it over the lip of the coupler tube helps a lot. It should eventually go over the edge, because you sized the big diameter to fit the big tube, which is larger than the tube coupler. Be careful not to push it too high over the coupler, or it will start separating the joint.

Once the shroud is over the tube and fits over the coupler, we're now ready to glue it into place. For this, I'd use CyA adhesive. Just tack down both ends.

Once it is glued into place, you can now saturate the

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paper with the water-thin CyA adhesive. This adds a lot of strength, and makes it easier to paint the rocket because the paint doesn't soak into the paper. After the CyA has hardened, you'll need to sand it with fine grit sandpaper to make it smooth again.

The benefit of the CyA glue into the paper is that it also seals the seam edges. Now you won't have to worry about the rubber cement letting go and coming apart as it ages. So make sure you put extra attention into putting CyA into the seam.

Finally, you'll notice a slight gap where the paper overhangs the tube coupler. I like to fill this gap with the Fix-It epoxy clay (www.ApogeeRockets.com/epoxy-clay.asp). See Figure 9.

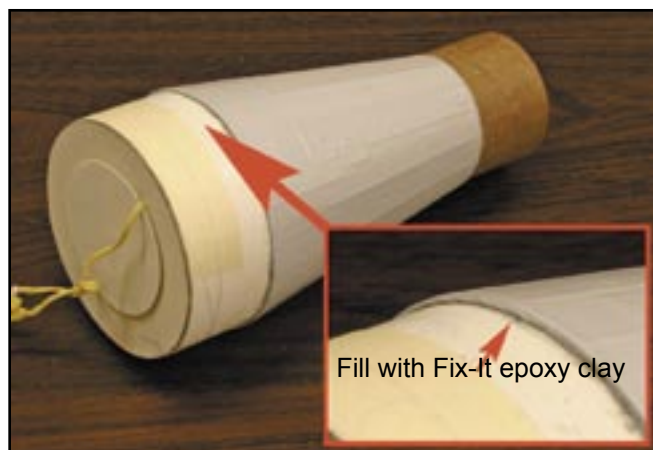


Figure 9: The small gap, where the shroud overlaps the tube-coupler, can be filled with the Fix-It Epoxy clay.

Once the epoxy has hardened, you can glue the big tube onto the coupler. This should be done with wood glue.

Options and Extras

At this point, you're done with your transition. But there are a number of modifications you may want to make depending on the use and the location of the transition.

The process of making a transition described above allows the ejection charge gases to pass through the transition and pop off the nose. If you decide you want

the rocket to break apart at the base of the transition, you'll need to cap it off, and maybe even adding a loop to attach the shock cord/recovery device.

Figure 9 shows how you can easily build a parachute loop into the design by using a piece of Kevlar® cord. (to order Kevlar®, visit the Apogee Components web site at: www.ApogeeRockets.com/construction_supplies.asp#shock_cord) You do have to plan to do this ahead of time, because it needs to be inserted as the coupler is being glued over the small diameter tube. Just cut a couple of notches on the inside of the centering rings

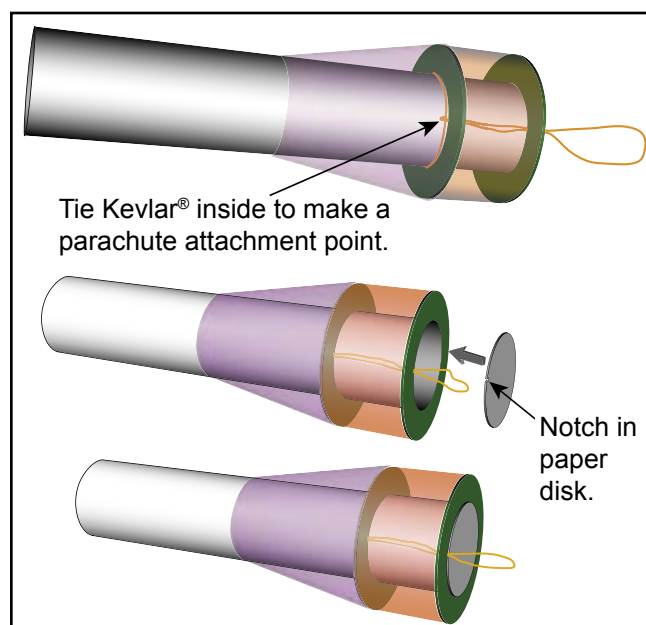


Figure 10: Adding a parachute anchor is easy!

for the Kevlar® to pass through. Put the knot in front of the forward centering ring, as this makes it stronger and less bulky inside the parachute area of the big tube.

To cap it off, simply make a disk to cover the hole over the smaller tube. A lightweight cardboard paper works fine for this. It isn't really going to take a lot of abuse. All the stress will be handled by the cord, which is securely wrapped and glued around the tube in front of the coupler section.

Do you want to separate at the small end? You can use the same basic transition design if you want the rocket to break apart at the small end. Just size the inside tube to be equal to the length of the transition/coupler sec-

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tion. I usually make it about 2mm longer than this, so I can sand off the forward end to get a perfect fit. The only thing extra you'll need to do is to glue another tube coupler into the front end of the transition so you can join the transition to the front end of the rocket. You can see how this is done in Figure 9 and Figure 11.

Figure 11 shows a two stage rocket that I built just for fun. The bottom stage held a cluster of 4 engines, while the top had a single motor. That is why I needed a transition to join the two together.

Because the bottom stage was pretty heavy, I decided to have it descend by parachute. This is attached to the base of the transition. So the transition acts like a nose cone in this rocket.

You'll notice that there is a coupler on the forward end of the transition. This is used to allow the 2nd stage of the rocket to fit on the transition.

Obviously, I can't use direct staging (see *Peak of Flight e-zine Newsletter #98* and *Newsletter #99*) on this particular rocket because the bottom tube is blocked off by the parachute and the disk on the base of the transition.

But I planned on using electronic staging anyway. So my only concern was where to put the electronics for igniting the upper stage motor.

One choice was inside the transition itself. There is certainly a lot of room inside of it.

But I decided to mount the electronics in the top stage, and just leave the inside of the transition hollow. My reason for positioning the electronics in the top stage had to do with a phenomena called *Drag Separation*. This is when the top stage coasts off the booster stage before the upper stage motor has a chance to ignite. If this were to happen unintentionally, it would yank the igniters out of the upper stage. So by putting the electronics and the wiring in the top stage, I don't have to worry about preventing drag separation. If it happens, it just makes a cooler looking flight.

Make it Beefy?

As you can see, the paper shroud in this design is non-structural. It could break, and the rocket's flight would

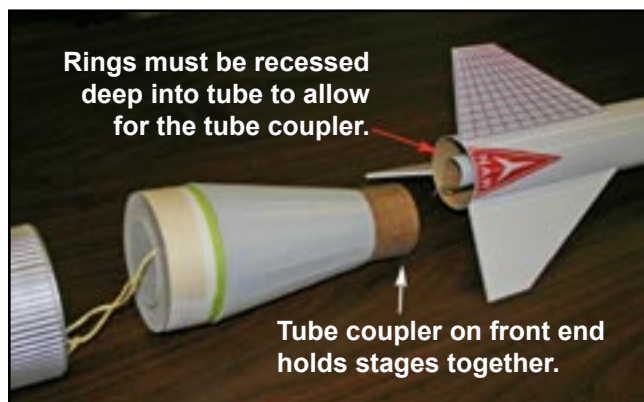


Figure 11: This transition separates at the both front and the rear ends.

probably still be fine. But when making large diameter transitions, the shroud may feel squishy. While this may be OK from a flight standpoint, a modeler might want it to be a bit more durable for ground handling.

Transition sections can be stiffened in a variety of ways. First, you can laminate another shroud over the top of the first one to increase the thickness of the shroud material. This is better than trying to make a shroud out of thicker cardboard, because thick cardboard doesn't wrap easily without creasing.

The hard part about this is getting a good bond between the two layers. I would suggest putting a thin layer of regular liquid-epoxy over the inside shroud before applying the outer layer. Unfortunately, this is a messy process.

The second way is to add internal braces or stiffeners under the cardboard before it is installed on the rocket. See Figure 12. When using these, you can use wood glue where the balsa attaches to the tube, but use epoxy where the balsa touches the inside of the paper shroud.

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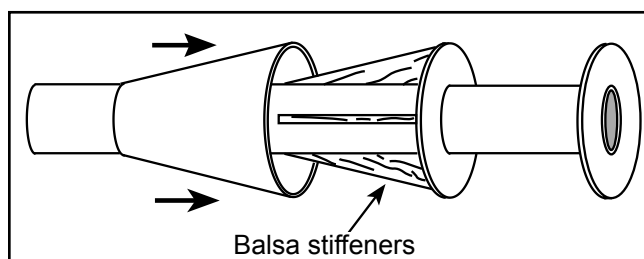


Figure 12: You can stiffen the shroud by placing balsa braces underneath the paper.

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Why? Because wood glue shrinks and would leave a little indentation on the surface of the transition. I personally like to use the Fix-It epoxy clay for this application, because there are always little gaps on top of the braces, and the Fix-It fills these easily (to get some Fit-It to try yourself, visit the Apogee Components web site at: www.ApogeeRockets.com/epoxy-clay.asp).

A more popular way to stiffen up transitions is to use polyurethane grow-foam inside the transition to fill the volume. As the name implies, it starts out as a liquid that can be poured inside, and then it expands into a foam during the curing process. In a matter of minutes it has hardened, making the transition into a near solid part - but still lightweight!

When searching for the foam, don't use the aerosol kind that is sold in hardware stores in spray cans and is used as a kind of foam insulation. That type of foam requires exposure to the atmosphere to harden. In other words, inside the transition, it will never harden. It will leave you with a gooey mess.

You should get the good stuff, which is a two part mixture in liquid form. Public Missiles carries it, along with a lot of other vendors.

One caution when using the expanding foam is that it can pressurize the inside of the parts and pop them open. The rubber cement seam on the transition is easy pickings to burst wide open.

The ends are also notorious for leaking and bursting open. So I would like to suggest that you do the foam process in two steps. First, pour a little bit of liquid epoxy into the innards of the transition. Slosh it around so that it seals the end edges and the joint seam. Then pour out the excess, unless you need the extra weight of the epoxy. After this is cured, pour in the expanding foam.

One other thing you have to do when using the expanding foam is to allow for the foam to have a vent hole. It needs some place to release the air inside, and to allow for any over expansion to ooze out. What you can do is put holes in both of the centering rings, like shown in Figure 13. This also gives you a place to pour in the foam.

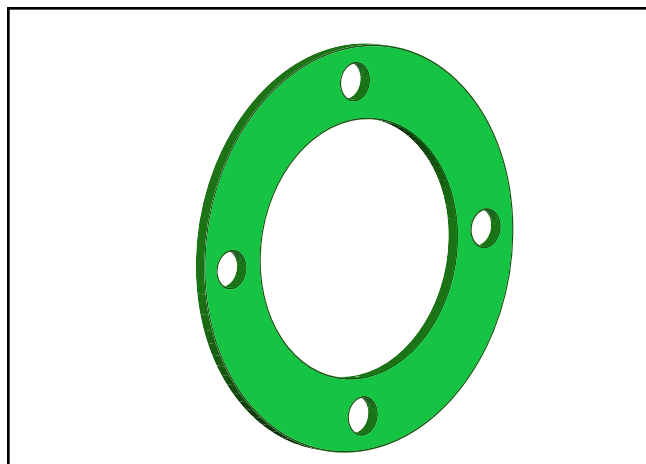


Figure 13: Holes in the centering rings allow you to pour in the expanding foam, and allow the air inside to escape out.

Other Useful Information

Model Rocket Design & Construction - The ultimate resource of useful information for rocket designers. Get it at: www.ApogeeRockets.com/design_book.asp

Model Rocket Origami - Using paper in unusual ways to make unusual rockets. Free article that gives you lots of neat ideas. www.ApogeeRockets.com/origami.asp

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How to Design Oblique Nose Cones from paper - *Peak of Flight e-zine Newsletter #127*. www.ApogeeRockets.com/education/downloads/newsetter127.pdf

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Tim Van Milligan is the owner of Apogee Components (<http://www.apogeerockets.com>) and the curator of the rocketry education web site: <http://www.apogeerockets.com/education>. He is also the author of the books: "*Model Rocket Design and Construction*," "*69 Simple Science Fair Projects with Model Rockets: Aeronautics*" and publisher of the FREE e-zine newsletter about model rockets. You can subscribe to the e-zine at the Apogee Components web site, or sending an email to: ezine@apogeerockets.com with "SUBSCRIBE" as the subject line of the message.