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**Now sue us!**

What follows is an attempt to answer your (Jim Masal's) "how'd ja do it?" inquiry re our home-grown "new" Q-2 canard.

About three weeks after we finished the "standard" GU airfoil canard , QAC came out with the new LS 4017 (1) MOD canard. Sheeit! They graciously offered to furnish all builders male and female with the "plans" for the new surface, plus some tapered-cylinder carbon fiber spar material (which the builder still had to join at the center) for something over 700 rupees, if memory serves. One still had to buy all other materials (foam, glass, hardware, etc.) which meant maybe and extra 1000 shekels you were obligated to put out so you and your airplane could fly in a drizzle.

It rains occasionally in Illinois, so we thought we probably ought to have the new shape but were loathe to cough up the all that extra coin. QAC mentioned a NASA report in which the dimensions and performance figures for the new airfoil were set forth. We made a search and were gratified to find the report was available on microfiche from our State Library. Since one of us is a pretty highly qualified technician with an innate understanding of things physical and the other knows the multiplication table all the way up to the elevensies, we decided to have a go designing our own canard. Our hotshot mathematician also has an engineering degree in a nonaero field and recognized the canard as essentially a classic cantilevered beam with a need for some resistance to twist and to (drag) loads perpendicular to the primary axis. He also recognized the circular cross section of the tube-type spars basically inappropriate to the application at hand since its bending strength is the same in all directions (dandy flagpole!) while by far the meanest stress on the canard is the flying and landing loads acting on the vertical plane only.

So, we blew about $10 on 5" of carbon fiber ribbon and did some playing around with it. Using our normal clumsy hand lay-up procedures, we made a test piece ten laminates thick and cut it up for testing to determine, in a gross way, the tensile strength and elasticity of the material. this was a fairly heartening experience, since it indicated that even with our undoubtedly resin-heavy methods, we had a material with an apparent ultimate tensile strength way over 125,000 psi and a stiffness only slightly less than structural steel. We scaled these values back to provide a large margin of safety and proceeded. We also had access to Draggin' Fly plans which is also built using 5" carbon fiber ribbon.

<u>Innyway</u>, we came up with a carbon fiber spar using a maximum of 11 plies on the bottom (tensile) flange and 14 plies on the top (compression) Flange. This is much beefier than the Dragonfly, but one must remember that their "beam" is a good deal deeper, because they use a thicker airfoil, and this adds a helluva lot to its bending resistance. 'Course, their span is greater also which makes the stresses commensurately larger. Convenience in building also dictated a "box-type" spar with two shear webs, as opposed to the single web in the QAC GU canard. the torsional resistance is provided by crossed UNI plies at 45 degrees to the direction of flight, exactly similar to the original canard. Also, two plies of spanwise UNI (in addition to the carbon fiber but not used in strength calculations) are used to harden up the skin. We've heard of people dimpling the top surface of the new QAC canard by kneeling on it!

Well, How do you go about it. All you've got is that spotted messy sheet showing airfoils at the three butt-lines covered by the original GU plans. You've got to have access to those plans, particularly for use in cutting and assembling your foam cores. These station airfoils are drawn with the trailing edge justified on the right, and with the middle airfoil the correct (vertical) spacing from the other two to be proportional to the 85-inch distance between them. You can generate a cross section for any station by connecting the tick points (or other corners, centers, etc.) of the BL-15 and BL-100 sections and finding points on those connecting lines that are the appropriate proportional distance between the root and tip. We used this method to make a drawing of the center elevator hinge bracket, and in fitting out pants, we generated a section 7.3" in from the tip so we could wire-cut a contour that the lower canard surface would exactly match. Worked good! Incidentally, when we mounted the pants and drilled the axle holes, we aimed the axle bore at a point 2.5" forward of and 5.5" above the hole in the opposite pant. This gives a little more than a half-degree of toe-out and enough camber to make the wheels bear vertically in the runway with a normal gross weight.

The foam blocks are sized and cut just like those on the original plans - note the newsletter change that reduced the anhedral angle at bl-15. Cut out your templates as one piece from the leading edge back to and including the elevator slot core. Note there is a kind of double line defining the airfoils in the spar area; you want to trim to the inside lines. This makes at least some allowance for the two additional spanwise glass skins on this part. Don't cut out the troughs, or channels, for the spar caps at this point. You'll note they have separate tic points (A<B<C<etc.) and will be cut out later. When you've finished cutting out the five main pieces, cut off the leading edge and slot core portions of your templates. Also, now cut out the portions of the templates above the spar cap channel "floor." The width of these channels on the drawing are a little tight; extend to about 5-3/8 inches. Reinstall the chopped off templates on your main cores, lop off the leading edge/slot core portions, and recut the main portion for the spar cap depressions. In our (half) vast experience, we think it advisable also to 5-minute some straight edges to these cores before making the cap cuts because they may arch and bow a little when freed from the gross block of foam.

The elevator cores are made essentially the same as called for by QAC. Don't be put off by the fact that these are 10% thicker than the rest of the airfoil and won't line up exactly (vertically) with it. this is deliberate and will not only minimize your hinge gap interference problems but will probably give you a 240-mph airplane because of reduced drag at that gap. You will also note some hatched areas on the top side at the trailing edges on the drawing. These are intended as guides for mounting the cores on plane surface prior to glassing the underside. We cut straight edges from good quality ¾" lumber to these approximate cross sections, laid the assembled elevator cores on the table with the leading edge tacked down with 5-minute epoxy and the tapered straight edges supporting the trailing edge (also 5-minute to the core). this builds in the required washout and gives you a non-wavy trailing edge - something everybody looks for in judging composite airplanes. This is really all I'm going to say about the elevator construction - goto your QAC plans and try to figure out where they should be cut off spanwise and where that length fits on the canard. We cut ours too long in the root area and had a bitch of a time making the root fairing. We ended up trimming them back spanwise a little bit. One other thing: we made the skin-to-skin joint at the trailing edge on the top side of the surface (which requires that the bottom skin be applied first), but I think QAC makes theirs on the bottom. Trust your smart enough to work this out for yourself. However, don't try for a sharp trailing edge - the airfoil isn't designed that way. Also, we've made up our own "sparrow strainer" trailing edge tabs to control the airfoil's innately large hinge moment (and inhibit flutter), but they don't agree completely with QAC's version. You'll need little airfoils 11" long by 2-3/4" wide mounted flat side up at a 27 degree angle to the top of the elevator. Mount them near the wing root and 2-1/2" behind the trailing edge. Before mounting the "sparrow strainers" go look at someone's Q-100. You may have to play with the positioning of these somewhat during early testing to get the proper amount of trim set in.

Now then! I assume you have marked the level lines on all your cores and are ready to set up the main surface on the table and glass the under side. Use exactly the same measurements for anhedral and sweepback as QAC. You will, of course, have to make "negative contour" jigging supports of the proper heights. Again, we found the unsupported cores difficult to align properly and ended up with two 80-inch wood straightedges 5-minuted to the lower (top of the airfoil) side of each 85-inch outer semispan assembly. We used 2-ply BID "ribs" at BL-15 and BL-48. These ribs are installed, cured and trimmed before the cores are joined endwise - don't forget the flox corners. Inspect the assembled cores and do any minor sanding necessary to make everything match up nicely.

You'll need at least three, and preferably four, guys to make these major layups. Start by magic-marking BL-0 and the ends of each carbon fiber laminate on the foam. Also, about every two feet, magic-mark lines across the surface at 45 degrees to the direction of flight - two sets of markings at 90 degrees to each other. These will help a lot when you lay on the torsion skins.

Everybody go pee. Make up some micro slurry and squeegee and thin coat on the spar cap channels. Get out your precious carbon fiber ribbon (it takes about 270 feet total with no allowance for waste - buy more!). There will be eleven laminates on this under side and fourteen in the top. Each (except the final full length one) is cut "on the bias" with a slope of 8:5 on the bottom side and 6:5 on the top cap. Following is a table of their limits. The first number is the BL station of the full-width laminate and the second is the station of its tapered end, i.e., BL-20/28 is a piece 40 inches long full width and tapered to 56 inches at the extreme ends.

## *THIS IS THE LAYUP SCHEDULE FOR THE CARBON SPAR.*

| Bottom side | Top side |
|---|---|
| BL-20/28 | BL-16/22 |
| 28/36 | 22/28 |
| 36/44 | 28/34 |
| 44/52 | 34/40 |
| 52/60 | 40/46 |
| 60/68 | 46/52 |
| 68/76 | 52/58 |
| 76/84 | 58/64 |
| 84/92 | 64/70 |
| 92/100 | 70/76 |
| 100/full width | 76/82 |
| | 82/88 |
| | 88/94 |
| | 94/100 |
| | 100/full width |

Lay out the lengths on your jig table and start cuttin', long ones first. Leave the plastic slip material in place until you pick the pieces up for lamination. Roll out the ribbon stick from alternate ends to take advantage of the bias cut on the previous piece. It makes no difference whether the points of the tapes are toward the front or rear of the wing, but lay them all the same way.

Our lay-up is at odds with QAC - they begin with the torsion skins and proceed to the spanwise laminates, longest one first. We start with the shortest spanwise lay-ups (each completely covers the previous one) and put the torsion skins on the outside. We also did our original canard this way, but be advised that QAC told us this was improper. They just didn't give us good reasons why, however, and we feel our method has a definite advantage in that it completely avoids "frizzy" edges and permits a generally dryer lay-up, so we did it that way even in the face of their caveat. Their only justification was that one might sand through the top layer of torsion skin and compromise the strength of the wing in that axis. Well, shit! Don't DO that! Anyway, you bin told.

So, begin your lay-up with the shortest carbon pieces, just the way they're stacked on the table. This stuff wets out nicely, but it's a little harder to judge how you're doing than it is with glass. Every third or fourth strip, use a squeegee to pull up the resin and make sure you have enough, but not too much. Don't forget to discard the slip material, Mortimer! Blow dryers are absolutely indispensable. Apply the resin with a 1-1/2" brush - you should have two guys brushing, and have them change sides periodically to balance out differences due to technique. At least with the longer tapes, all four guys should pick them up, the two center guys adjusting the center of the tape over BL-0 and gently smoothing it down through the slight bend at BL-15. **TRY TO MINIMIZE WRINKLES AT THIS POINT!!** Once the bend is made, the outer guy holds a little tension from his end and the inner guy guides the tape into the trough and smoothes it down.

When all eleven (or fourteen- I'm only going through this once!) layers are in, you're ready to micro slurry the rest of the surface, including both vertical shear webs. Now lay on two full-span lengths of UNI oriented spanwise. Have two guys grab the ends and, holding some tension, line the fibers up with corresponding points on the BL-100 chord. As they relax tension, someone nails the laminate at center span and everybody smoothes it outward keeping the fibers as straight as possible. The resin spreaders nail it down, and then it is trimmed off approximately at the top corners of the shear webs; that is, it doesn't drape down the webs.

Now you're ready for the torsion skins - one UNI at 45 degrees in each direction. The QAC plans tell you pretty much how to do this - the only things we've added are the guide marks on the foam (which can be seen through the spanwise skins) to keep the orientation more or less honest. The individual bias panels will not have to be as wide as the plans call for since the leading edge portion of the airfoil has been dropped off. Another tip: we find that after rolling out the yard goods and adjusting it so the warp threads are near 90 degrees to the main fibers, it helps to lay ¾" masking tape along the 45 degree cut lines before cutting. This aids in keeping the panels from getting all whopperjawed in handling. Just split the tape with the scissors. Start laying these panels at one tip and work toward the other. As each piece is oriented on the surface and allowed to drape naturally, **immediately** cut off the half-widths of masking tape so you can whopperjaw it as needed to correct its orientation and straighten the fibers. You'll make another cut later to the final trim line. Work the resin in on the top surface and nail the cloth to both shear webs. When I say "nail", I mean substantially immobilize the fabric by wetting it down. Make the final cut as near as possible to the bottom corner of the web. When you've worked your way across the full span with these panels toward the first tip. Adjacent panels do **not** overlap - just butt them up to each other, but don't worry if there is an eight inch gap or even a little more here and there - straight fibers are more important.

Well! Straighten up now and massage each others backs- you've probably been at it for six hours. While someone goes for beer, somebody else can stipple on some peel ply along the spanwise edges and on the shearweb faces.

Let things cure a couple of days and then follow QAC's instructions for bondoing on miscellaneous lumber to rigify things, turning the surface over, and rejigging preparatory to doing the whole nine yards over again. Make sure your end level lines are level and parallel - last chance to build in a twist! The top is done just like the bottom except for the more numerous carbon laminates. Remove the shear web peel ply before you apply the beam and that portion of the rear shear web that will be inside the fuselage - lots of junk gets attached there. Also, get two $1.75 (maybe $3.75) now due to inflation) string levels from the hardware store and bondo one on each axis at center span; this is much better to work with than level boards out on the wing.

At this point we built a sort of tent out of black visqueen and cured the beam at 170 degrees or so for a couple of hours. We did this because we knew the shear webs would be insulated from the standard post-construction cure by considerable thicknesses of foam, and we wanted to be sure they got their share of the cure. Possibly this is unnecessary since we are redundant in shear strength anyway - just thought we'd tell you.

Install the leading edge cores, one at a time on the front shear web with a liberal coating of fairly thick micro slurry punctuated by half-dollar-sized dollops of 5-minute about every eight inches. The 5-minute works fast enough that two guys can accurately position the core and simply hold it in correct alignment while the stuff hardens. Don't bother extending the "ribs" through the leading edge, but coat the mating faces liberally with micro slurry.

Now you have to cut some more bias panels of UNI long enough to wrap completely around the leading edges and overlap the top and bottom surfaces of the beam by about an inch. Use the masking tape trick again and cut the panels excessively wide so you can use the two-cut trim for final sizing. Maintain the 45-degree orientation as closely as possible and put on two opposing plies, just like you on the main beam. In preparation for this step you will want to fill the inevitable little joint discontinuities with micro (dry) and, even before that, touch up the alignment with a long sanding board. Same goes for the slot cores, of course.

You can also minimize the "frizzies" at the overlap line by stippling on some peel ply, although this isn't absolutely necessary.

Before we added the leading edges, we installed some tie-down anchors made of .063" flat steel pop-riveted to the (locally reinforced) front shear web. These plates have internally threaded steel bushing stock welded to them so that a small hole in the lower skin will permit eye-bolts to be installed when needed. The rivets are supplemented by vast patches of bid over the whole lashup. Of course, the leading edge cores had to be coped around these protuberances and the messy voids filled with dry micro.

When this latest disaster has cured, you rotate the (almost) canard and rejig it on the table with the trailing edge up. Run your brake and pitot lines on the rear shear web and route out the face of the slot cores to accommodate them. We'll leave it to you to design your own pitot line terminal- just make something you can later mount an L-shaped pitot tube to. Leave a modicum of excess length in both tube installations. Go through whatever agony is necessary to determine where the slot cores will be cut off and installed spanwise. Skin the slot core hinge wells a la QAC. Here again, its smart to use some wood straight edges and 5-minute anchoring to line up the foam in both axes - they don't bend worth a dern once those skins harden up. After curing, install them on the rear shear web perzactly like QAC says.

There, by gum! I think you're done. The wheel pants will be attached pretty much as prescribed by QAC, although the axles should be moved forward from the location on the original plans.. Ours are 1-1/2" forward of the rear edge of the elevator slot. It seems evident to us that at least part of the squirrelliness exhibited by the Q-2 on the ground is due to a lack of weight on the tail wheel and consequent poor steering traction.

We apologize if we've either over-or under-estimated your experience and need for detail in composing this sermon - be glad to discuss anything with you by phone, however memory fades with passing years so ask quick. Oops ur 2 late. You will have to work your own elevator spars, hinges, phenolic bearings, etc. They're not too different from the original, but not interchangeable.

This next is not a recommendation but, for your information, we used blue polyester foam from the local lumber yard rather than the orange stuff used by QAC. We got 10"x 24"x96" blocks for about $55 ea. (1986 prices). It's marked for use as boat dock flotation devices only and specifically says it contains no flame retardent. We burned samples of both types and could see no difference in their flammability (both **real flammable!**). The blue weighs exactly the same (2lbs. per cubic foot) and has a somewhat finer and more uniform cell size. Be advised though that Burt Rutan has issued a warning against the use of this foam because of possible voids in the foam. We encountered none of these in any of our blocks (**caveat emptor**).

We hope this will be useful to you; ya gotta admit the price is right.


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