INTERNAL RUDDER BELHORN INSTALLATION
PERPENDICULAR (BOTTOM MOUNTED) METHOD

OVERVIEW

This write-up describes the installation of the internal (hidden) rudder belhorn in Rutan Aircraft Factory's Long-EZ Internal Rudder Belhorn plans. This method is similar to the RAF method, but with two main differences: the belhorn was installed perpendicular (i.e. at 90 degrees) to the hinge axis, and it was mounted at the bottom of the rudder core.

A small cove was cleared out around the nylon rudder conduit near the wing tip, and the conduit was cut back to make space for the cable attachment hardware. A cavity for the belhorn was created by using a polystyrene plug that the outer winglet attachment layup went around. The rudder was cut out (slightly different than plans) and the belhorn cavity was opened up by removing the plug. The belhorn was temporarily attached to the bottom of the winglet, aligned for maximum rudder throw, and then permanently floxed/glassed in.

This method was done on a new build, with the nylon rudder conduit routed near the wing's trailing edge as shown on page A2 of RAF's Internal Rudder Belhorn instructions.

STEP 1. PREPARING THE CONDUIT COVE AND BELHORN CAVITY

This method started immediately after the wing was turned over at the beginning of Step 4 in the plans. Before starting layups #1 and #2, a cove was created around the rudder conduit. First a 3 to 4-inch-long wedge-shaped piece of wing skin was removed to access the conduit. (Figure 1). Foam/micro was cleared out around the conduit to create the cove. The conduit was cut about 2 inches from the end of the wing. This was more than adequate since I used an AN111 bushing which is more compact than a thimble. At a minimum, the conduit needs to be cut back enough to provide clearance for the length of the cable attachment hardware (bushing/thimble, sleeve) that extends from the belhorn, another 1/8" so part of the fork can tuck into the cove, and maybe another 1/8" to allow for error and ensure that the hardware will not contact the conduit when the belhorn deflection is maximized. A bit more foam/micro was removed around the end of the conduit so it has a bit of flex when the cable changes its angle as the belhorn goes through its range of motion.

The winglet dimensions on page 20-1 of the plans were used to find the approximate location of the hinge line. It was about 7.8" forward of the TE measured along the winglet skin edge. (Figure 2) With a compass centered on the hinge point at the winglet edge, an arc was drawn on the winglet foam surface from the forward edge of the conduit cove to the winglet's outboard skin. (This arc represents the forward-most edge of the space needed for the belhorn, therefore a straight line is ok too if it creates sufficient clearance.) Another line was drawn across the winglet foam at the hinge line, at an angle that roughly formed an isosceles triangle with the rudder tip. Then a Dremel with a router attachment was used to remove about 1/2-inch of foam between this line and the arc to create a depression in the winglet. The bottom of this depression forms the top of the belhorn cavity when the wing is right-side-up.

STEP 2. INSIDE LAYUPS

Triangular foam corners were removed as per Step 4 of the plans, between the belhorn cavity and the leading edge. This foam was not removed in the belhorn cavity area or aft of it. The forward face of the belhorn cavity was protected with a release barrier (thin flexible plastic, e.g. from a report cover/sleeve)

which was held in place using some small blocks of foam secured with nails. (Figure 3) This was to prevent epoxy/flox from oozing in. A similar barrier was placed along the forward face of the conduit cove.

Then layups #1 and #2 were completed. They did not extend back as far as the plans require, but only covered the area where the triangular foam corners were removed, i.e. from the LE to the forward edge of the conduit cove and belhorn cavity. To compensate for this slight shortening of the layup, one more ply was added to each of layups #1 and #2, bringing the total number of plies to 9. Foam block A was not attached immediately after layup #2 as instructed in the plans. Instead, the layup was peel plied and allowed to cure. (Figure 4) After cure, the glass was trimmed to the edge of the conduit cove and the belhorn cavity depression. The plastic barriers were removed.

A 1-ply BID cover plate was made to patch the opening in the wing skin that had been made at the conduit cove, and was trimmed about ¼" larger than the opening so that it lapped onto the skin. The bonding surfaces were scuff sanded, the cover was epoxied in place, allowed to cure, and then sanded to blend the edges with the surrounding surface. (Figure 5) One ply was enough for this cover because it would later be strengthened by the overlying plies of the winglet attachment BID (layup #3).

The peel ply was removed from the surface of layup #2, and foam block A was microed into position according to the plans. After cure, the aft face of the block was shaped to form a vertical surface that extended up from the belhorn cavity depression and lined up with the conduit cove. A line was marked across the aft face of block A, aligned with the top corner of the conduit cove and parallel to the base of the belhorn cavity. (Figure 6) The rest of the block was carved according to plans and shaped to meet this line. Foam was not removed below the line except for the slight rounding of the outboard edge that the plans allow to enable the glass to conform.

The base of the belhorn cavity was glassed with one ply of BID, covering the exposed foam and forming a glass-to-glass bond with the insides of the winglet skin. As usual, micro slurry was squeegeed onto the foam surface for better glass adhesion. This layup extended to about 1.5 inches from the hinge line so it would not interfere with cutting out the rudder. After partial cure, excess glass was trimmed, including any that protruded over the opening to the conduit cove.

STEP 3. FOAM PLUG

A piece of scrap polystyrene (blue) foam was used to make a plug that would form the inside of the belhorn cavity. The outboard edge of this plug was rounded just enough to allow fiberglass (layup #3) to conform over it. (Since any material removed from the plug reduces the size of the cavity that it will form, rounding the edge too much could later create interference that will limit belhorn deflection.) The plug was shaped to fit snug into the 1/2-inch-deep depression that was milled out of the winglet. The forward height of the plug was matched to block A, so their top mating edges met the top corner of the conduit cove. (Figure 7) The plug sloped back toward the TE at an angle perpendicular to the hinge line.

Figure 7 shows the plug made of two blocks, but this can be a single block that extends far enough aft to fully support layup #3. (At the time, the method was still being developed and it was determined that the first plug would be too short, so an extension was added. This can be seen in figure 8 where removal of the second block reveals the triangular section of the layup that would have been unsupported without it.)

The plug was covered with packing tape so it would release from the winglet attach layups that would go over it. Initially, the tape-covered plug did not fit into the depression in the winglet, so the foam had to be sanded down slightly in order to have a snug fit without distorting the winglet skin. (This required removing and re-applying packing tape.)

Note: The size of the plug made for a relatively large cavity, considering that the belhorn just needs a narrow slot to go through its motion. It was made this big because:
(1) it facilitates belhorn positioning and alignment since it makes it easier to see the fork at the bottom of the cavity when it is being positioned for permanent attachment;
(2) it makes it easier to glass exposed foam inside the cavity for a cleaner finish, if desired;
(3) when installing the rudder cable into the conduit (initially, and if it ever gets replaced), it can be fed through the belhorn cavity since there is enough space for tools, e.g. long-nose pliers, dental mirror, etc.;
(4) when the plane is in service, it will be a bit easier to visually inspect the cable attachment without removing the rudder.

Voids between block A and the plug were filled with dry micro, and then layup #3 was completed. Since the BID could not be stretched into the inside corner where the wing meets the plug, the fiberglass was cut so it covered the top of the plug and the wing surface, including the patch over the conduit cove. (Figure 8) This left the inboard face of the plug un-glassed, but the area would later be covered by the inboard skin of the lower winglet.

The lower winglet was then attached according to the plans. When shaping the foam in the lower winglet, just enough material was cleared out for a close fit to the plug and overlying layup. No micro was applied aft of the glass around the plug because some of the foam in that area would need to be removed later to open up the belhorn cavity.

STEP 4. BELHORN LAYOUT

On the inboard surface of the winglet, the layout of the top rudder cut line and the “vertical” (i.e. parallel to the hinges) line were drawn as shown on page 20-1 of the plans. (Figure 9A) The vertical line was extended an inch or so farther down toward the bottom of the winglet. A perpendicular line was then drawn from the vertical cut line so it ran about 1/8” below the wing TE. (Figure 9B) (The 1/8” dimension was specific to the geometry of my conduit cove relative to the TE.) This line represented what would be the bottom of the rudder core (i.e. the mounting surface for the belhorn), as well as the top of the belhorn fork. The objective was for the belhorn to be mounted to the bottom of the rudder core such that the rudder cable ends up in the aft part of the conduit cove when the rudder is fully deflected. A parallel line was then drawn about 0.75” further down, which would be the bottom rudder cut line. This 0.75” offset provided for the glass-to-glass bond in layup #6 of the plans. (Figure 9C) The three rudder cut lines were now complete (Figure 9D) and were copied to the other side of the winglet.

Note: This bottom cut line is a bit lower than the plans location in order to provide a sufficient flange for the layup that will cover the belhorn and form a glass-to-glass edge at the skin. In an installation where the rudder has already been cut according to the plans and layup #6 completed, attachment of the belhorn will reduce the height of the remaining flange and the glass-to-glass bond of the layup that will cover and retain the belhorn. But it may still be possible to mount the belhorn at the bottom. It depends on the particular geometry, but if the glass-to-glass bond of layup #6 was done correctly, then it should be providing the required strength at the bottom of the rudder. In that case, the primary function of the additional layup over the belhorn would be to keep it secured to the rudder, so a narrower G-to-G bond <u>might</u> be adequate.

STEP 5. RUDDER

The rudder was cut out according to the layout. The remaining layout lines were used to locate the plug, and foam was removed where necessary to open up a channel to it. With long-nose pliers, foam was picked out of the plug core until the whole thing could be peeled away from the sides of the cavity and

pulled out. The plans were followed in removing the foam all around the winglet cut-out and rudder edges. The inside surfaces of the foam channel to the cavity were straightened and smoothed out with small sanding blocks. On the rudder, foam was milled from the bottom to create the mounting surface at the line drawn in the layout, so the depth was about 0.75" from the bottom edge of the rudder skin.

The plans were followed and layup #6 was completed. When glassing the bottom of the rudder, the layup was kept flat on the foam surface and squeegeed tight into the corners (i.e. minimum fillet). This was done in order to maximize the flatness of the surface that the belhorn would be mounted to, and facilitate positioning adjustments. In the winglet, layup #6 was extended into the belhorn cavity and a skin of BID was added to the exposed foam for a cleaner and more complete inside finish.

The plans were then followed until hinge installation was complete. The rudder return spring was also installed at this point.

STEP 6. BELHORN ALIGNMENT

While it may be possible to install the belhorn in one step by simply floxing it in place, it was done in two steps - first with 5-minute flox (5-minute epoxy and flocked cotton) and then with normal flox - for better control over its positioning.

The entire mounting end of the belhorn was covered with a layer of thin packing tape for release. A cheap brand was used because it is thinner and less bulky when wrapped. With the rudder removed from the winglet, the belhorn was positioned on the bottom surface of the rudder so it was just behind the hinge (Figure 10), the back of the belhorn fork was in line with the outboard skin (Figure 11), and the curved part of the belhorn fork reached the aft corner of the conduit cove. The belhorn was attached to the rudder in this position using two drywall screws with washers through the two large lightening holes closest to the back of the belhorn. (Figure 12) These holes were used because they are along the centre line, and because they are the larger ones so they will allow for more adjustment of the belhorn position if needed. The screws were tightened just enough to hold the belhorn in place but still allowing it to be re-positioned with a bit of force. The rudder was re-installed onto the winglet by attaching the hinges.

> *Note: As with ailerons, the rudder needs to be removed and re-attached several times. To make this easier, Clecos were used to temporarily hold the hinges in place. (This was VERY useful, and the credit for the idea goes to other builders.) When the hinges were screwed in position, additional 1/8" holes were drilled in line with the screws and the corresponding size Clecos were installed, then the screws were removed. When re-attaching the rudder, a 6-inch machinist's scale was slid between the knuckles of the hinge and pressure was applied on the leaf to hold it in position while inserting the Cleco. When no longer needed, the Cleco holes can be repaired with flox.*

With the rudder deflected, the curves of the belhorn fork should be able to tuck into the conduit cove close to the trailing edge, so the belhorn was shifted along its mounting surface as needed. Because it was still slightly out of line due to error in the foam surface, small shims were made from cardstock and placed where needed under the belhorn to bring the fork into perfect alignment.

The belhorn also has to be positioned so that it almost touches the inside surface of the outboard winglet skin in the belhorn cavity when the rudder is neutral. This maximizes rudder throw while ensuring that the rudder stop (which is installed later) will be the thing that actually stops the rudder, and not the belhorn hitting inside the cavity. It was done by first moving the rudder so the trailing edge was slightly inboard of neutral – maybe 1/16" - and the belhorn shifted so the end was contacting the outboard surface inside the cavity. Then the rudder was put back 'in trail' and this created the gap for the fork end.

STEP 7. BELHORN ATTACHMENT

Locators were made by putting dabs of 5-minute flox around the perimeter of the belhorn base – enough to keep it in position but not locked in. After the 5-minute flox solidified, the screws were removed, the belhorn was detached from the locators and the release tape was peeled off. The belhorn was then placed back into the locators and secured with the screws to verify correct alignment through full rudder motion.

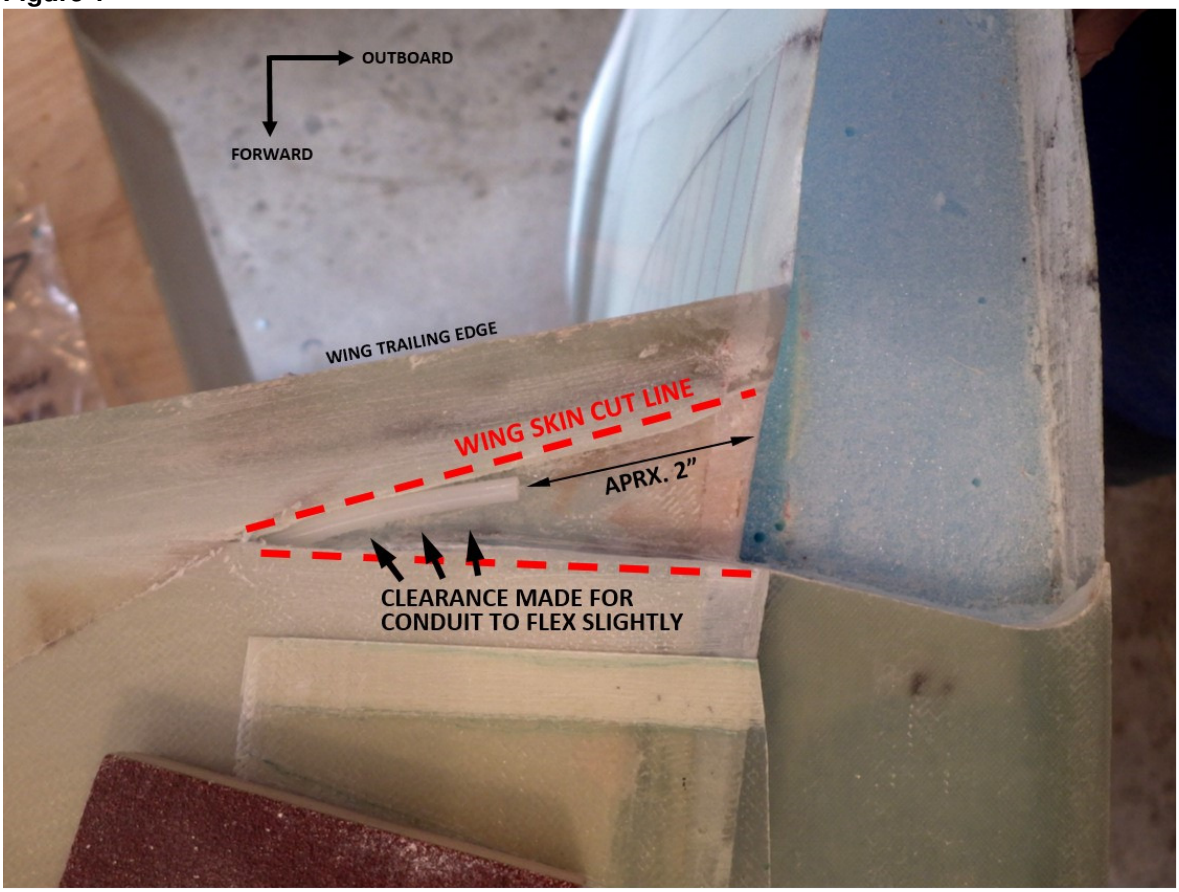
The rudder cable was attached to the belhorn and fed through the conduit, the rudder was mounted to the winglet, and the belhorn/rudder movement was actuated for the first time using the cable. The deflection, measured at the TE as shown in the plans, was 5.25 inches.

The assembly was taken apart, permanent flox was applied to the belhorn, and it was set into the 5-minute flox locators and secured again with the screws. When the flox was partially cured (enough that the belhorn stayed put), the screws were removed and the flox was allow to fully cure. As the flox cured, the rudder could still be deflected to verify that the belhorn remained in the correct position. There should be no reason for the alignment to be off at this point, but since the flox attachment is permanent, it was nice to be able to re-check it for peace of mind.

Finally, a layup was added on top of the belhorn, similar to layup #6, consisting of flox fillets around the belhorn, and two plies of BID at 45 degrees that covered it and created a glass-to-glass bond with the rudder skin.

JP

Figure 1



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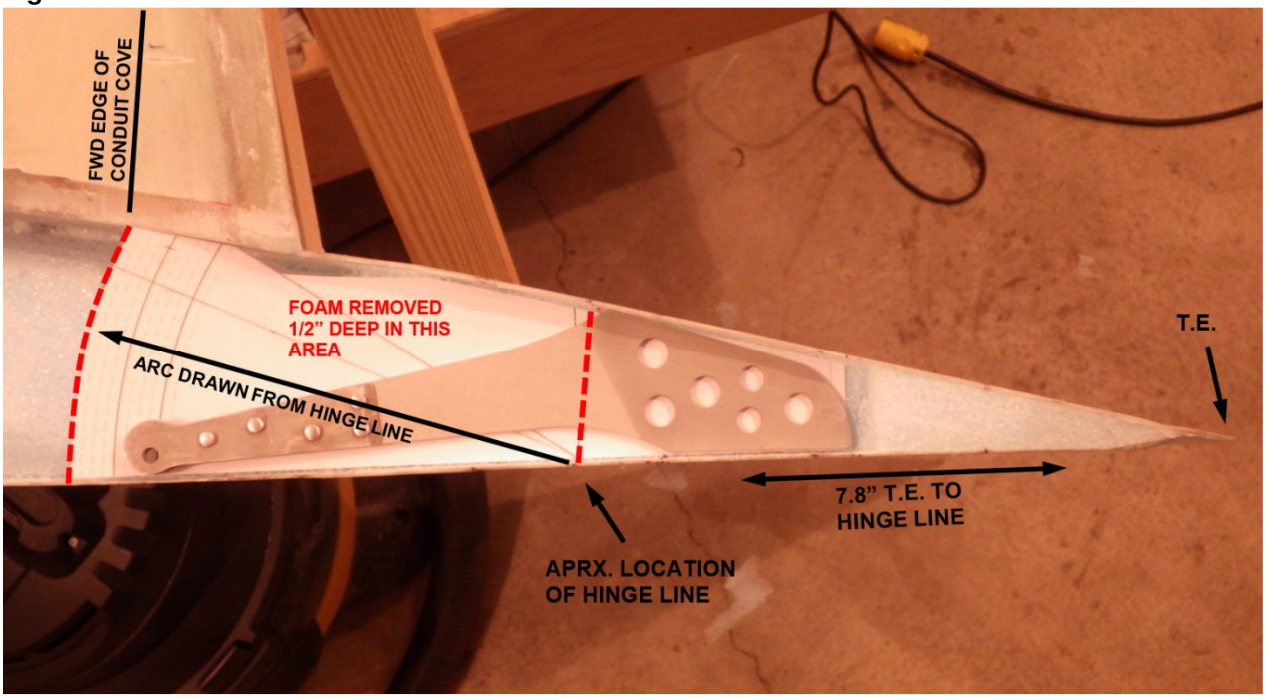

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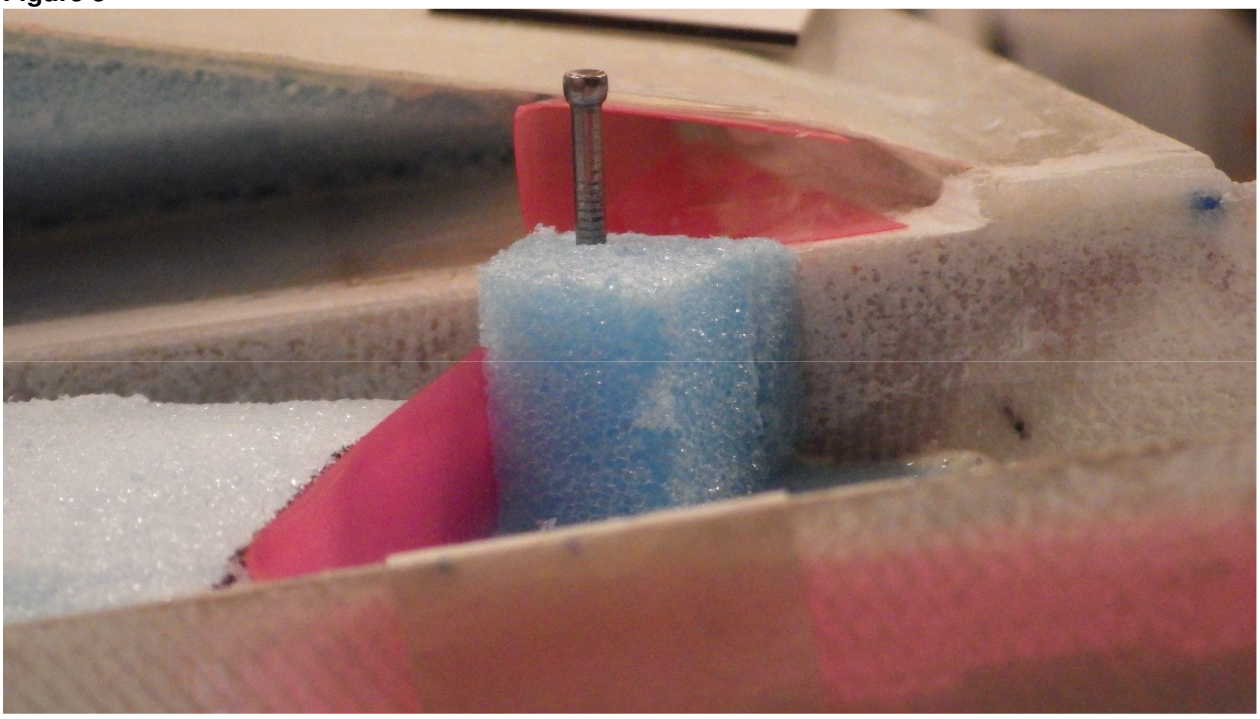

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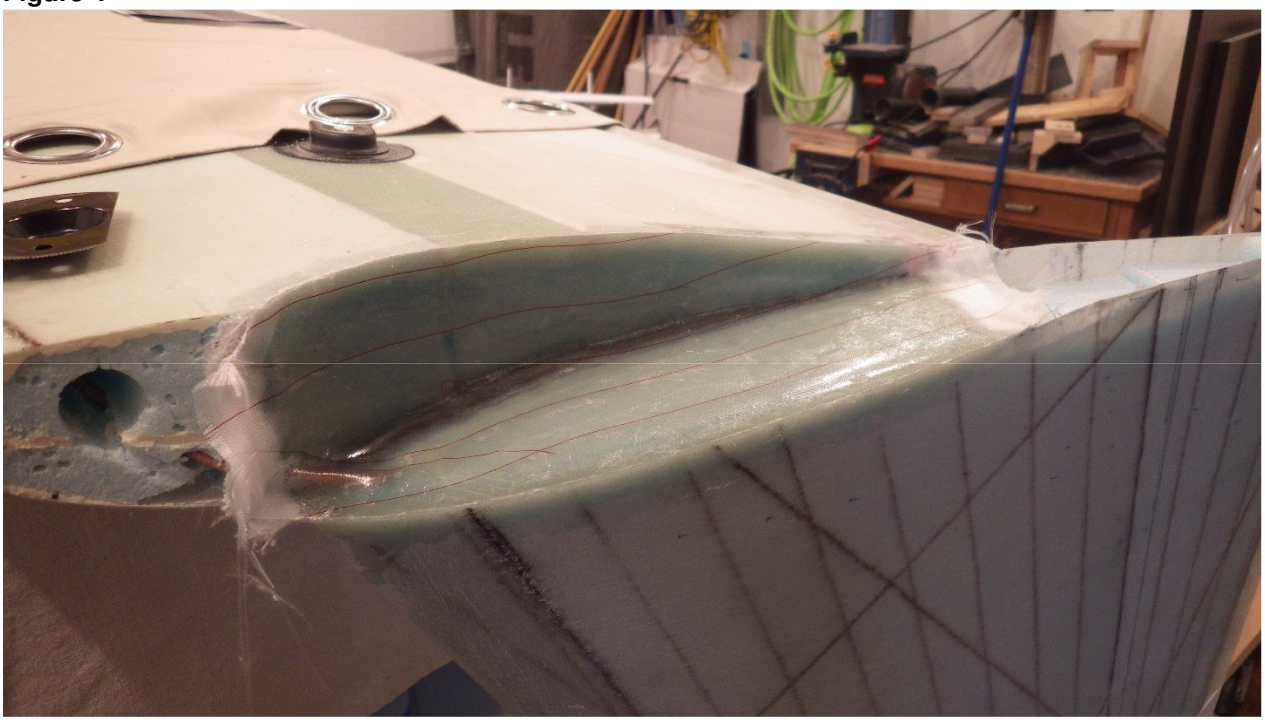

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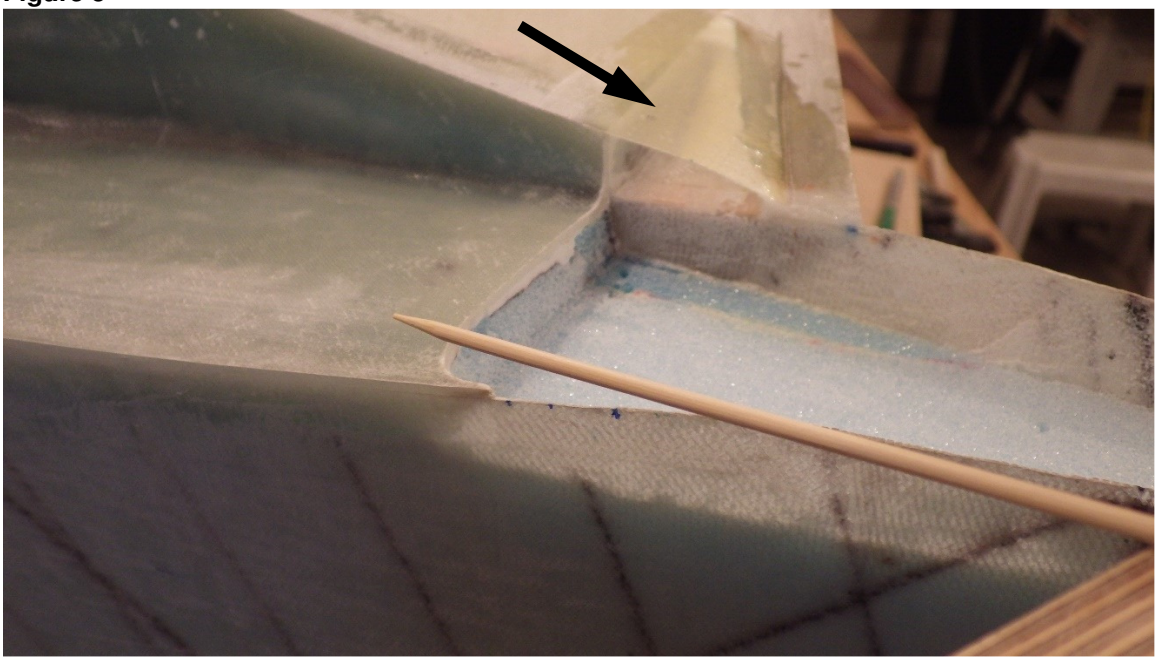

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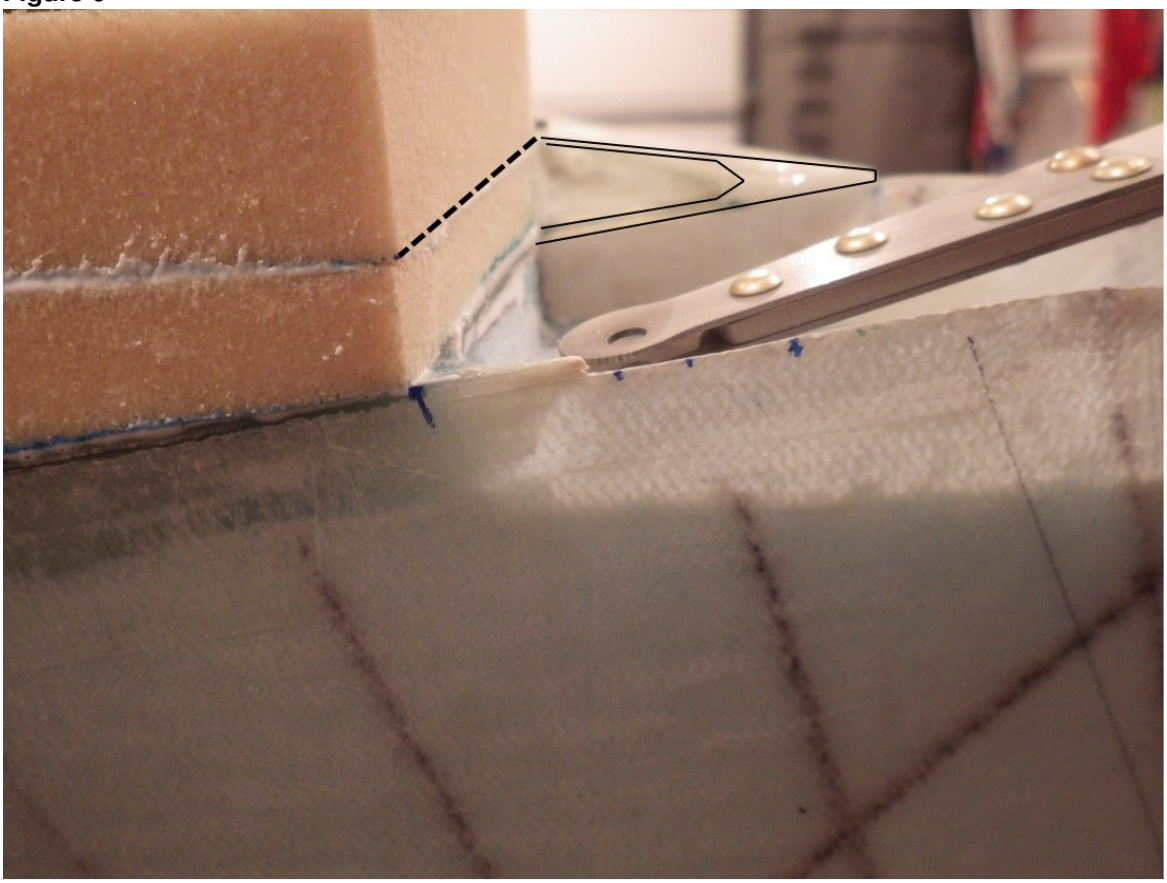

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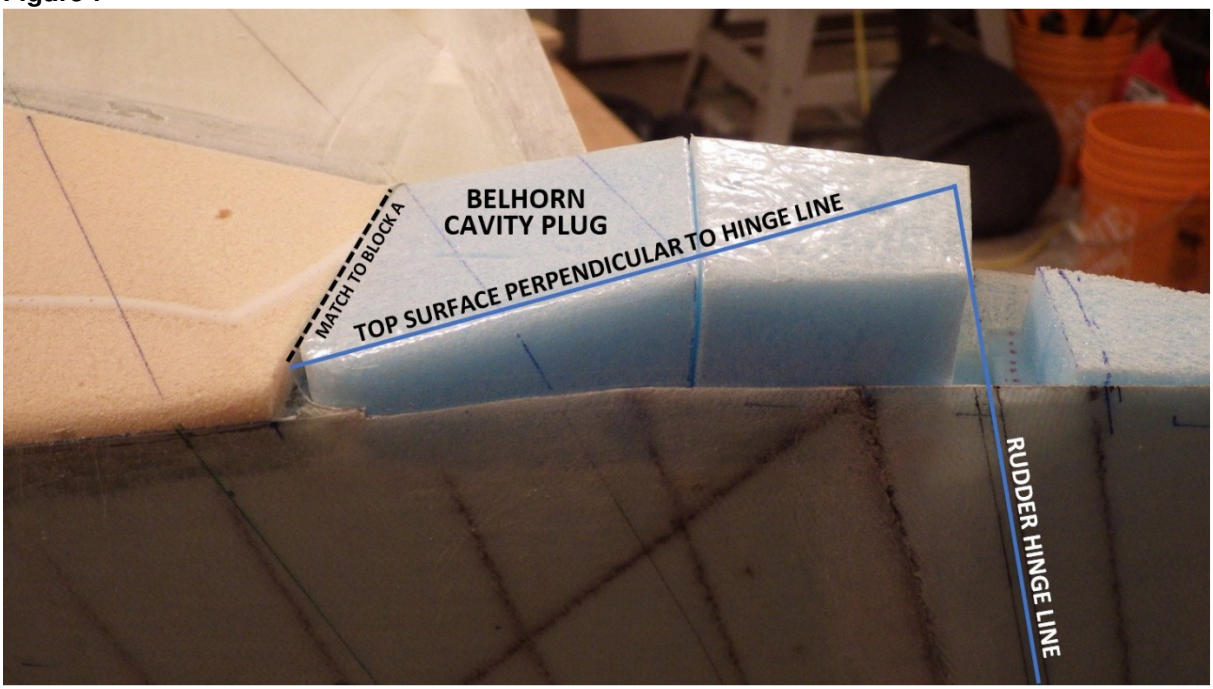

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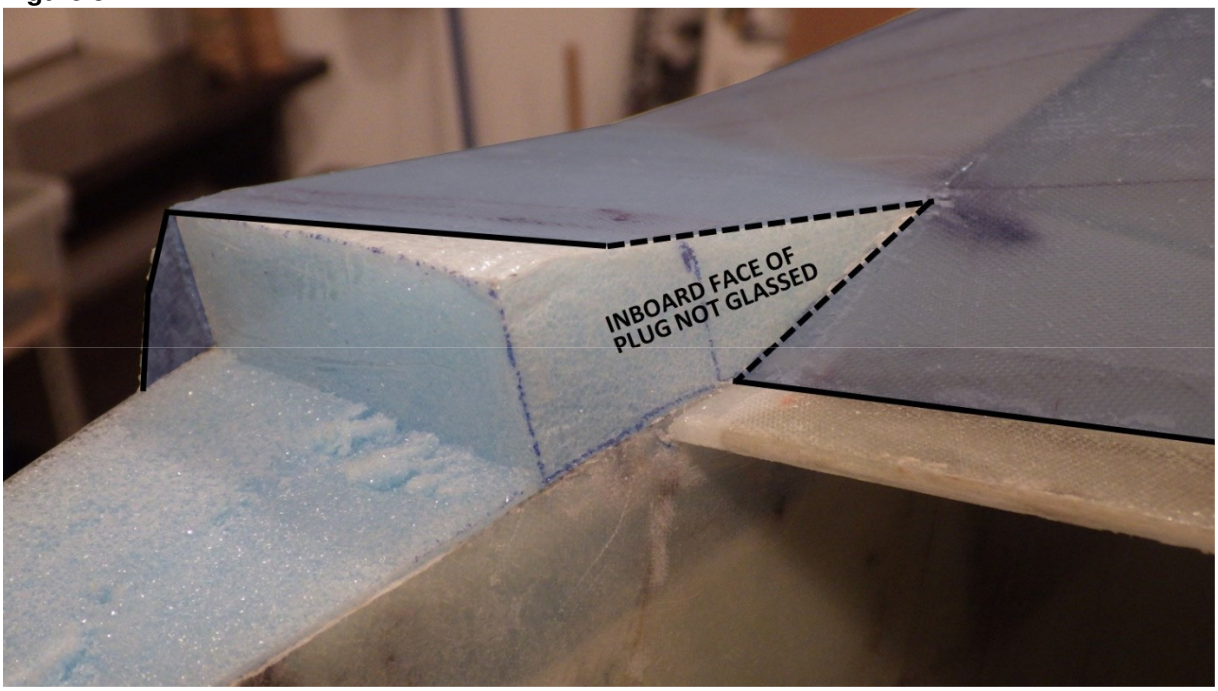

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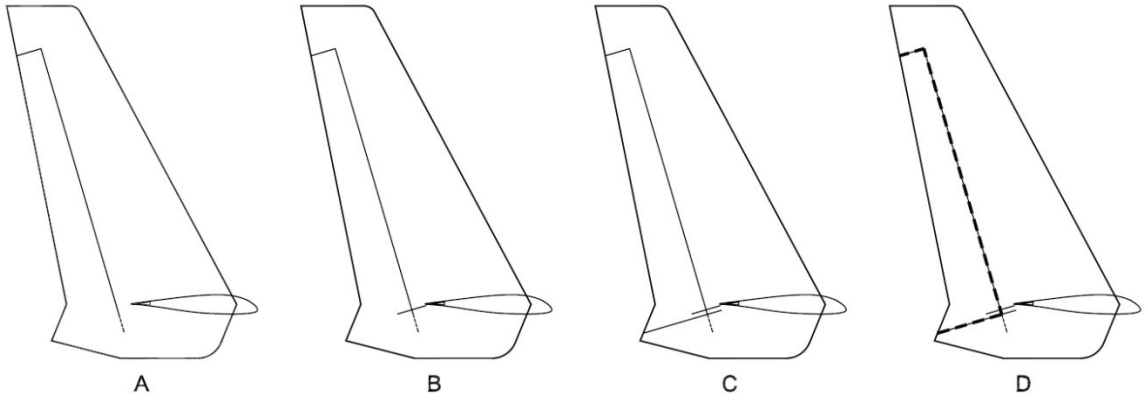
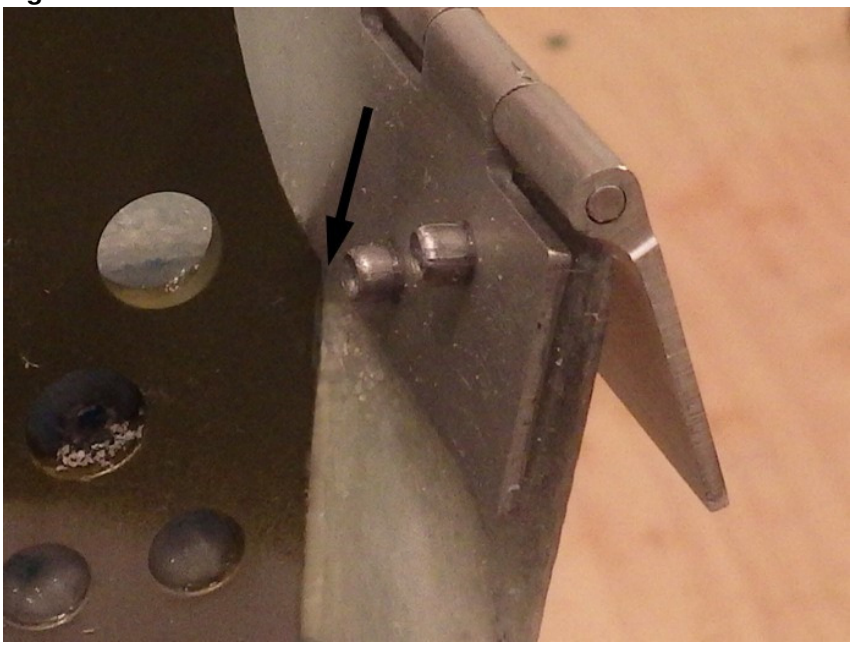


Figure 9

Figure 10



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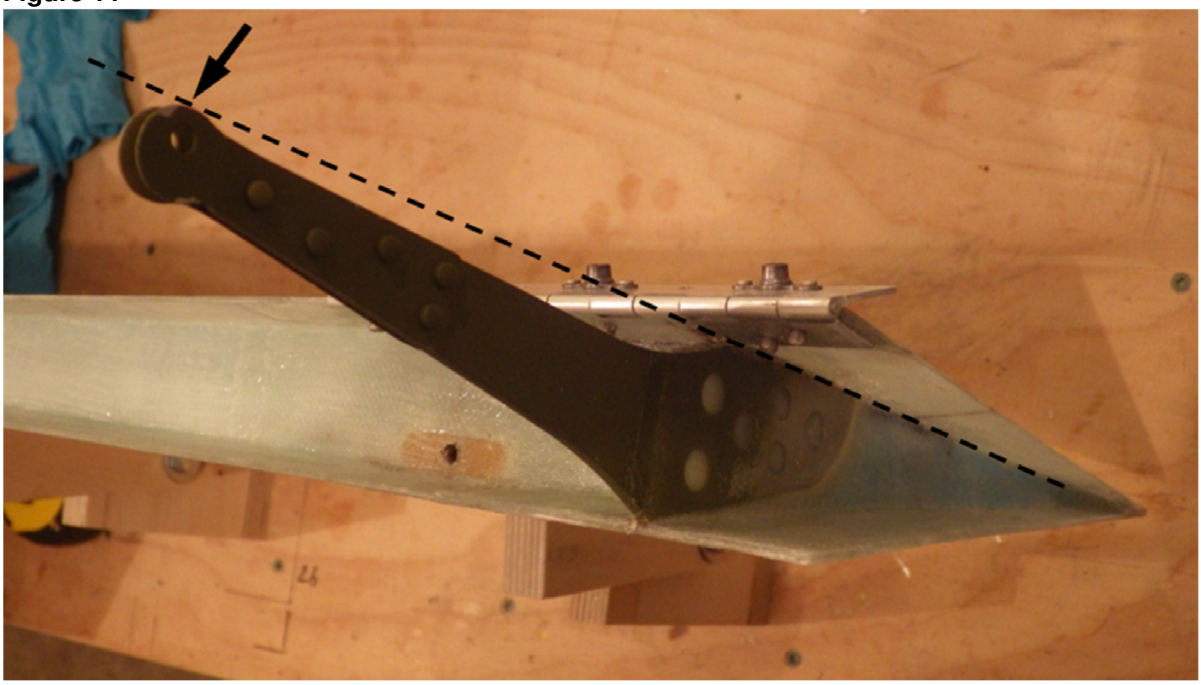

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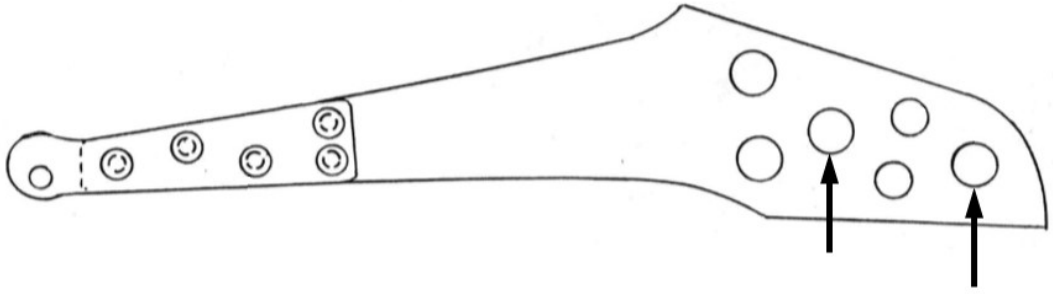
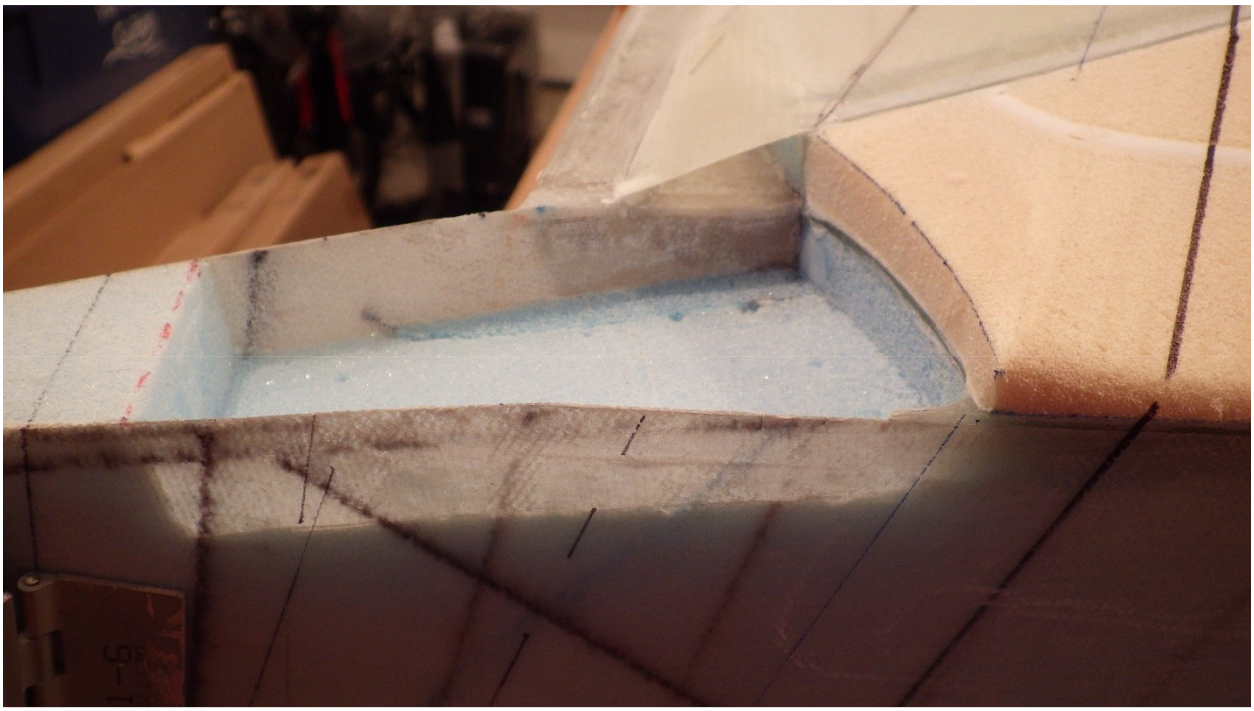
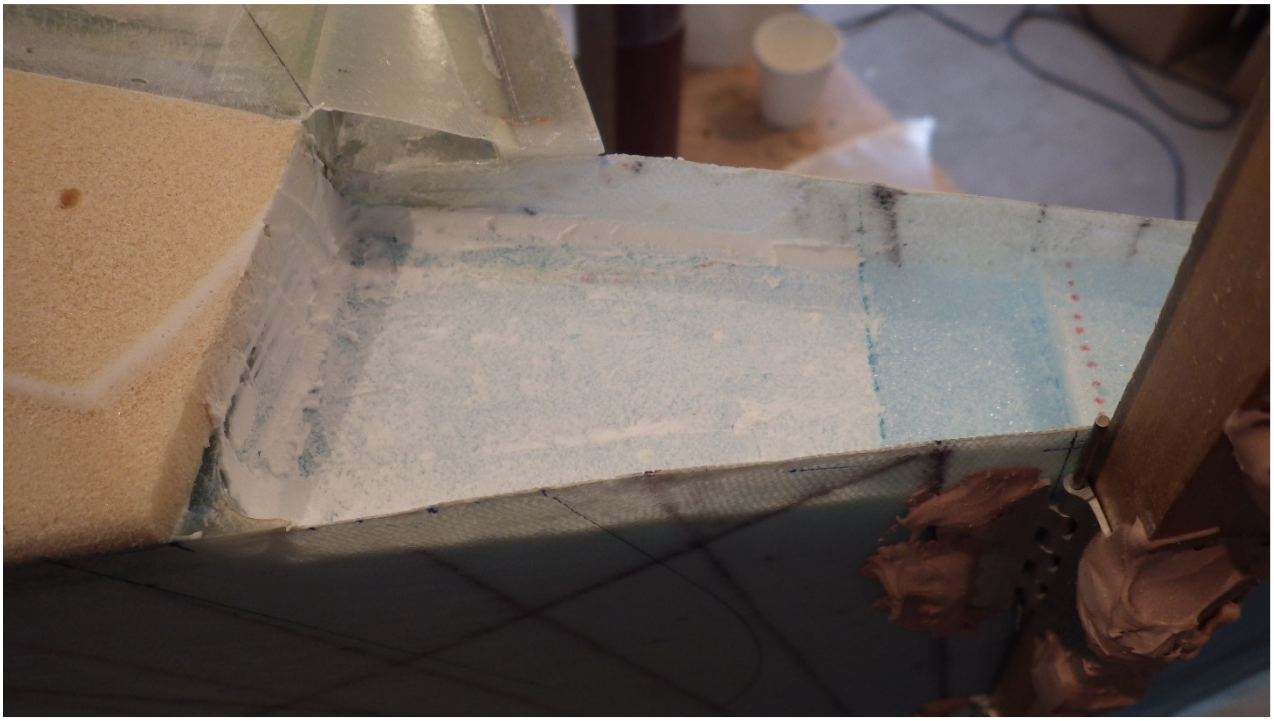
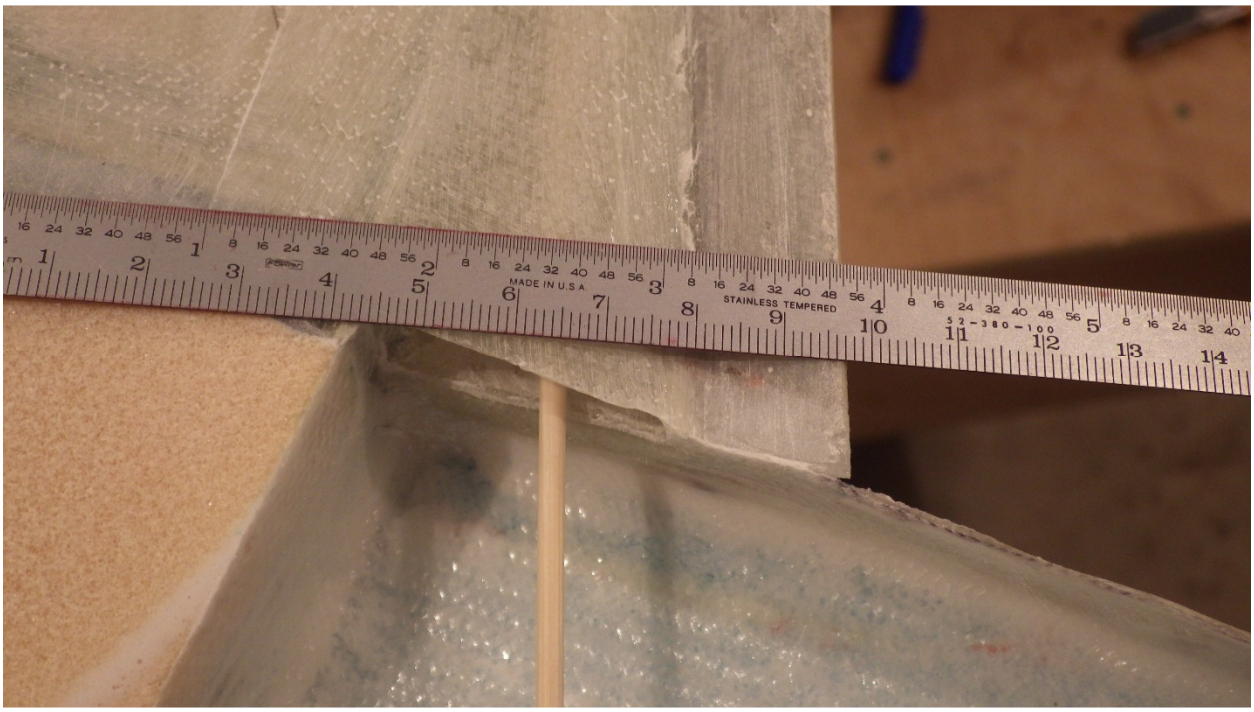


More Photos



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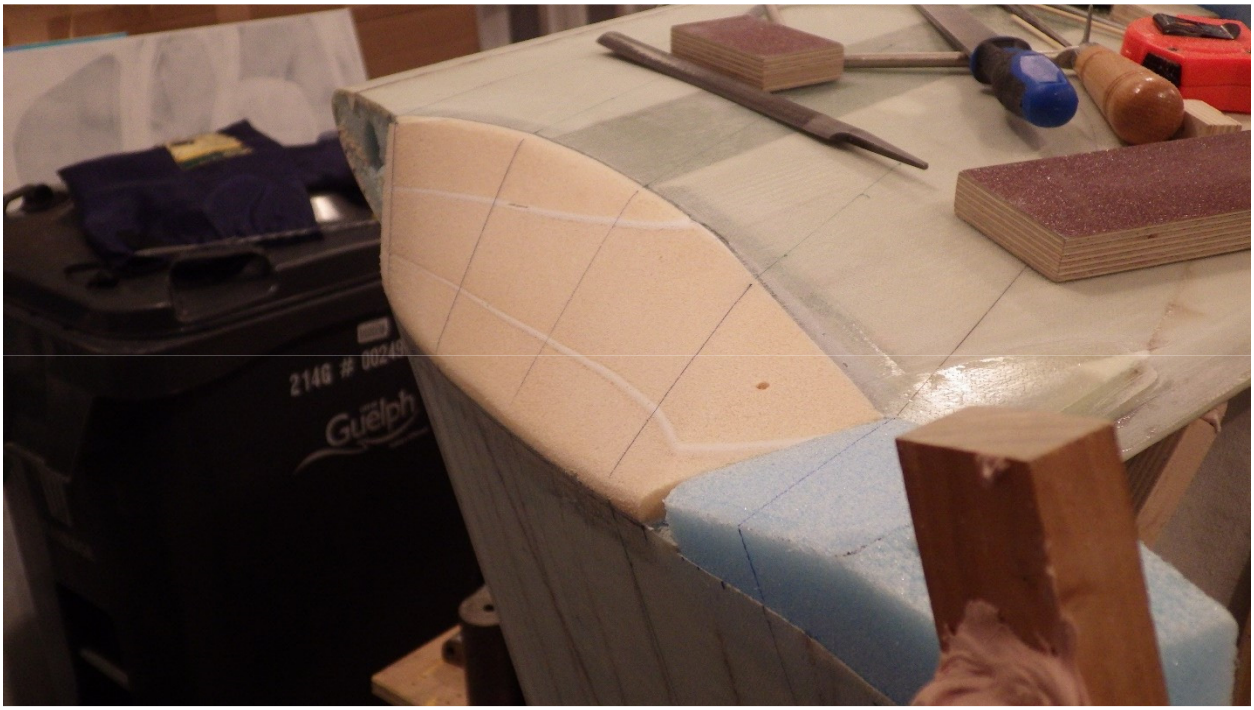
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