INTERNAL RUDDER BELHORN INSTALLATION
PERPENDICULAR (BOTTOM MOUNTED) METHOD

OVERVIEW

These instructions describe the installation of the internal (hidden) rudder belhorn given 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. 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 using a polystyrene plug that the outer winglet attachment layup went over. 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 the 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" if part of the fork is going to tuck into the cove, and maybe another 1/8" to cover error. 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 rotates.

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 face of the conduit cove to the winglet’s outboard skin. (A straight line would have worked too.) Another line was drawn across the winglet foam at the hinge line. Then a Dremel with a router attachment was used to remove about 1/2” of foam between this line and the arc to create a depression in the winglet. This depression would form the top of the conduit cavity when the wing was right-side-up.

STEP 2. INSIDE LAYUPS

The triangular foam corners were removed as per Step 4 of the plans, from the leading edge to the belhorn cavity. This foam was not removed in the belhorn cavity. The forward face of the conduit cove was protected with a release barrier (thin flexible plastic, e.g. from a report cover/sleeve) so that overflow from layup #1 would not ooze in. Another release barrier was placed along the forward face of the belhorn cavity and held in place using some small blocks of foam secured with nails. (Figure 3)

Then layups #1 and #2 were completed. They did not extend back as far as the plans require, but only as far as the triangular foam corners were removed – to the conduit cove and belhorn cavity. To compensate
for this, one more ply was added to each layup, bringing the total number of plies to 9. Foam block A was not installed immediately after layup #2 as instructed in the plans. Instead, the layup was peel plied and allowed to cure. (Figure 4)

After layups #1 and #2 were cured, 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 wing skin that had been opened up at the conduit cove, and was trimmed about ¼" larger than the opening. 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 this area would later be strengthened by the overlying plies of the winglet attachment BID (layup #3).

The peel ply was removed from layup #2 and foam block A was microed into position according to the plans. After cure, the aft face of the block was trimmed so it lined up vertically with the trimmed edge of layup #2 at the conduit cove and with the belhorn cavity depression. A line was marked across the aft face of block A, level with the top corner of the conduit cove and parallel to the winglet foam surface. (Figure 6) 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.

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 plug was shaped to fit snug into the 0.5-inch-deep depression that had been milled out of the winglet. The forward height of the plug matched block A, which had been carved to the height of the conduit cavity. (Figure 7) The plug sloped back toward the TE at an angle perpendicular to the hinge line. 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 so it had a snug fit without distorting the winglet skin. (This required removing and re-applying packing tape.)

Note: The depth of the depression and the height 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 as it is being adjusted; (2) it makes it easier to glass exposed foam inside the cavity for a cleaner finish, if desired; (3) when installing the rudder cable (initially, and if it ever needs to be replaced), it can be fed through the belhorn cavity if there is enough space for long-nose pliers and a dental mirror; (4) when the plane is in service, it will be a bit easier to peek in and inspect the cable attachment without removing the rudder.

Layup #3 was completed. Since the BID layers could not be stretched into the inside corner where the wing meets the plug, the BID was cut so it covered the top of the plug and also covered the patch over the conduit cove, but left the inboard face of the plug un-glassed. (Figure 8)

The lower winglet was then attached according to the plans. When shaping the lower winglet foam, just enough material was cleared out for a close fit to the plug and overlying layup. No micro was applied aft of the glass near the plug because some of the foam in that area would later need to be removed 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 further down toward the bottom of the winglet. With a set square, a perpendicular line was drawn from the vertical cut line to about 1/8" below the wing TE. (Figure 9B) This 1/8" dimension was specific to the geometry of this conduit cove relative to the TE. The perpendicular line represented the
general alignment of the mounting surface for the belhorn at the bottom of the rudder, and also the top of the belhorn inside the rudder conduit cove. The objective was for the bottom of the rudder core to align the belhorn so it positioned the rudder cable in the aft part of the conduit cove when the rudder is fully deflected. Another parallel line was then drawn about 0.75” below this to allow for the glass-to-glass bond at the bottom of the rudder. (Figure 9C) This was the rudder bottom cut line. The layout was completed on both sides of the winglet.

Note: This bottom cut line is a bit lower than the plans location in order to create enough of a flange for the layup that will cover the belhorn, so the glass-to-glass edge is not too narrow. 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 is to retain it under the rudder deflection loads, so a narrower G-to-G bond might be adequate.

STEP 5. RUDDER

The rudder was cut out according to the layout. (Figure 9D) On the winglet, the layout lines were used to locate the plug, and foam was removed as necessary to open up a channel to the plug. 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 cavity. 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 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 outboard surface inside 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 re-attached in the locators 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 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.

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

- OUTBOARD
- FORWARD
- WING TRAILING EDGE
- WING SKIN CUT LINE
- APRX. 2"
- CLEARANCE MADE FOR CONDUIT TO FLEX SLIGHTLY

Figure 2

- FWD EDGE OF CONDUIT COVE
- FOAM REMOVED 1/2" DEEP IN THIS AREA
- ARC DRAWN FROM HINGE LINE
- APRX. LOCATION OF HINGE LINE
- 7.8" T.E. TO HINGE LINE
- T.E.
Figure 5

Figure 6
Figure 9

A  

B  

C  

D

Figure 10

![Image of rudder installation](image-url)
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