Rudder Stiffeners

The first step in rudder construction is to gather up the stiffeners made of .025 formed angle. You have to mark about 1/4 inch on either side of the outermost holes on the inside of the rudder skins, and cut each piece of angle to match that size. After I used my band saw to cut the stiffeners down to size, I used my break to bevel one end and taper the other. I measured and cut the first stiffener, then subsequently used that piece for a stencil to mark and cut the others.

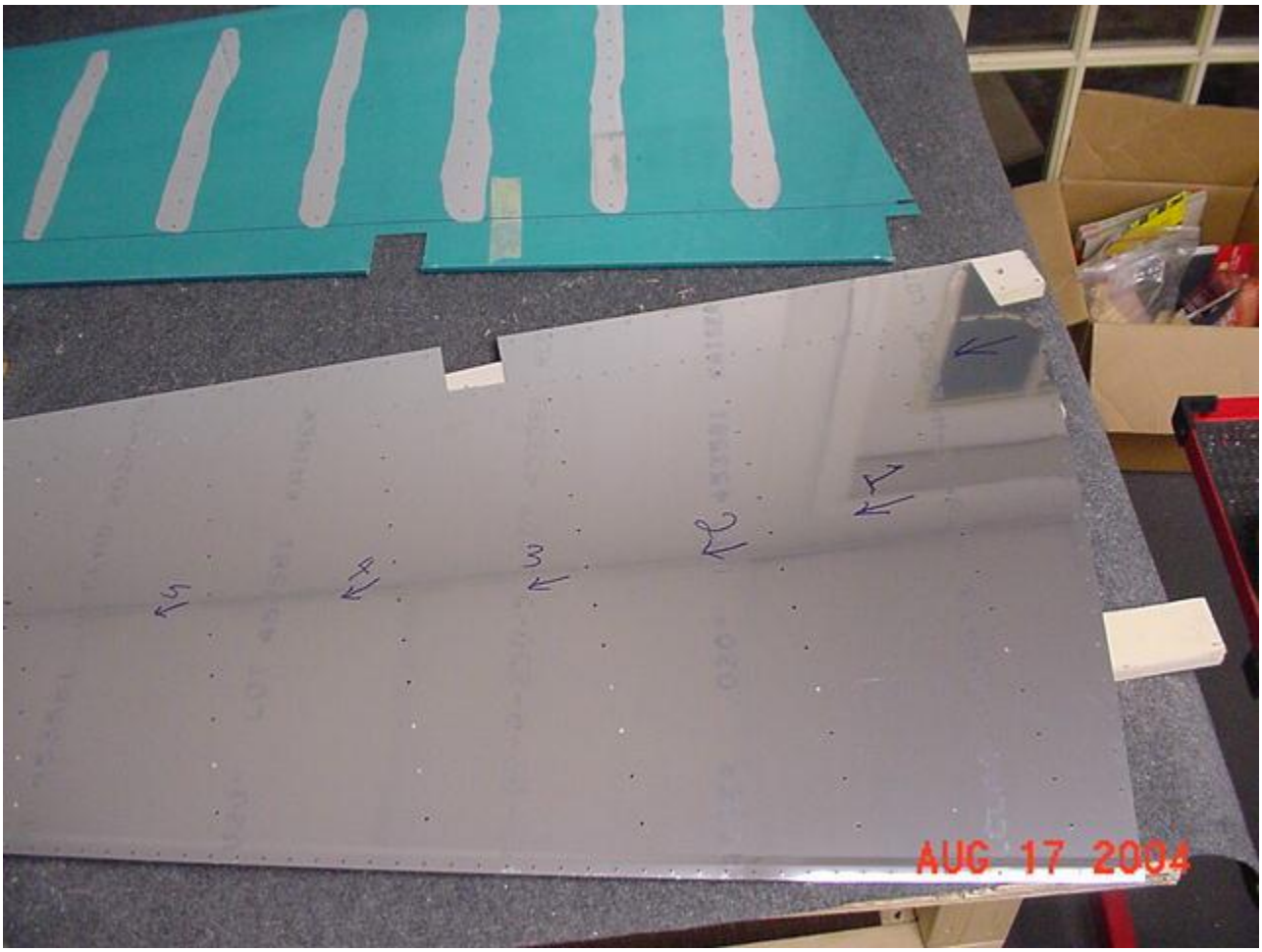
As part of this process, I numbered and marked arrows on the stiffeners and the skins to make sure I got the orientation of the stiffener/angles correct. These pieces end up being nested together inside the closed rudder "sandwich" and the stiffeners on one skin have to form a sort of a box with the stiffener on the other skin. So they have to be riveted in opposite orientation.

The bold line on the right is where the spar sits. The arrow at the bottom shows where the "open" side of the stiffeners will sit. I marked 1/4 inch on either side of the outer holes and cut all the pieces to length. The layout shows the approximate position of the stiffeners. I don't know what the 38 is at the bottom. Something the Czechs wrote on there.

The stiffeners have to be marked for drilling. They are to be drilled 5/16 from the back of the flange, not the edge. I used a green Ultra Fine Sharpie for this. Since you have to back-drill the stiffeners using the pre-punched skin as a guide, you also have to mark the position of the first hole on the stiffener. You could measure that, but I eyeballed it, having positioned the stiffeners and choosing the best fit of the stiffeners between the end holes. I used a red ultra fine Sharpie to cross mark the location of the end hole. That way, I can see the green line through the holes on the skin, and I also know the end hole drill point has a red hash mark on it. It's very easy to see the red and green through the tiny holes.

The way I drilled the holes in the stiffener/angles was pretty much per plans. I used a pair of clamped 1x2's to hold the stiffeners. I stuck the tapered side of the stiffener down in the crack between the boards, and laid the skin over the top. I then positioned the red cross mark under the end hole and drilled it through into the board @ #40. I clekoed that hole and then made sure the green line was visible int he holes and drilled the other end and clekoed it. Then I drilled all the holes in between. There are 7 stiffeners on each skin. And you have to be very careful to orient the skins and the stiffeners properly. The red cross mark always goes on the spar end, forward.

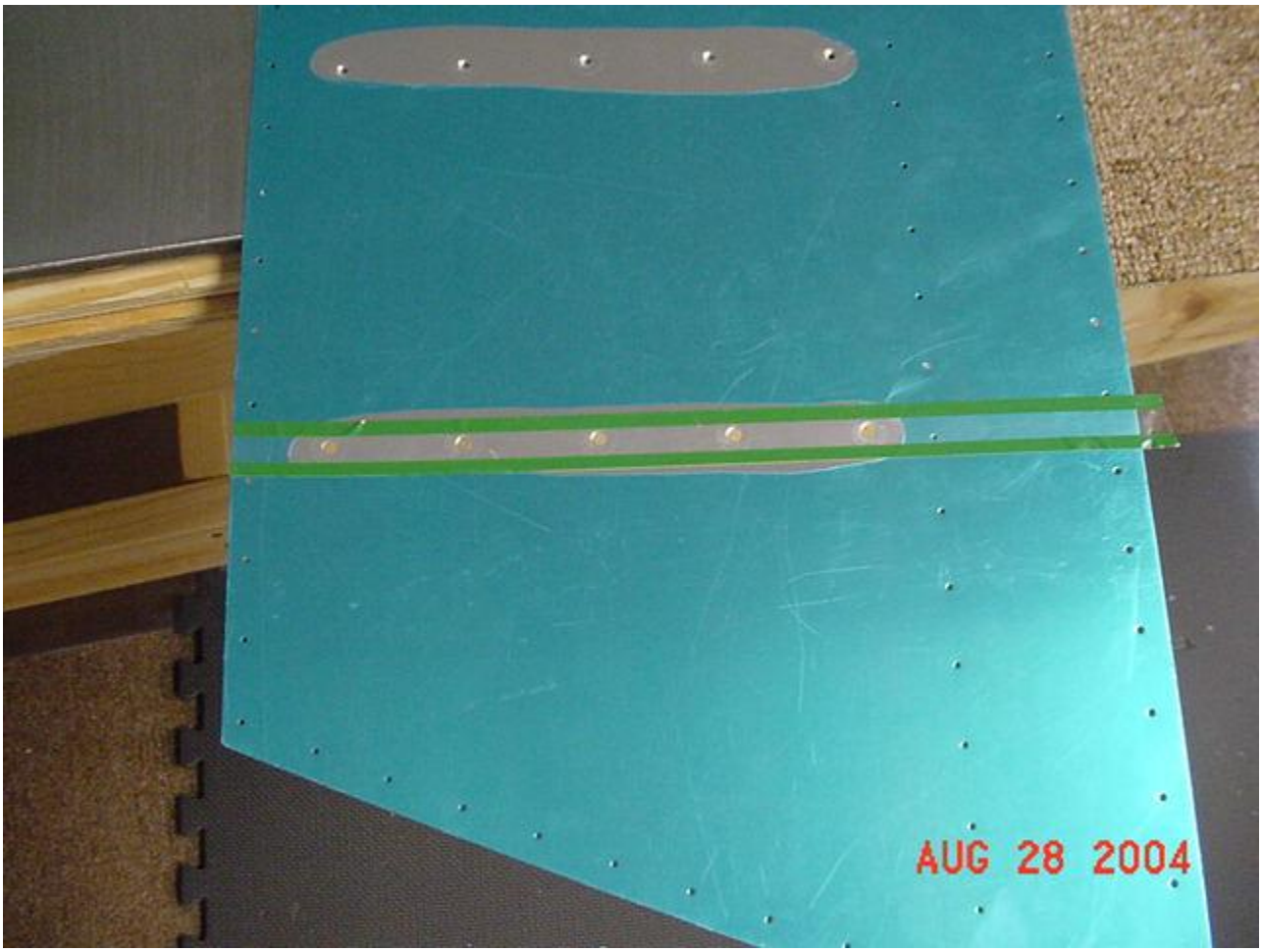
Notice in the pic above how the taper is to the doubler (aft) side of the skin. Also notice that the "open" side of the stiffener faces the same direction as the arrow. Just for good measure, I put numbers and arrows on the stiffeners and near the line of holes they will be attached to. It's VERY easy to get confused.
Another note: I used several 1x2's to lay under and support each skin as I was drilling them. They are very flimsy in their natural state, and having the boards keep everything at the same level is essential.



You can see the upper skin in the pic above has just the vellum removed from around the holes. I did this with a pencil soldering iron. This stuff is really thin and easy to remove.

One the inside of the skins, I could care less what they look like, so it was easiest just to go ahead and remove ALL the vellum (plastic protective film).

Now I am ready to debur and dimple these parts prior to riveting! At this point I was working on all 6 empennage control surface skins in a big batch. The processes and tools are the same, so it's fewer steps to get these parts all "stiffened" together.
Deburring the Rudder skin was easy. Dimpling was scary at first, but turned out to be a simple affair. I did all the empennage control surface skins and stiffeners in one big lot. That did save me a little time. And once you establish a good rhythm, you can make pretty good time on one of these repetitive processed. It was FUN!



I used 3-3.5 rivets and a 3x gun to attach the stiffeners to the Rudder skin. That process was also fun. I used that 3M/Scotch tape to hold an entire row of rivets in place, flipped the piece over (very carefully!) and oriented the stiffener over the rivets. No clekos this time. I found that when I pressed the stiffener down over the rivets that the pieces sat very nicely in position. Theoretically, I should have started in the middle of the stiffeners, I supposed, but I didn't. I went from end to end. Carefully making sure I didn't go off the end of the back plate. Another good thing to do is bop the gun down on the rivet before hitting the trigger. You get that good metallic sound and a solid stop, and you know you can have at it!

Rudder Skeleton

Now it's time to go back and make the rudder skeleton. I hadn't enough coffee in my system at 7 am when I started looking at this part of the plans, but I finally figured it out... I think!

I gathered up the parts and laid them out. I set the exploded view in front of me, and then read the first few pages of the rudder skeleton part of the plans. I was a little confused about using a shim to square the rudder horn. Then I figured out that the formed bottom rib of the rudder fits between the rudder horn and the spar. A shim is necessary on the back of the rudder horn below the rib to complete the "sandwich" of parts. This keeps all the thicknesses the same and ensures that everything is flat. "Square"? OK... I guess...

Plans call for a 3/8 bolt to hold parts together. I decided to just use the control rod ends supplied with the kit. You simply line all the parts of the sandwich together and tighten the "bolt". At the bottom of the rudder, I used a flat plate to make sure everything was "square". Lining these parts up is a snap once you get the idea. The pics in the plans are very helpful.

I didn't tighten the control rod end that much. I decided to clamp everything, using the rod end to make sure the big hole was centered well enough. After clamping, I drilled everything, including the .032 shim I made from floor panel scrap, using a #40 bit and clekoed as I went.

The bottom of the rudder has a doubler that goes on the outside, opposite the rudder horn/rib/shim sandwich. The doublers at the middle and top of the rib go in the inside, which is to say the aft side, of the spar. I used my rod end and my fingers to line everything up and hold the parts in position. I then drilled #40 through all of the pre-punched holes and clekoed as I went. This was easy peasy.
I drilled the two flat doublers to the spar and drilled them @ #40. Then clekoed and drilled up to #30. Deburred and then riveted using 4-5 (and longer) universal (regular?) rivets. This was pretty fun. I had to turn the pressure up on my 4x gun to 40 pounds to get a good fast buck on these rivets.
The big job was the assembly at the south end of the rudder. I first drilled all the parts (without the R-010 rudder horn bracket in place) up to #30 and deburred them. I riveted the top row of rivets on the doubler to get it in place. Then I riveted the k1000-6 nutplate, which hold the 3/8 inch rod end. I then used 4-9 rivets on the thickest sandwich of parts.
Having riveted the major parts of the rudder spar, I moved on to the counterweight/top assembly. Basically, you trim the small "rib" to 5/8 inch and rivet it to the big top rib back to back. The smaller part has a joggle in it that I will drill to the R-002 spar (already assembled) later on. Waiting for verification of what angle I am supposed to use to help support this counterweight/rib assembly.

Just for funsies, I put the R-010 under the spar and lined up the pre-drilled holes on the rudder horn. I went ahead and confirmed that the Spar/counterweight assembly measures to the nominal 47.5 inches. I kind of set all the skeleton parts together on the bench to better understand the creation of this assembly. It really makes beautiful sense once the light comes on!
The counterweight skin was the next task. I wasn't sure if I had the correct piece, but guessed at the U-shaped piece bundled with the elevator counterweight skins. Guess they forgot to mark this one.

The c/w skin is bent pretty close to shape, but I had to coax the bends a bit to form around the corners at the leading edge. There was quite a gap at the corners, and of course the skin needed to be more or less flush with the r31 assy. It only took about 10 minutes to bend/re-bend the piece until it sat rather passively on the rudder.
As the plans say, you can't use too many clamps on this part. I used all 10 of my little cleko clamps and a couple longer cleko clamps. I measured for the flange centers, marked the skin appropriately, measured for the rivet holes and drilled everything @ #40, clekoing each hole as I went along.
I went ahead and clekoed the rudder skeleton parts together. It's a nice piece. I'm starting to understand how this stuff all works, and I'm amazed at the design that these parts have undergone. Very nice.
I was on a roll this night, so I grabbed a rudder skin and the doubler that goes at the trailing edge. I lined the bottom edge with the edge of the skins and carefully clamped the very outer edge. I lined up the top end of the parts and clamped them. I used at least 6 clamps to hold these parts tightly and carefully together. I ended up with about 1/32 of the doubler exposed. I used a #40 and drilled through the doubler using the pre-punched holes in the skin, starting in the middle and clekoing every third hole. Then I swapped skins and back-drilled through the pre-punched holes using the doubler as a guide. This process was easy enough to be "cathartic" or "therapeutic"!

Rudder Jig (Fixture)

Now it's time to construct a wooden fixture to assemble the skin and skeleton of the rudder.

I searched and searched and searched for the right pieces of wood to make the fixtures. I couldn't find anything dimensionally stable enough for the exacting dimensions call for in the plans. Well, OK, I lied. I used scrap particle board shelves I took out of my office about 10 years ago. This is the GOOD stuff. Probably about 30 - 40 years old. Dense. FREE! I thought it might fall apart, but amazingly, it is no where near the crap they sell today.

I laid out the dimensions on the boards and drilled holes in the lower corners. Used a hand saw to cut the long center cuts and planed on using a jig saw to cut across the bottom. No blades in the jig... all broken... duh. So I used a coping saw instead. And a rasp and file.

The important thing to remember here is that the location of the kerf at the bottom of the "slot" and the width at the top opening of the "slot" are the important dimensions. Then, as long as the boards of the fixture are square and plumb, you got no problems.

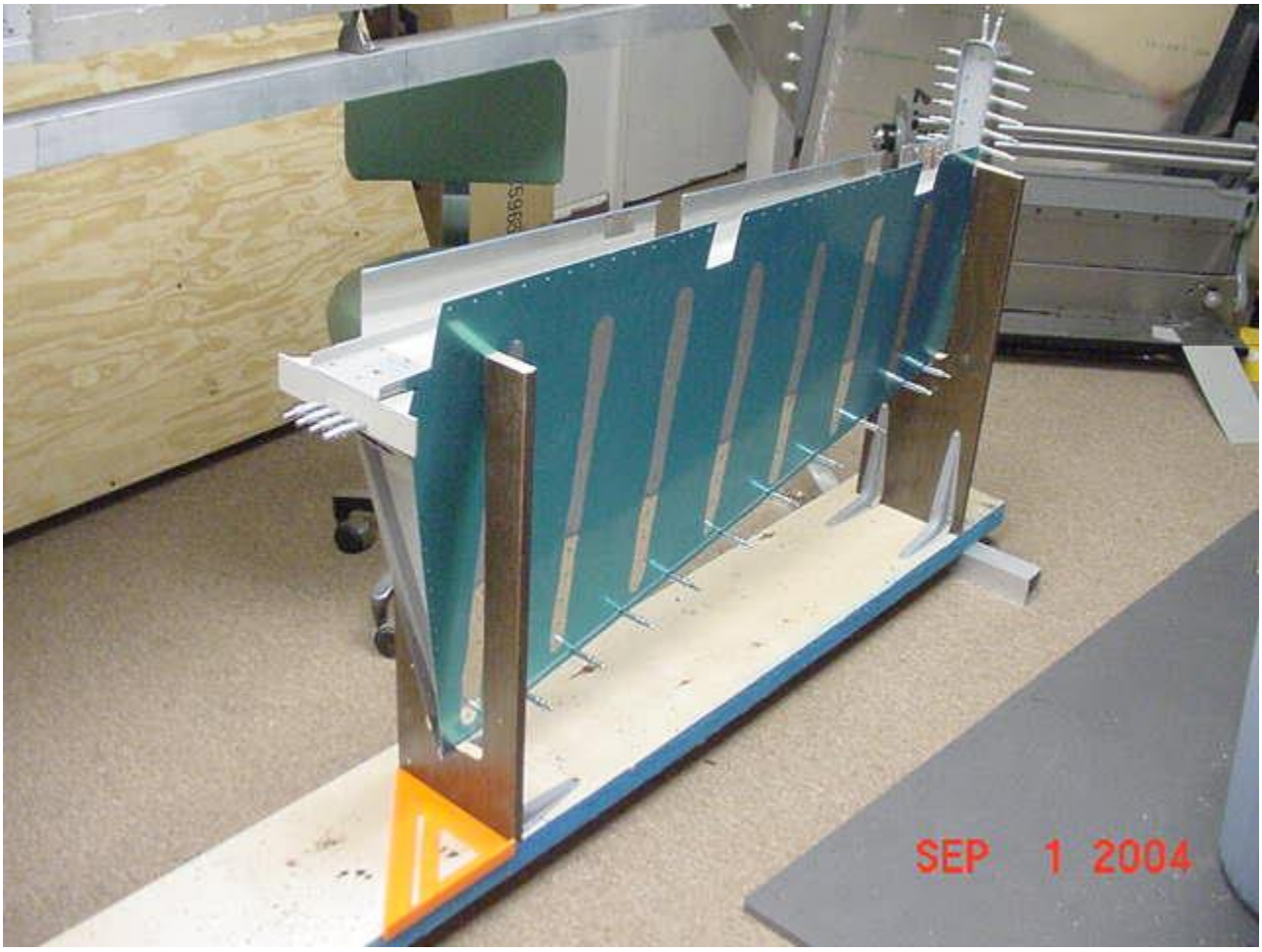
I mounted the boards on my handy beam that I used earlier in the construction of the HS and VF. I put the boards PERFECTLY (hah!) along one edge and marked on the beam 41 inches on center. I used a speed square to make sure the boards stayed square when screwing down the boards with shelf angle brackets. I then verified that I had 41 inches along both sides of the fixture between the boards.

On nice thing about using this shelving is that it is so square on the ends that the boards stand straight up on their ends without support. It makes locating the angle brackets VERY easy.

Rudder Skins

At this point I deviated from the plans a bit. I already had the skins clekoed with the trailing edge doubler in between.

Rather than take this all apart and clamp the skins to the skeleton, I just put the skins int he fixture, and then dropped in the skeleton. It WANTS to go right to place! SWEET!
Another deviation from the plans: Don't bother finding the centerline of the lower rib. The spar is 5/8 wide and the rib is 3/4. The pre-punched holes are centered on 5/8 on the skins, so drawing the lines on the rib was a waste. Instead, I am just going to clamp the rib flush along the bottom edge of the skin. Easy peasy!

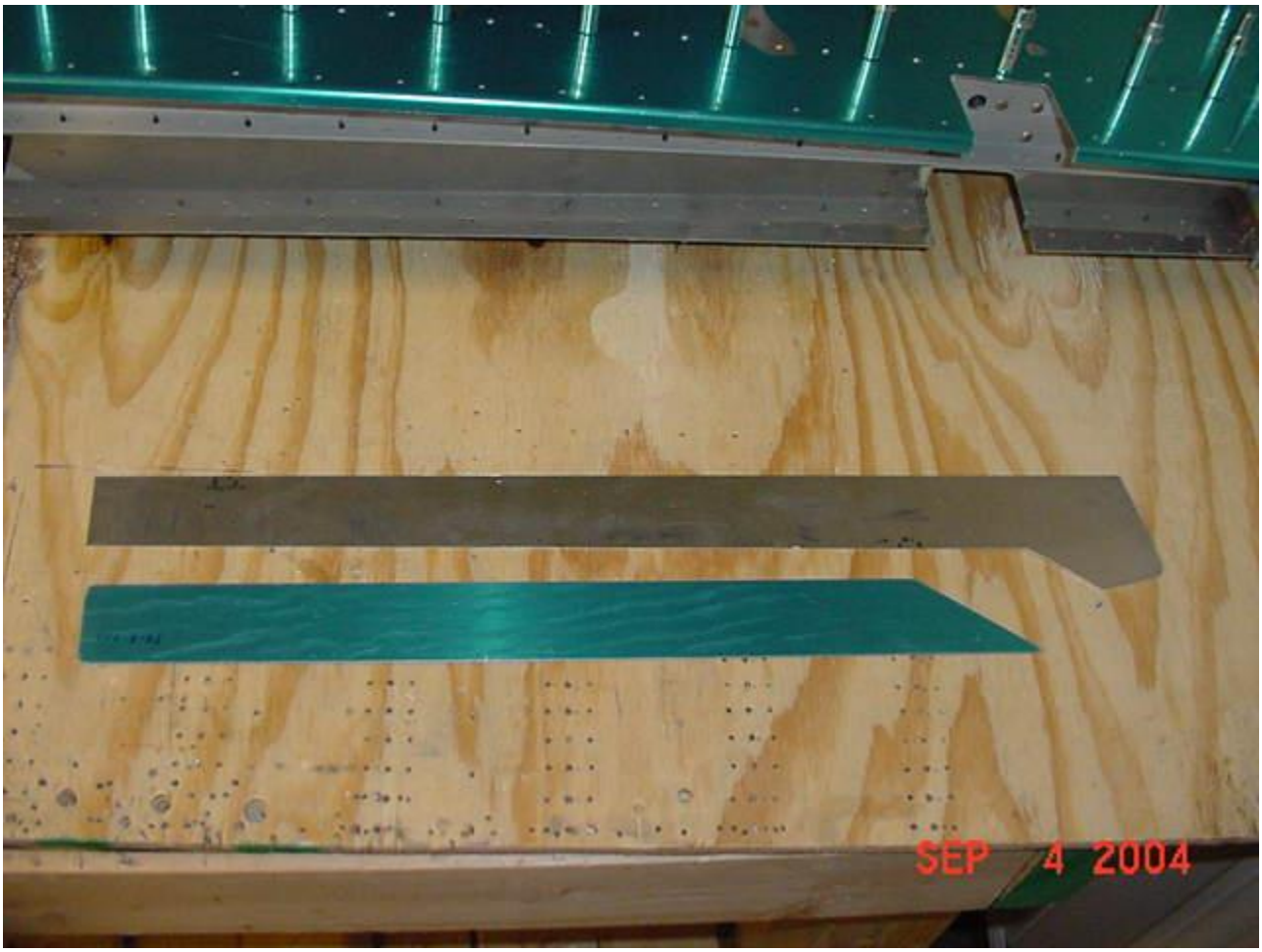


I double checked the dimensions of the fixture and I used a straight edge to check the trailing edge for straightness. I used a #40 bit and drilled the skins to the skeleton after lining up the flange centers with the pre-punched skin holes. I clekoed every 2nd or 3rd hole as I went along.

I removed the rudder assembly from the fixture and set it on my work table, still all clekoed together. I marked the extra rivet line on the counterbalance weight, mimicking the pre-punched holes directly above.

The rudder assembly is now ready to D&D and then rivet together. COOL!

I dimpled and deburred the skins and skeleton. I did not use the C-frame at all on the skeleton, but of course did use it on the skins. This was a fun little process. I had to hand squeeze a few places and countersink others.
Before final assembly I made up some replacements "skirts" to replace the R-022 doublers. These pieces are used to attach the fiberglass fairing. Unfortunately, they do not close the ugly hole around the rudder horn. I chose to make a set of "extended" r-22's that completely close in this area. It will not be flush with the fiberglass, but will only block the hole.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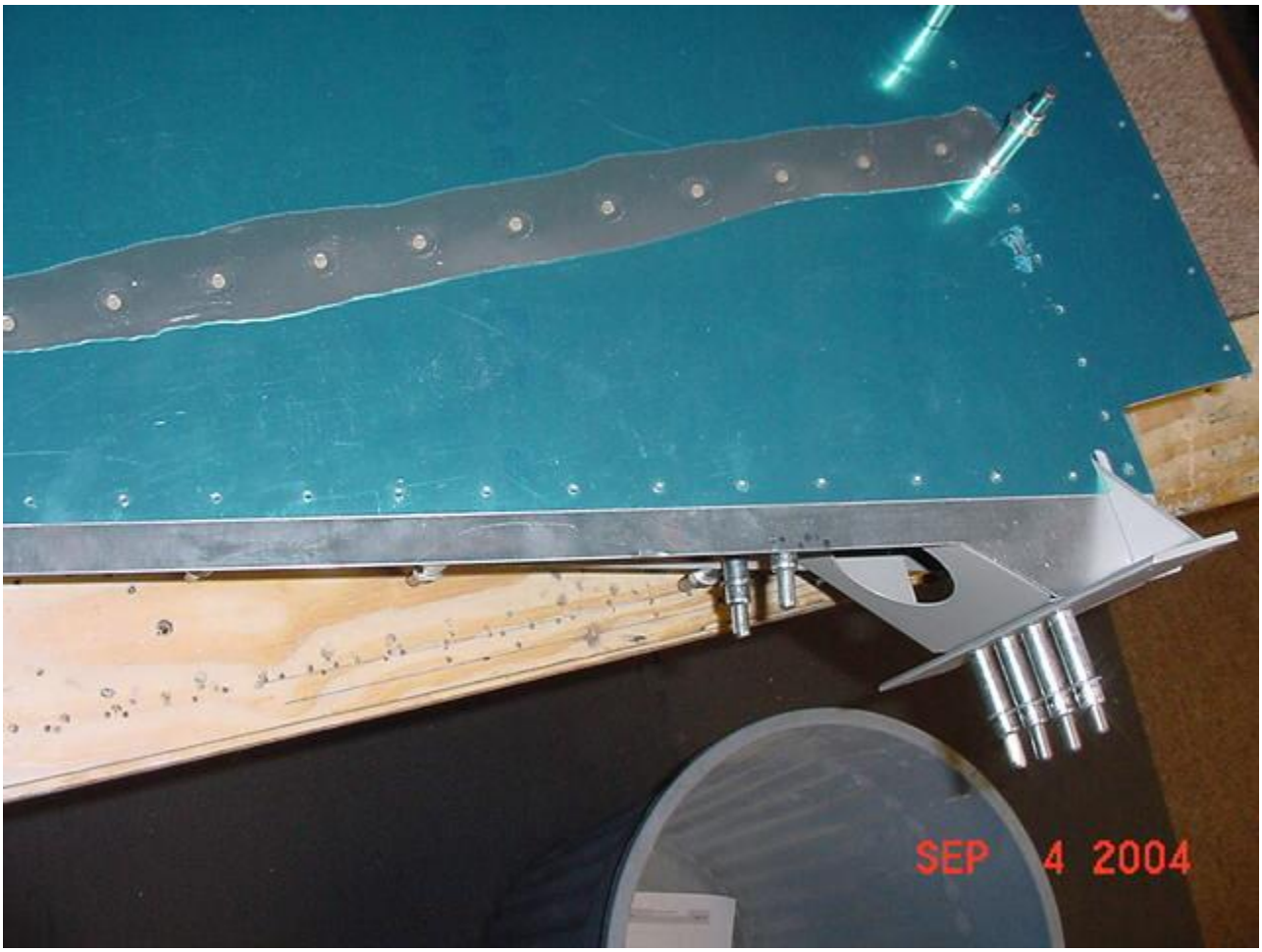


I scotchbrited the inside of the skins and all the parts. I primed them with self etching primer prior to assembly.

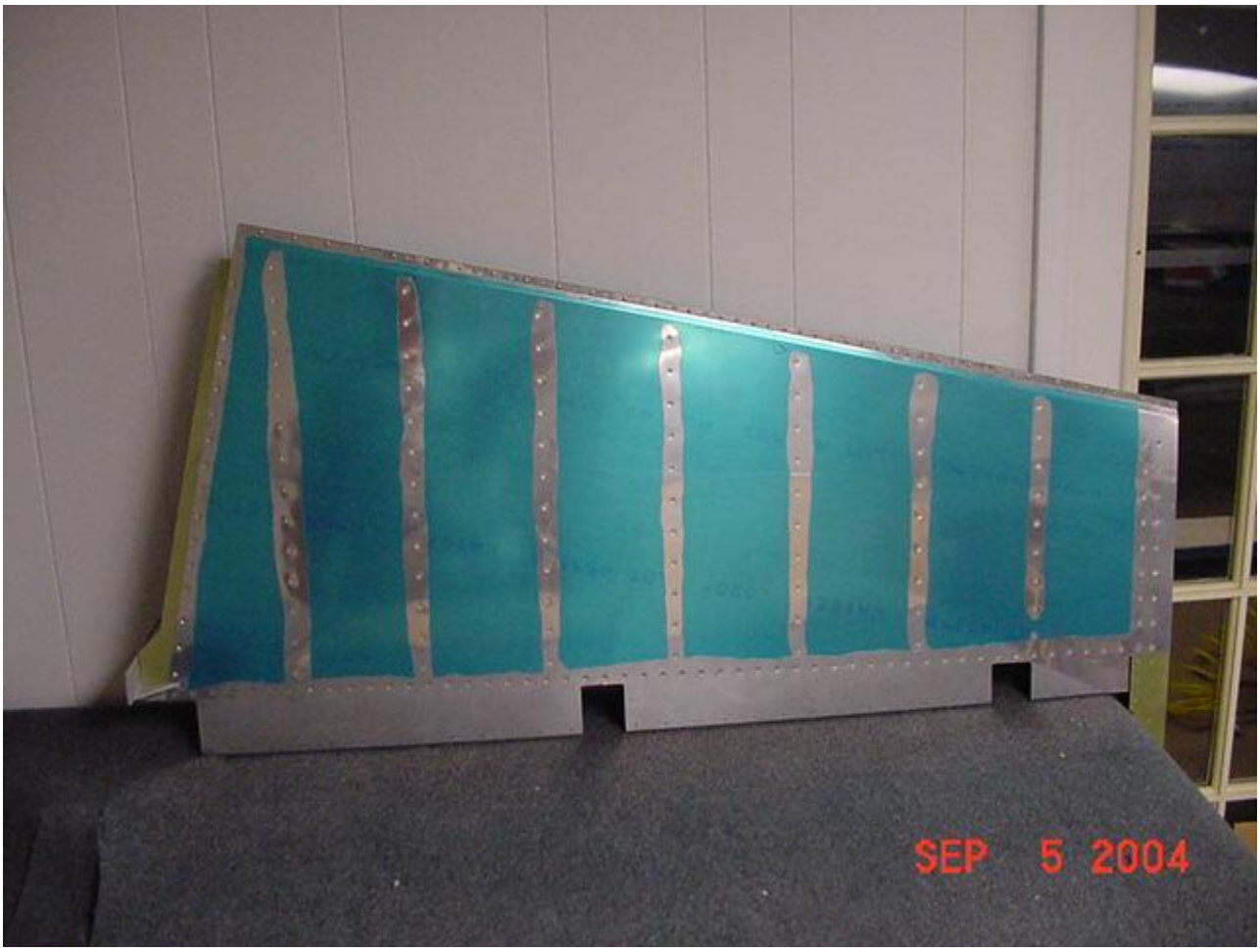
Before clekoing the entire skin/skeleton it is necessary to rivet 8 holes on each side of the counterbalance skin on the top of the rudder. You cannot get access to this area after the skins are closed onto the skeleton, so you have to rivet this area before all others. I back-riveted these holes on my bench.

Before re-clekoing the parts, you have to re-bend the corners of the counterbalance. Then cleko these REAL tight. I riveted this area first, from the leading edge back. Then I put the assembly in the wood fixture and riveted along the spar. Then back on the bench, I inserted the R22 skirts and riveted along that side.
The final closure of the skin is at the trailing edge doubler. I clekoed every other hole and placed universal rivets (3-4) in every hole. I then checked alignment of the trailing edge with my 4 foot metal ruler. I had to coax the edge a bit, then got out the pneumatic squeezer and put in two cup sets for the #3 rivets. The double cup sets makes for a nice round edge on the shop head of these rivets.

I tried to completely round the rivet heads and ran into two problems. One, the smaller the shop head is squeezed, the more it wants to deform the skin around the rivet. It kinda tries to bunch out the metal, roll it away from the rivet, and opening the skin away from the doubler. Not good. Second, the cup set would dig into the metal and make an ugly smiley. So I abandoned this process and was content with normal sized shop heads with nice rounded edges that won't catch clothing, sponges or wash cloths.

Roll The Rudder Leading Edge

After closing the trailing edge of the rudder, the next step is to round the spar side so it can swing around the aft end of the VF. That's the next chore. Time to take a break and regroup!



The rudder and VF have been sitting around for about a month, waiting for construction of their sibling control surfaces. I have rough cut the top part of the skin to allow for the counterbalance to swing though and have the VF primed. As far as metal work goes, all I needed to do on the rudder was roll the leading edges of the skin to curve at the hinges.

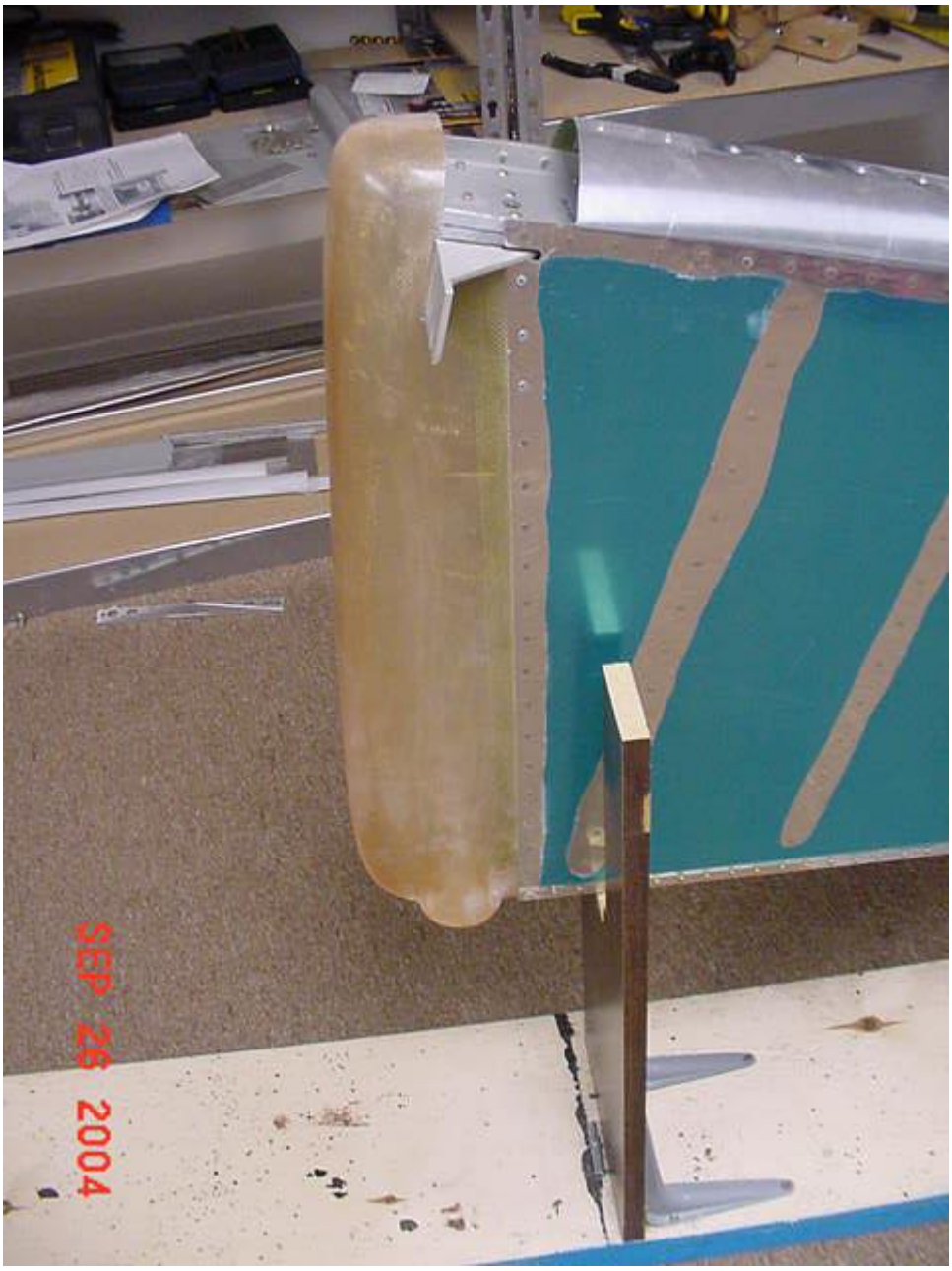
Rolling the skins is pretty simple, really. I used a 3/4 copper pipe and drilled it to the pre-punched holes in the skins with a #40. I clekoed every hole in one skin segment at a time and used vice grips to twist down the skins. That starts the roll. It's surprising how much work it is to get the roll to stay put.

Once the skins are preliminarily rolled, I went back and coaxed the skins to nearly closed, i.e. the holes in the flanged skin are visible directly under the holes in the straight skin. Well, I couldn't quite get them to overlap nicely like I did the two elevators, but I got them pretty close.

When getting ready to rivet the rolls closed, I decided to cleko every other hole. Once clekoed, I drilled every other hole up to #30. I got out the 117 AVEX blind rivets supplied with the kit, and my Stanley pop rivet gun, and started popping them in from the centers out. This all went pretty quick. Second phase, pull the rivets, drill the remaining holes to #30 and pop those puppies. Easy.

Rudder End Caps

I dug out the fiberglass tips and started doing some preliminary shaping just to get an idea of what's ahead. Boy, am I depressed now!



I started whittling on the rudder cap with a big hand file and my dremel. I really don't like the way this thing sits in here. It was hard to determine whether to set the glass inside the rudder, or mate it with doubler/flanges edge to edge like the plans. I decided to go with the plans, but modified to my own technique. I intend to screw on all the fiberglass parts, so I'll make doubler/flanges to set the top cap in place.

At the same time, I'm going back and forth from the top to the bottom caps. Trimming the bottom cap was tricky around the rudder horn, but at least the metal doublers are already in place. I just have to line up the finish edge and that part is ready to screw down. I'll need to determine what to do with the tail light pretty soon, though.

I ended up trimming down the top cap on the rudder about an inch shorter than the plans. I just didn't like how tall it was. It didn't look right. So my cap is under 4 inches at the leading edge and the trailing edge is about 3 inches.

The only problem with this is that now the VF cap, which was cut nearly to the exact size (big DUH) is going to be too short fore and aft. I had to shorten it height-wise about 1 1/4 inch to match it to the rudder. Since that piece has a curve off of the leading edge to the top at an angle, as you shorten it, it also becomes narrower. Now I'm going to have to glass about 1 inch onto the back end of this cap to match it to the rudder cap.

Scrap from my HS skins worked nicely for flanges on the rudder cap. These pieces are a little over 18 inches. Inside the counterbalance, the flanges of the skeleton are about 5/8 down from the top edge of the skin, so the flanges on my rudder cap have to be this long or a little less.

I measured and drew a 5/8 line to mark the edge of the fiberglass. I then drew a line at 3/8 above that line and drilled #30 holes in the doubler/flange every 3 inches along this , starting just about 1/4 inch front the LE, planning to set the metal just behind the leading edge curve of the fiberglass. I placed the 5/8 line along the edge of the fiberglass and drilled the #30 holes through the glass by just sighting the holes in the doubler. I clekoed the end holes.

I countersunk the #30 holes in the fiberglass and rounded up some #3-4 flush SOFT rivets. I squeezed these beginning in the middle holes and working my way out to the ends. I used a flat/thin nosed yoke to get into the deep taper at the TE.

When I gather up some courage, I'll mark a 3/8 inch line on the CB skins and mark holes every 3 inches, probably very symmetrical to the rivets in the cap. I plan on using the nifty little #4 nutplates and screw I got from Cleveland Tool. But I'm going to do some more finishing on these parts before I jump ahead to attaching them to the rudder.

Now I have a VF cap that has a short side at the trailing edge. I went to the crap pile behind my 3in1 break and got an appropriate piece of metal. This one just happened to still have the vellum on it. Good. Hope epoxy doesn't stick to it. Even if it does, at least I'll be able to separate the metal.

I took my trusty glue gun and sealed down the strip of metal on the aft edge of my VF cap. I opened my virgin can of West System epoxy and grabbed a cup, brush, and aluminum foil. The metal went onto the outside of the cap hoping that I would get a relatively smooth surface.
I cut two pieces of Bi cloth for the "extension". One was exactly the width, and one was about double that width. Set the wide piece down and filled it with epoxy. Then I set the narrow piece on top of that and wet it, "squeegy" off the excess as I went. I wet the piece (already roughened) where the extension was to go. I cut the foil and took the whole (minor) mess and reversed it. That way, I could mash, er..., place the glass precisely where it needed to go in the INSIDE of the VF cap.
Four tongue blades (Ahhhh sticks) made good retainers for the edges of the foil, which I folded over the edge of the cap. I used some nifty spring clamps to hold them all down and hopefully keep the glass from sliding too much.

I don't have much experience with this stuff, so I hope it works. After it hardens, I plan to put two or three layers on the outside of the extension for strength and adhesion. Then I'll grind the inside as necessary. I hope the piece doesn't end up too heavy. There was already about a 1/2 inch pool of hardened epoxy inside the curve of the piece, so it's already hefty. If I wasn't so lazy, I would have dremeled that out. We'll see what happens. I may be calling Brian to buy new parts.
Both extensions worked well, and I'll need to reinforce them, as well as extend the other side of the rudder tail cone. That West System is pretty nice! Virtually no smell. But the slow set is TOO slow for

my taste with little projects like this. So I ordered a quart of fast catalyst. And on the tail cone extension I used 1:1.5 (pumps) resin to catalyst, and it seemed to turn out fine.

Now I need to reinforce them and get them finished out. I need to get that rudder and VF off my table so I can do the same thing on the HS and elevator tips. Still have a ways to go, though.
My lead counterweights came from Van's. The rudder requires 830 grams. The E-614-020 weights are precisely 830 grams. Without the hardware. One weight in the C/B of the Rudder should be sufficient.

I ordered 6 of the weights. 5 of them go in the elevators. You're supposed to split one in two and stack a half weight on top of the other pair. The half weight goes outboard of course, under the fiberglass cap. I'll just use hardware bolts and fender washers to retain all these weights.

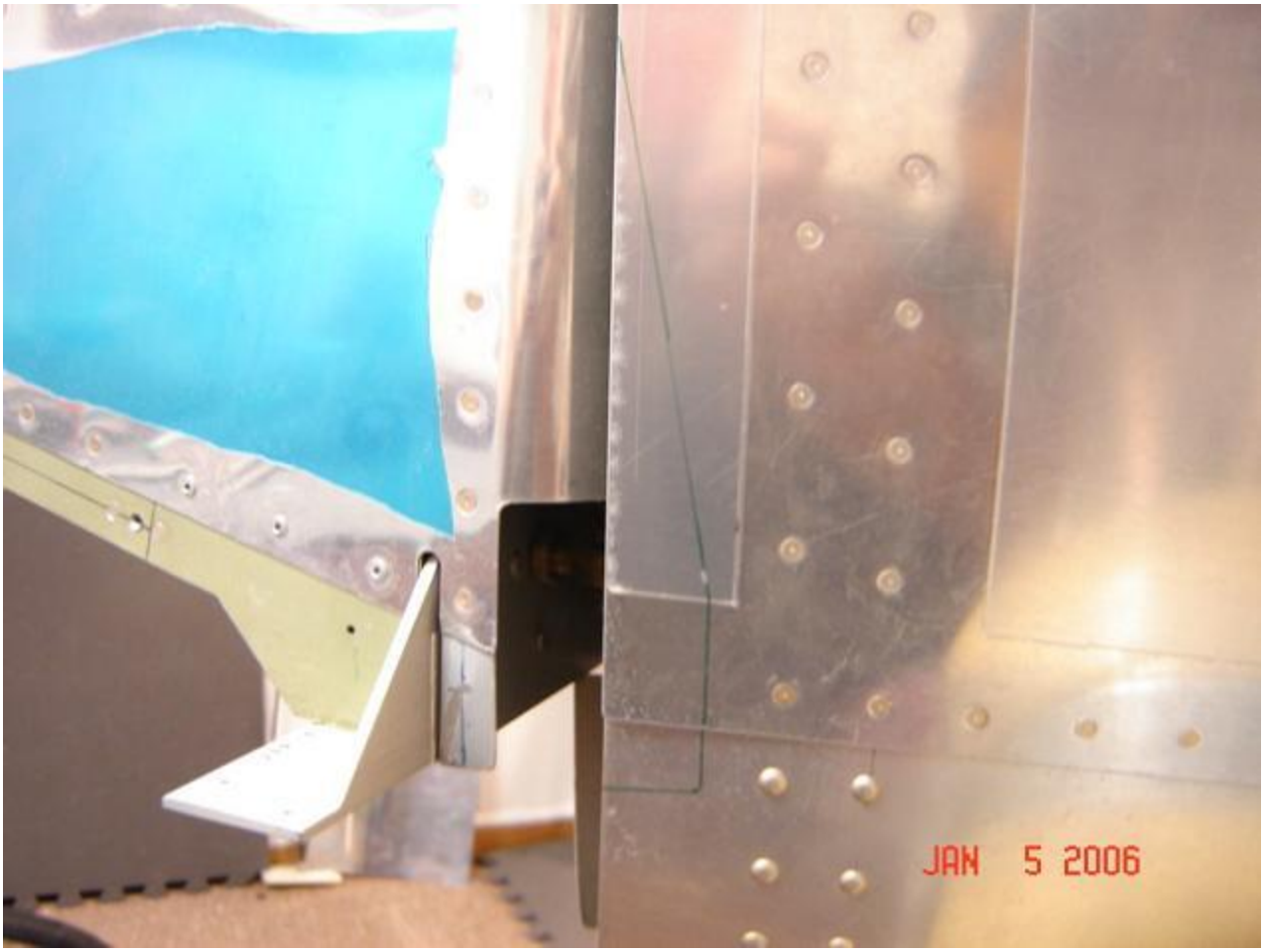
Hang the Rudder

The fuselage came down off my table and put the cherry picker away. I had to scoot the whole project forward about 2 feet just to have a chance to start hanging the feathers. As it is, my work table is in the way. I'm going to have to figure something out there, or just climb around a lot more....

I gathered up the rudder and wiggled the rod ends into the VF brackets. I just dropped some spar AN3 bolts through and viola! Looks pretty good with the rudder in place I must say.

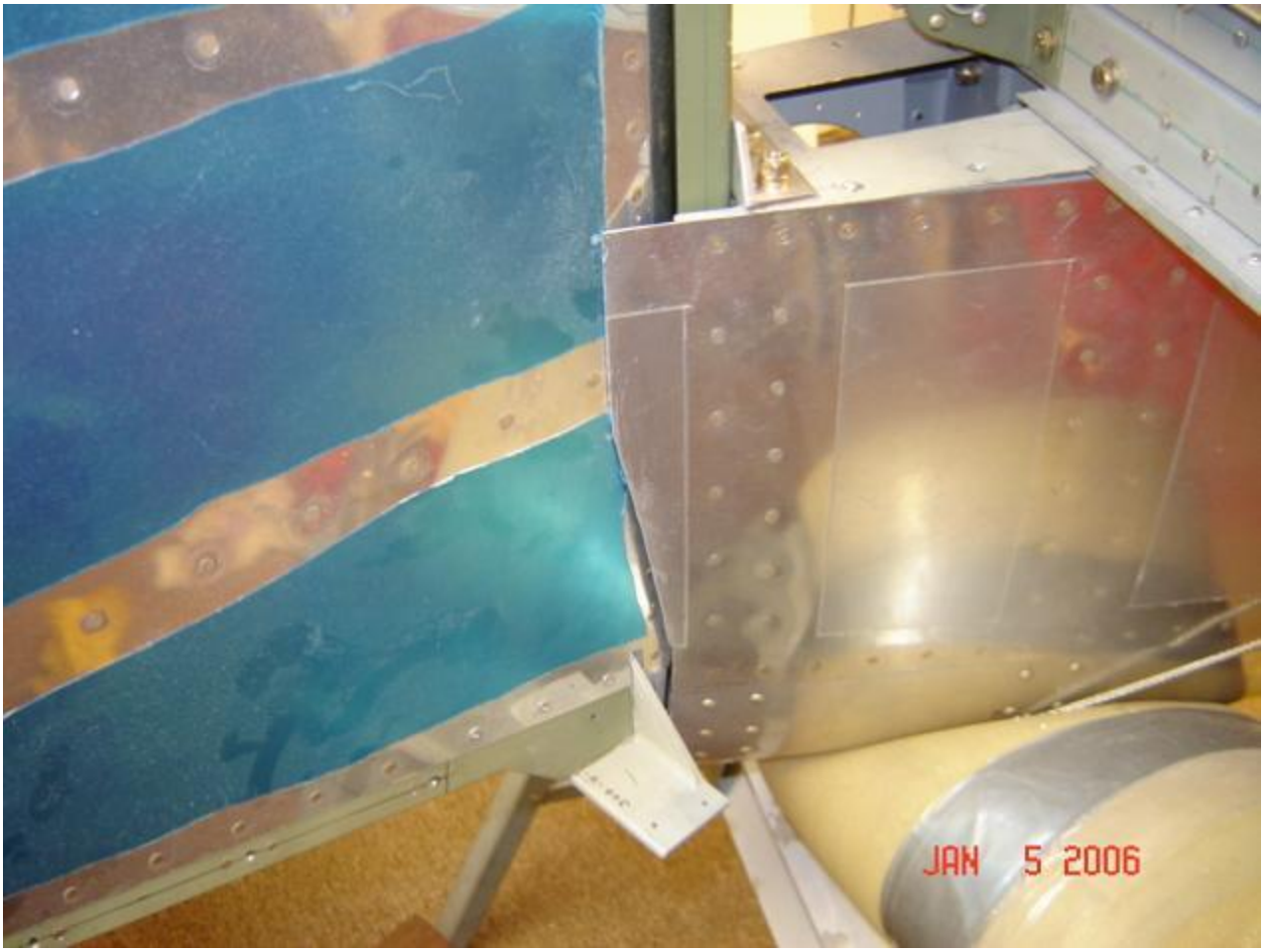
The manual calls for "30 degrees R/L" Now I'm stupid, and I don't know if that means 15 each way or 30 each way. I looked in chapter one and it says the same thing. Since the other control surfaces move 25+ degrees for the most part, I'll ASSume that I am supposed to be able to crank that rudder 30 each way.

You have to trim a bunch of skin off the emp to let the rudder swing on the hinges. I went through about 4 dremel discs figuring out the first side, then measured it and went to town on the other side.



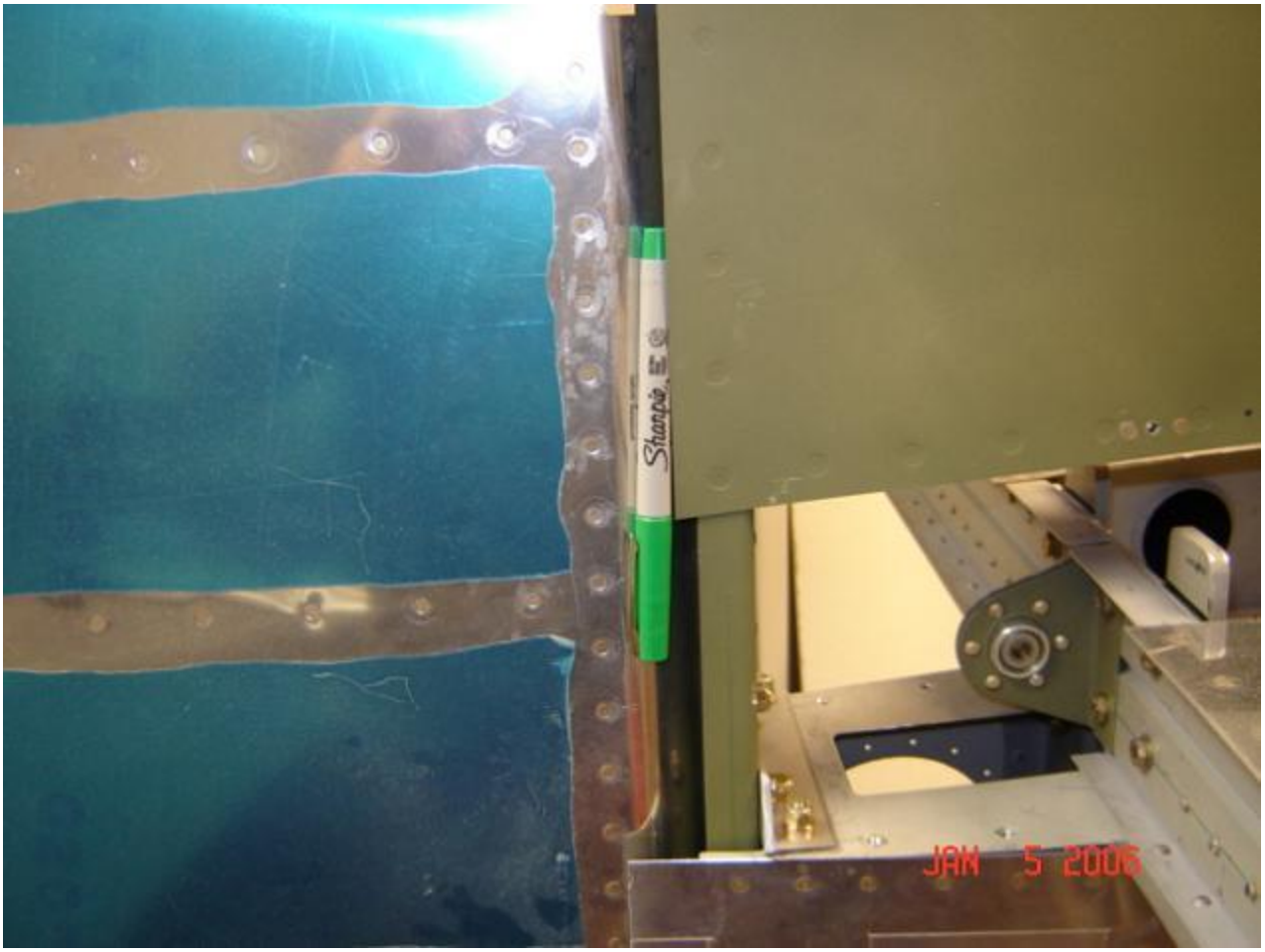
Sorry, but my new camera SUCKS. I need to go back to the old Mavica. It takes pretty pictures and stays in focus with less flash and better color.... but I digress.

The cut mark shown above is about 7/8 in, then 2 inches up, then I just counted rivets and made the mark. It was a pretty easy to cut, but both sides are going to take some trimming.



At this point I don't know whether I should tweak the rod ends and pull the rudder tighter to the VS skins or not. I have 30+ degrees of travel each direction, but if I reposition the pivot point of the rudder, I'm probably going to need to do a lot more massaging of the emp AND VF skins to make it all "tight and right".

I think there is too much gap between the rudder and the VF skins. By taking the rudder off and screwing in the rod ends, I could reduce the gap some. However, you can still only go so far because you will contact the skin. I guess the trick there is to reposition the rudder toward the VF and try to reduce the gap in between as much as possible.



That's about 3/8 inch gap where the sharpie is. Sure wish I could reduce that down. Not only for cosmetics, but for performance. The skins on my VF aren't perfectly even on each side at the trailing edge, so some trimming is going to be necessary just to even up the sides. I sure hope I can reduce that ugly gap.

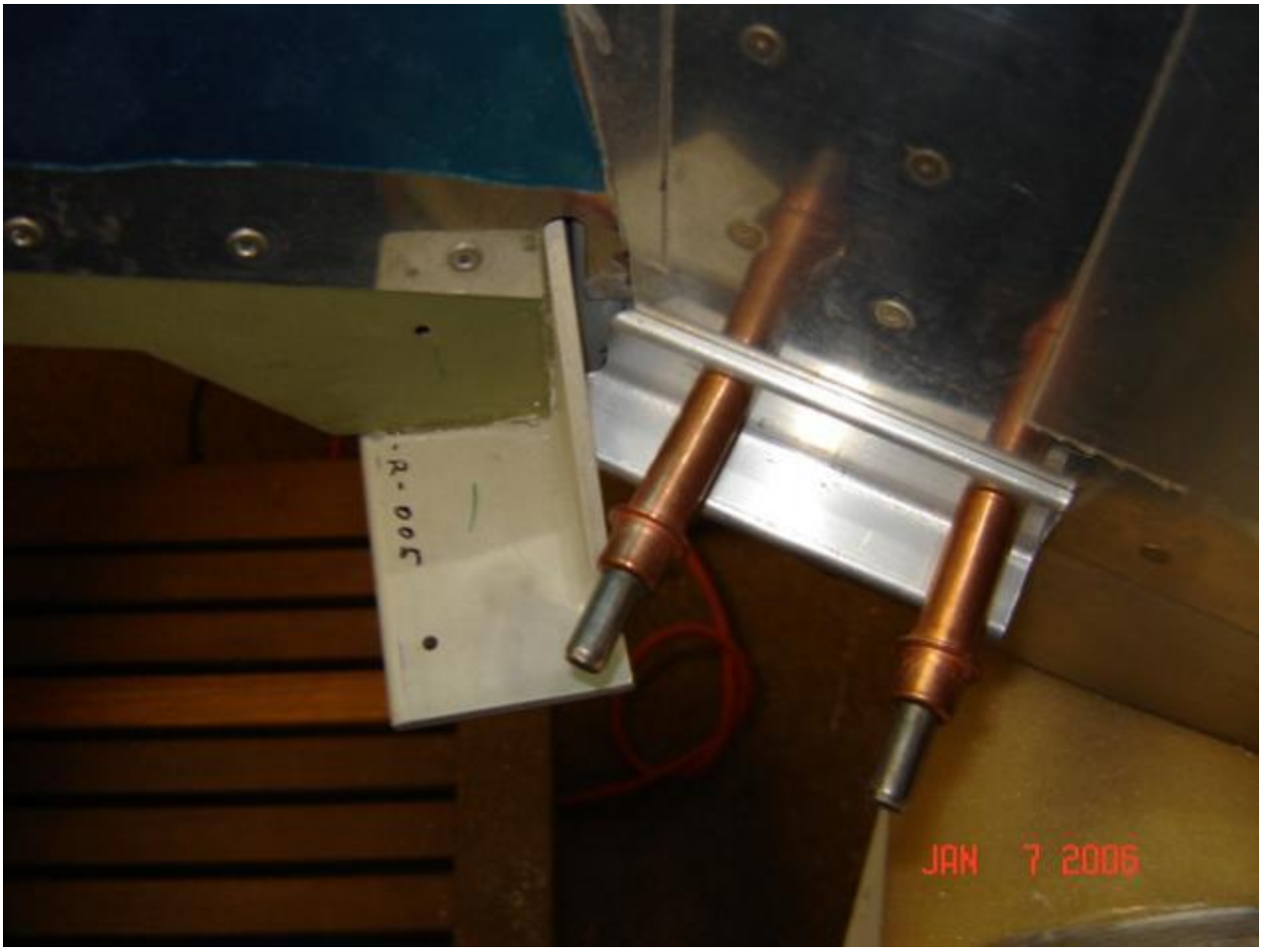
The 3 bearing in the rudder spar are adjustable. Initially, I had them set per plans. But my VF skins were trimmed short before I riveted them down. Consequently there is more gap than I would like to see between the rudder and the VF. I removed the rudder and screwed the bearings inward. 8 each half turns is all I could do. The big bearing at the bottom of the rudder ran out of threads way before the smaller two bearings in the middle and top. Well, I took what I could get. It moved the rudder enough that I had to take my dremel and cut out 1/8 or so at the counterweight area on top of the VF. So I didn't get very much closure of the gap. But I wasn't going to get much more than that because when the rudder goes full swing, it would contact the VF skin if it stuck off the back of the VF spar too far. I wish I would have left 1/4 inch more skin on the VF!

The bearings were binding a bit when the rudder swings. As I had left it a long time ago, I could barely get an AN3 bolt in the VF bracket holes. I put 2 bolts in the hung rudder bearings and observed the 3rd bracket/bearing holes with a dental mirror and selected the hole to file that was least offensive. What I found out was that I could twist one bearing 1/2 turn to take out some of the binding. The middle hole seemed the most offensive, so I took a long time filing and rehanging the rudder. I didn't want to create too much slop in the holes. After about 3 hours of work trying to get the rudder in closer and remove the slight binding of the rudder movement, I'm finally happy with the results. Now I can easily get the AN3 bolts into the holes to hang the rudder, and the rudder is quite free to swing. Evidently I twisted something, either constructing the rudder or constructing/mounting the VF. Doesn't

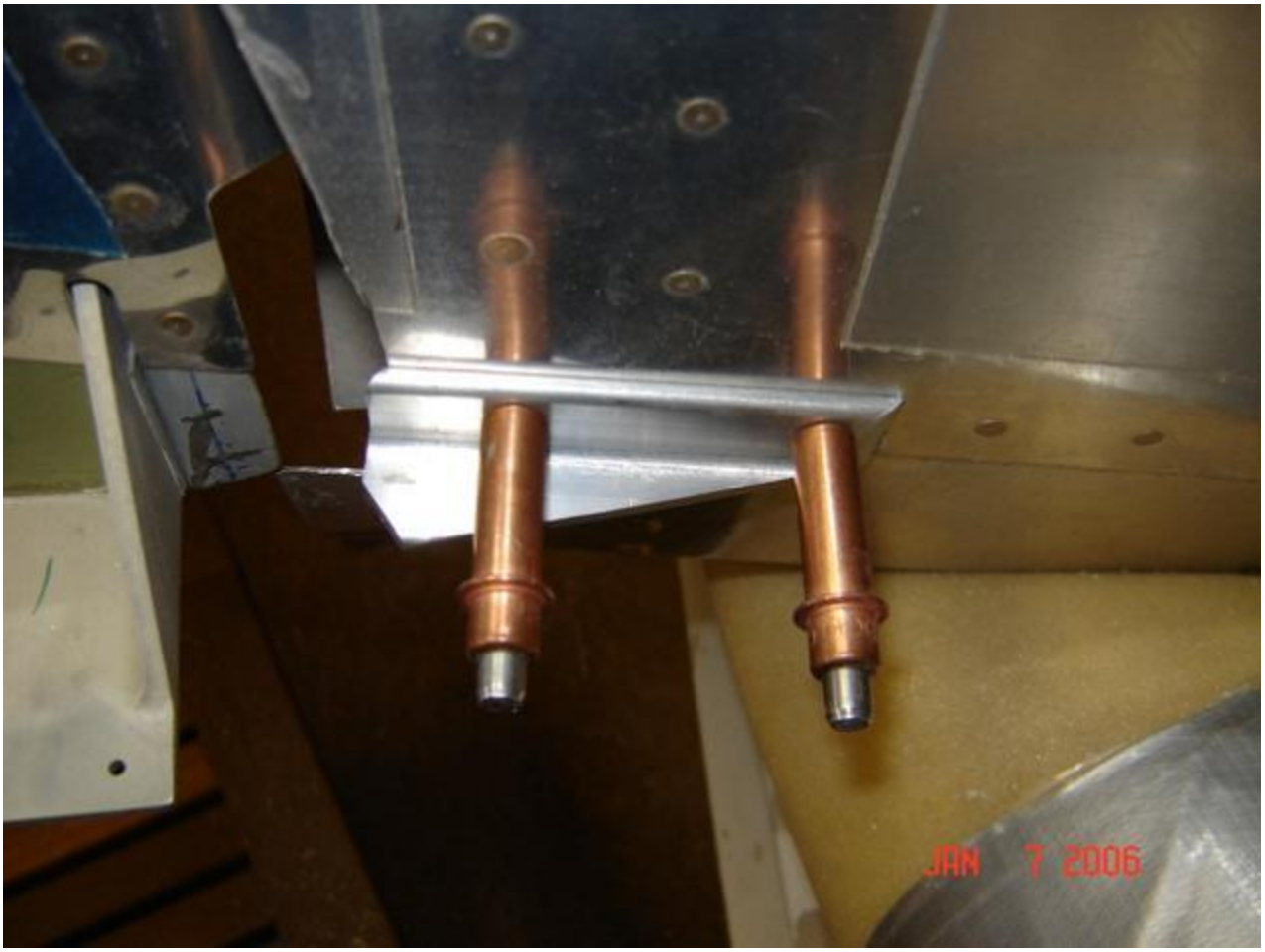
matter now, it works fine.

Rudder Stops

The rudder stops are just made with 3/4 angle. I cut 2 pieces each 3 inches long. Per the plans, I drilled out two rivets on the emp longerons in line with the rudder arm. I drilled the stop with #40 to match the emp factory rivet holes, then match drilled to #30 in place. Over at my bench grinder, I rough cut the angles to clear the rudder skin and trimmed the angle to get a square face for the stop. The rough angle rudder stop looks like this:

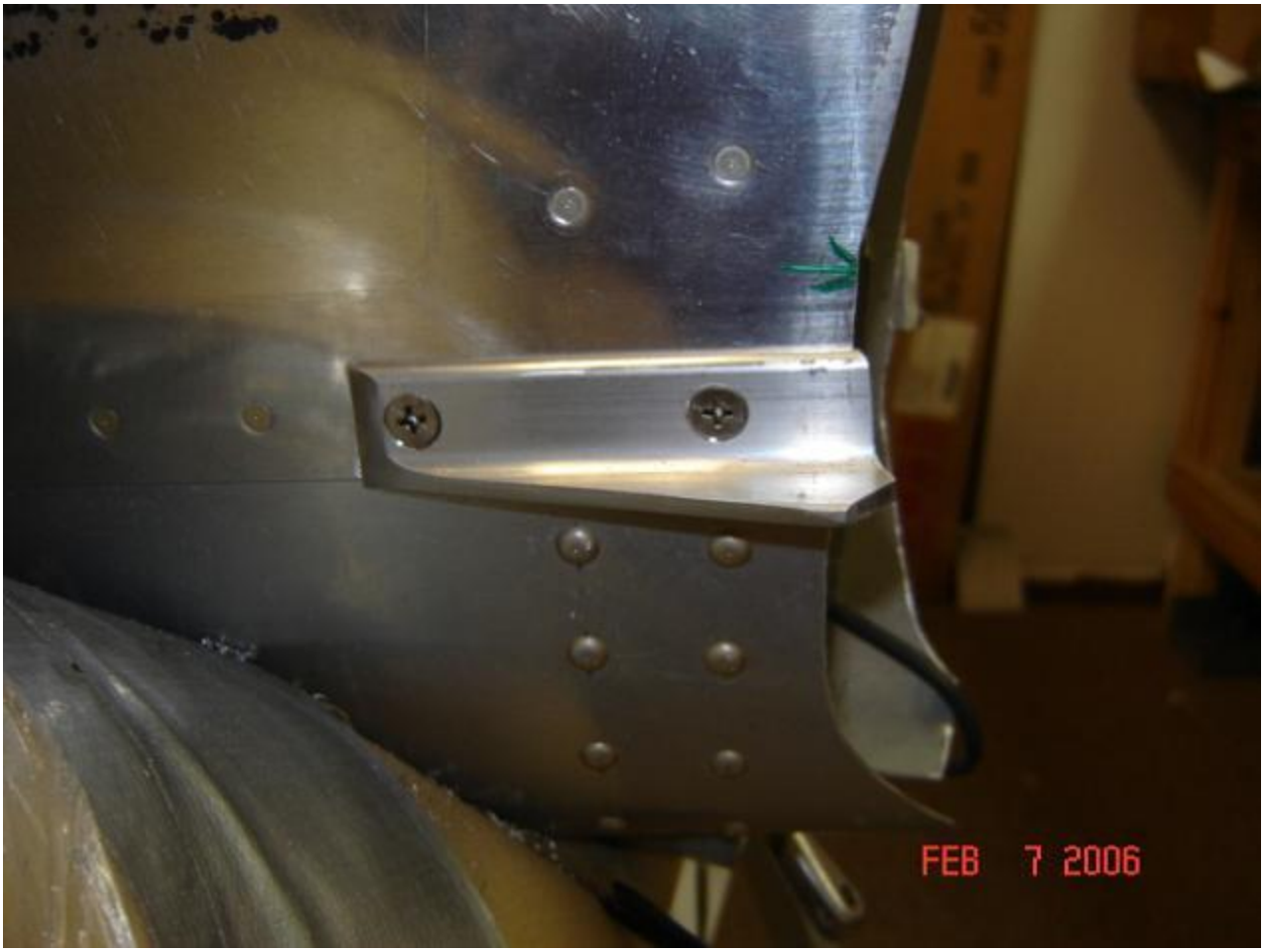


The stop isn't particularly aerodynamic, so next thing is to shape it up to reduce the weight and drag.



Now if I could do something about that big assed rudder horn out there in the breeze.

The stop is supposed to be fixed to the emp with #8 hardware. I read in passing about someone TAPPING their stops for a #8 screw. I decided to tap the stop and the fuselage for short #8 stainless screws. I could get a nutplate on the rear one easy enough, but I'm just tapping them. I think I'll put some blue thread locker on the stainless screws and call it finished.



Now that the rudder is hanging, I went to mount the Elevators.

Rudder Counterweight

After the elevators were hung, I attached the lead counterweights to the elevators and the top of the rudder. I used the Vans weights that I purchased a long time ago. the CW area of the rudder only takes one weight and two AN3 bolts. You could mount the weight to the underside of the rudder, but why chance it. Plus it's easier to check and service on the top, under the fiberglass cap. Unlike the elevators, the thinner end between the bolt holes of the lead block goes forward.

The Van's kit was pricey at $6 each block plus shipping LEAD, but it was worth the hassle reduction. I attached the CW block with the rudder off the ship. Time to pin it back in, and run the rudder cables to the rudder horn. Maybe attach the tailwheel and steering link after that.