Method Three . . . The Cold Chisel

If a sheet of steel is not too large, and if you have a large solid vise, a large cold chisel (about 1" wide) and a baby sledge hammer, you can easily chisel off a small piece. Using this method you should leave about an ⅛" margin for later grinding and filing the part to its exact dimensions. It might sound like a crude method, and it is, but it is also an effective method when properly done. The chisel should be held against the metal at an angle, when struck with the sledge, so that it acts as a shearing tool. This results in a fairly smooth cut along the surface of the vise jaws.

Method Four . . . The Metal Shear

A metal shear completely eliminates the problem of cutting little pieces away from a large sheet unless the metal is too thick for the capacity of the shear. If you don't have access to a metal shear you might, nevertheless, find it worthwhile to have several strips sheared off at some local metal shop. A project having a lot of wing strap fittings, for example, could be expedited by having a number of lengths of a uniform width sheared off the sheet.

Method Five . . . The Aviation (Tin) Snips

Aviation snips are effective only on light gage sheets. They will, however, adequately handle both aluminum and steel stock in thickness up to .050". Some types of snips distort the cut edges considerably and you should therefore not cut closer than 3/32" of the line. These aviation snips are made in three types. That is, in Left Cutting, Right Cutting and Straight Cutting models. There are also offset snips, or hand held shears, which can cut easily across a large sheet without distorting the edges.

Method Six . . . The Cutting Torch

Cutting torch? Never! It wastes too much steel and also causes a hardened area along the cut which is very difficult to file or grind away. A large margin must be left in order not to damage the part you want to use. It might be all right to use the cutting torch for very heavy steel plate but even here I wouldn't recommend it because of the possibility of creating localized locked in stresses. This type of cutting introduces a greater risk of crack generation.

Method Seven . . . The Table Saw

With the proper blade, a table saw will cut strips of aluminum to uniform widths but this method is not for steel. I don't think your neighbors will appreciate this method nor will your ears.

Method Eight . . . The Carburundum Disc

These discs will cut through steel easily but are really not suited for making many long cuts. I prefer to use these discs with a drill press and primarily for slotting tubing.

Method Nine . . . The Power Hack Saw

The power hack saw will cut steel and aluminum plate, tubes and rods as easy as pie, but it is not suitable for cutting sheet material. This is more of an off-cut machine for tubing and heavy metal stock.

Method Ten . . . The Bandsaw

Ah! This is the way to go. A metal cutting bandsaw will really turn out the pieces rapidly and you should be able to cut all the fittings for an entire airplane with one blade.

Aluminum may be cut at the regular speed with a bandsaw. Try to do the same thing to 4130 steel and the blade will become overheated and quickly ruined.

The bandsaw blade speed could be slowed for cutting steel by attaching a speed reducer. Sears has one for their regular 12" bandsaw. Or you can obtain the same kind of speed reduction by using large pulleys mounted on jack shafts. When the saw is ready to cut steel, its blade speed will be noticeably slower than it originally was. A blade speed of 125 to 150 feet per minute is good, but in a pinch you might get away with a blade speed somewhat higher.

Method Eleven . . . Hand Operated Nibbler

The manually operated nibbler works fine for lighter gages but cannot be considered as a practical means for cutting many pieces. It is wasteful of metal as it cuts a wide swath and is very tiring to use.

Method Twelve . . . Pneumatic Metal Shears

Most of these are not suitable for heavy gage metal. They do cut easily and smoothly and are enjoyable to use, but do require a source of compressed air.

Any of the foregoing methods used to cut a small piece of metal away from a larger sheet will give adequate results sometimes . . . but not always.

Make Them Smooth

Whatever method you elect to use for the initial separation of a fitting from that large sheet, keep the saw cut well to the outside of your drawn line. Allow yourself plenty of margin for error. The final shaping of the part may be done on a grinder (for steel parts). Follow that up by filing it with a smooth cut file.

You soon find that a file cuts very smoothly when the file is pushed into the work at an angle. Keep the file level . . . you want square edges not sloped or rounded ones. And finally, remove the sharp edges and fuzz by passing the file lightly along the edges of the fitting. All file and saw marks must be removed. Rub the edges over sandpaper or emery cloth laid on a smooth hard surface. For other hard to get to edges you might try a piece of emery cloth wrapped around a dowel or block of wood.

Making Bending Blocks

A single bend up to 90 degrees is simple to make provided the part to be bent is wide enough and you have a solid heavy-duty vise and bending block with the appropriate radius. Making a second bend is more difficult but the blocks illustrated will probably allow more options for bending than other types.

Larger vises have removable jaws with a serrated or knurled surface on one face and a smooth surface on the opposite side. Always use the smooth surface sides for gripping aircraft work. If you wish, you can radius one edge of the vise-jaw-insert and use it as a utility bending block. A separate bending block, however, lends greater versatility and it permits a choice in the bend radius used.

Bending blocks should preferably be made of steel, or of aluminum alloy if only small parts will be bent with them. I find the most practical size for my use is one approximately 8 inches long made of a piece of 1/8 inch aluminum alloy plate. Its width is 3 inches although sometimes it seemed that a 4 inch width would have been better. It really depends on what size a piece of metal plate you can find in the junk yard. A piece of steel plate measuring 3/8 inches thick by about 4 inches square would be adaptable to most small bending jobs.

Prepare your bending block by grinding or filing a radius along one edge. You might consider preparing a different radius for each of the four edges. Unless you require some specific radius I would suggest one edge be radiused to 1/16", another to 1/8", and the remaining two to 3/16" and 1/4". Make templates as shown in Figure 4 to check your radii for accuracy. Punch marks on the ends of the bending block will identify which is which.

That's right, one punch mark for the 1/16" edge, two marks for the 1/8" edge, etc. See Figure 4.

The most effective bending block will be one that has its edge beveled so that it will allow the metal to be bent slightly beyond the 90 degree point. Metal has a spring-back tendency. Beveled bending blocks will naturally be limited to only two different radii per block.

A good bending block is a handy thing to have around the shop and it should serve you well through a couple of airplane and boat projects. If, however, you need a bending block for only one or two bends in light metal, you may do as well with a block made of hardwood. Using a wood bending block for making more than a few bends, however, will result in its radius becoming larger and larger because the wood will flatten slightly with each part bent.

IMPORTANT REMINDER: Never make a bend in a metal part until its edges have been filed and/or sanded to a smooth finish. Saw and file marks certainly increase the risk of cracks particularly in parts subjected to heavy load reversals and vibration.

So much for the basics. More about bend allowance, setback, bend radii, the sight line and difficult bending problems next month.

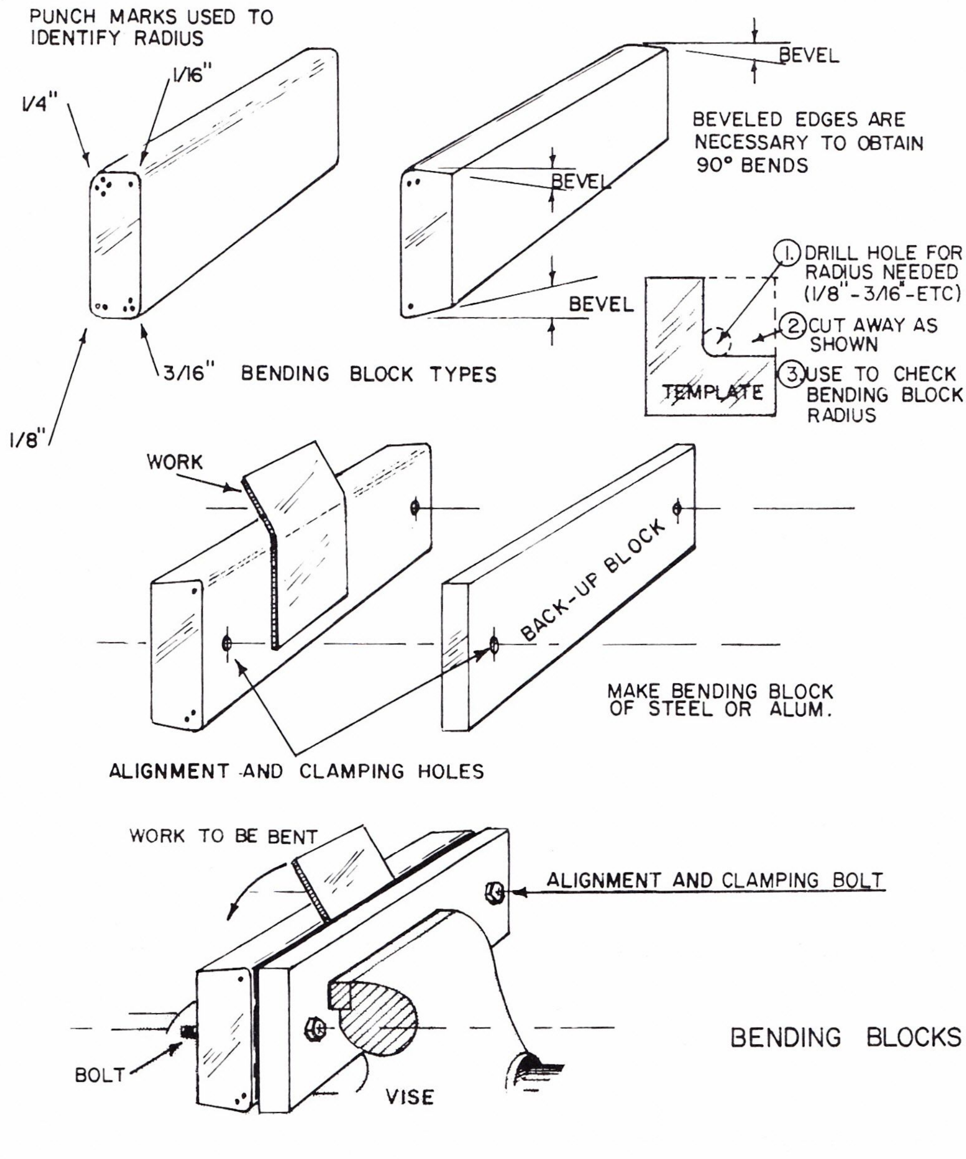


FIGURE 4.

Making Fittings/Part 2

by Antoni (Tony) Bingelis

JUST ABOUT ANYONE can take a piece of metal, bend it to a 90 degree angle and trim the excess off both ends to make a satisfactory fitting for his airplane. That is one way, a fool-proof way of making angle fittings that is as practical as it is predictable. Making your bent parts that way, you don't have to know about bend allowance set back, sight line, mold line and neutral axis . . . or how to use that information to your advantage.

Well, you say, if I can bend accurate enough fittings without messing with formulas, tables and charts, why should I bother about getting familiar with some other, more demanding methods, and have to learn new terms besides?

Several reasons. Not all fittings are angles consisting of a single 90 degree bend. A number of fittings have two or more bends, and in some instances, the angle of bend may be greater or smaller than 90 degrees.

When making something like a battery box, for example, the material dimensions (flat pattern) must be established before any bending can be started. Sometimes, even the sequence of making the bends is important.

Take for example a "U" fitting (channel) that must be made to fit snugly between some other parts. How large a piece of metal must you use? How would you determine where to make the bends so that part would fit? Trust to luck and use the trial and error method? You would waste a lot of material that way before you got one just right. Or what if you are building an all-metal airplane and have a lot of aluminum angles to bend. You'd find it very wasteful to pre-cut large pieces for bending and then later have to trim them to size. The trial and error method of bending metal has its place, but under certain conditions could become a very time consuming way of building. Then, too, here's another reason. It is possible that you might become interested in obtaining your FAA Airframe Mechanic license. Quite a few builders have obtained theirs, after receiving credit for the FAA's mandatory practical experience requirement, simply because they did construct an aircraft. They still had to pass a written examination, of course, and possibly answer a few questions thrown in by the inspector. One area of questioning regarding the builder's aircraft knowledge often explored by the inspector has to do with metal working. After all, aren't most present day aircraft all metal? Even those that aren't have a lot of metal parts in them, so any knowledge or experience gained in metal working is important. Yes, it is handy to know how to lay out flat patterns which have been compensated for bend allowance and have the necessary set-back established and sight (or brake) lines clearly drawn. Understand the meaning of each of the following terms, and where and how each is applied and you should be able to lay out, make and bend metal parts with confidence.

Lay Out Procedure . . . Select the Radius of Bend

This is the easiest requirement to understand because most of us are already familiar with the fact that metal has a minimum radius around which it can be bent. If the bend radius is too small (too sharp) the resultant stresses and strains in the metal will weaken the part and perhaps cause it to crack . . . later, if not immediately.

Incidentally, many builders are not aware that aircraft fittings are normally bent cold nor may they realize that the cold bending strain-hardens the metal slightly and makes it even more vulnerable to cracking unless a reasonable bend radius is used.

Tables giving the minimum bend radii are available from somewhere, I suppose, but not knowing of a source I submit the following abbreviated table of minimums which were derived from reliable USAF and FAA references. The numbers are presented as a function of the thickness of the metal sheet for making 90 degree bends.

MINIMUM RECOMMENDED BEND RADII FOR 90 DEGREE BENDS (In terms of approximate metal thickness)

Sheet Thickness	.016	.032	.064	.125	.188	.250
Aluminum Alloy						
2024T-3	1t	2t	3t	*4t	4t	5t
6061T-6	1t	1t	1t	2t	2t	2t
7075T-6	2t	3t	3t	4t	5t	6t
Aircraft Steel 4130	1t	1t	1t	1t	1t	1t

*2024T-3 aluminum sheet 1/8 (.125") should never be bent around a radius less than 4t or 1/2", etc., etc.

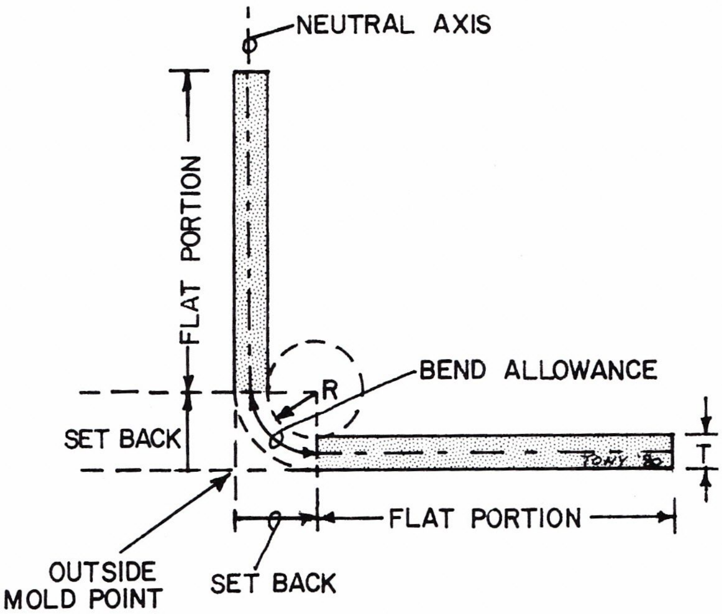
NOTE: A good rule is to never bend any kind of metal around a radius less than its own thickness. Notice that the hard tempered aluminum alloys require much larger radii than does 4130 steel.

Annealed steel and aluminum parts can be safely bent around smaller radii than can normalized steel or hardened (tempered) aluminum alloys but they should never be installed in aircraft unless the material has been heat treated after forming.

If a very small radius is bad then a very large radius must be good . . . you know there must be a flaw in that kind of reasoning! A large radius is, indeed, good if its location and use permit it. However, for the most part, a fitting with a very large radius may result in the attachment bolts gouging the metal in the bend area . . . a most unsatisfactory condition.

Determine Set-Back

An angle fitting cannot be laid out to exact dimensions unless you first know where the bend begins. This point (line) is called the set-back. Set-back is actually the distance as measured from the point where the bend begins (or ends, depending on how you look at it) to the



METAL BENDING NOMENCLATURE

FIGURE 1.

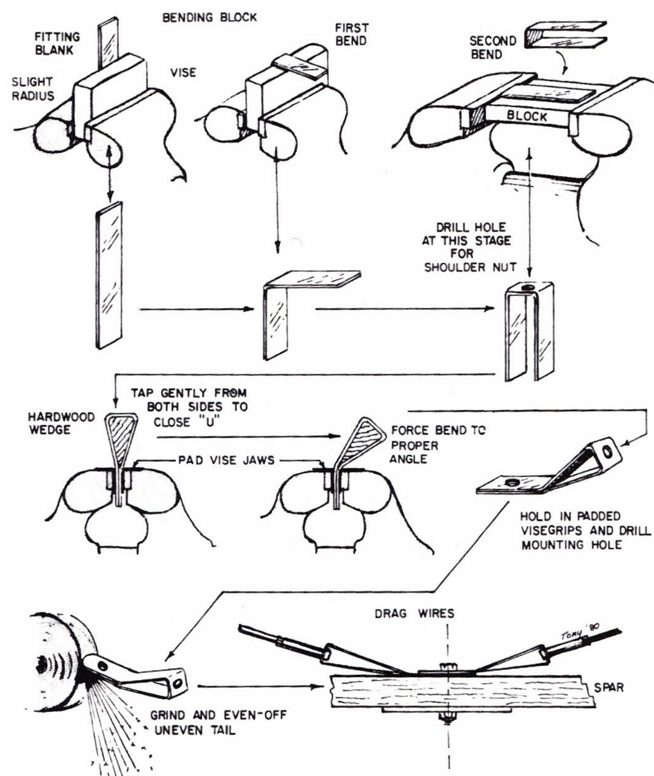
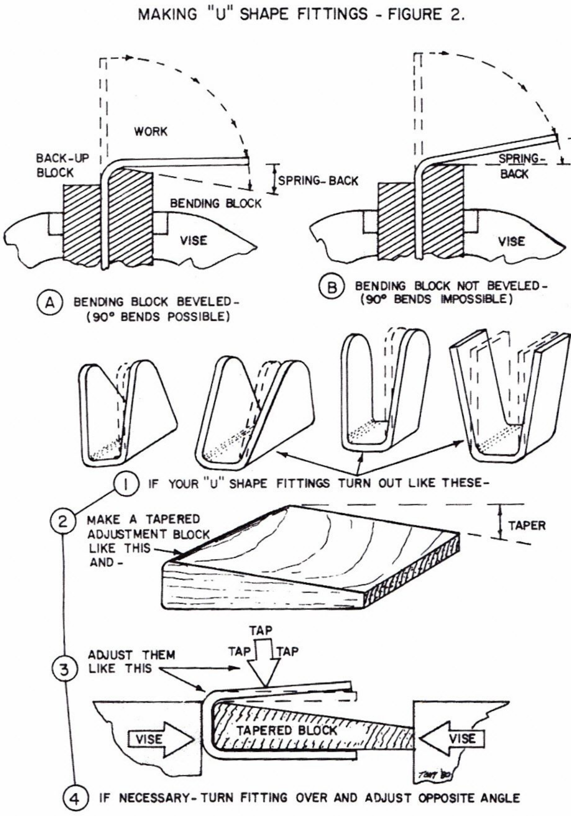


FIGURE 3.

MAKING DRAG/ANT-DRAG WIRE FITTINGS

MAKING "U" SHAPE FITTINGS - FIGURE 2.



fittings base line or mold point. This length actually consists of the bend radius and the thickness of the metal. (Figure 1 — SB = R + T) Therefore, to find the dimensions for the flat portions of the fitting you must subtract the radius plus the thickness of the metal from each leg of the fitting to find the point where the bend tangent line will be. That's all there is to set-back for any part that must be bent to form a 90 degree angle. A part that must be bent to a larger or smaller degree must have its set-back figured in a slightly different manner. The set-back for bends greater or smaller than 90 degrees is normally obtained from standard set-back tables (not included in this article).

After you have your dimensions for the flat (unbent) portions of the fitting, you are ready to accommodate the bend allowance.

Figure Bend Allowance

Bend allowance and set-back are often looked on as a baffling mystery to many builders who are used to practicing the cut, bend and fit method of metal working, but it shouldn't be at all.

Both bend allowance and set-back are measured from a common point . . . the bend tangent line. Remember, that is the point where the bend begins. The difference between the two is that the set-back is measured along a straight line while the bend allowance is measured along the radius of the neutral axis in the bend. Bend allowance determination is based, primarily, on the thickness of the metal, the radius of the bend used and the number of degrees through which the bend will be made. Better take another look at Figure 1 to make sure your mental and visual images are the same.

There are several ways of determining the amount of bend allowance for laying out a fitting prior to bending it. Here are a couple of them.

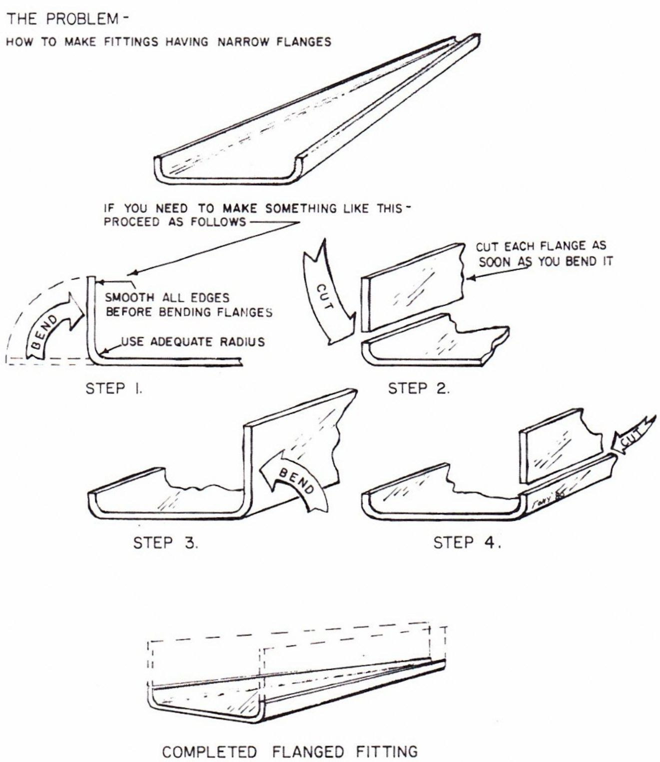


FIGURE 4.

The Formula Method of Determining Bend Allowance

A scholarly means of determining bend allowance is through the use of a simplified empirical formula which assumes the neutral axis in a bend to be in the middle of the metal and not at a point — .445 x t from the inside of the bend radius where it is really located. This mathematical transgression apparently doesn't affect the accuracy of the formula method:

BEND ALLOWANCE (BA) = (0.01743R + 0.0078t)N

R stands for the preselected inside radius of bend (use decimals of an inch)

t is the metal thickness . . . also in decimals of an inch

N is the number of degrees of bend to be made in the metal

Here's how you put it all together:

Let's assume you need to find the bend allowance needed for a .040" part which must be bent to a 60 degree angle around a ¼" (.250 inch) bend radius. Let's proceed.

R is .250 inch
t is .040 inch
N is 60 degrees

Using the BA empirical formula (.01743R + .0078t)N, the arithmetic works as follows:

BA = (.01743 x .250 + .0078 x .040) x 60
BA = (.00435 + .00031) x 60
BA = .0046 x 60

Answer: BA = .2796 or .280 inch (reduced to a fraction, about 9/32 inch)

NOTE: The Bend Allowance Table shows that the bend allowance for a .040" metal part bent 60 degrees, as in the above example, is .00468 per degree of bend, or .00468 x 60 which equals .2808'. That is quite close to the answer obtained using the empirical formula above . . . and a lot easier to determine.

If your memory is no better than mine, you will probably forget the formula by the time you need to use it.

BEND ALLOWANCE TABLE

RADIUS / GAGE	1/32	1/16	3/32	1/8	5/32	3/16	7/32	1/4	9/32	5/16	11/32	3/8	7/16	1/2
.020	.062 .00069	.113 .00125	.161 .00179	.210 .00233	.259 .00287	.309 .00343	.358 .00397	.406 .00452	.455 .00506	.505 .00561	.554 .00626	.603 .00670	.702 .00780	.799 .00883
.025	.066 .00074	.116 .00129	.165 .00184	.214 .00238	.263 .00292	.313 .00348	.362 .00402	.410 .00456	.459 .00510	.509 .00566	.558 .00620	.607 .00674	.705 .00784	.803 .00892
.032	.071 .00079	.121 .00135	.170 .00189	.218 .00243	.267 .00297	.317 .00353	.366 .00407	.415 .00461	.463 .00515	.514 .00571	.562 .00625	.611 .00679	.710 .00789	.807 .00897
.040	.077 .00085	.127 .00141	.176 .00195	.224 .00249	.273 .00303	.323 .00359	.372 .00413	.421 .00468	.469 .00522	.520 .00577	.568 .00632	.617 .00686	.716 .00796	.813 .00904
.051		.134 .00141	.183 .00203	.232 .00258	.280 .00312	.331 .00368	.379 .00422	.428 .00476	.477 .00530	.527 .00586	.576 .00640	.624 .00694	.723 .00804	.821 .00912
.064		.144 .00160	.192 .00214	.241 .00268	.290 .00322	.340 .00378	.389 .00432	.437 .00486	.486 .00540	.536 .00596	.585 .00650	.634 .00704	.732 .00814	.830 .00922
.072			.198 .00220	.247 .00274	.296 .00328	.436 .00384	.394 .00428	.443 .00492	.492 .00547	.542 .00602	.591 .00656	.639 .00711	.738 .00821	.836 .00929
.081			.204 .00227	.253 .00281	.302 .00335	.352 .00391	.401 .00445	.449 .00497	.498 .00554	.548 .00609	.598 .00664	.646 .00718	.745 .00828	.842 .00936
.091			.212 .00235	.260 .00289	.309 .00343	.359 .00399	.408 .00453	.456 .00507	.505 .00561	.555 .00617	.604 .00671	.653 .00725	.752 .00835	.849 .00944
.125				.284 .00316	.333 .00370	.383 .00426	.432 .00480	.480 .00534	.529 .00568	.579 .00644	.628 .00698	.677 .00752	.776 .00862	.873 .0097
.188						.417 .00475	.476 .00529	.525 .00583	.573 .00638	.624 .00693	.672 .00747	.721 .00801	.820 .00911	.917 .01019
.250								.568 .00631	.617 .00685	.667 .00741	.716 .00795	.764 .00849	.863 .00959	.961 .01068

NOTE: Bend allowance for 90 degree bends-use upper numbers.
Lower numbers give bend allowance for 1 degree. (Multiply the number by the number of degrees of bend intended.)

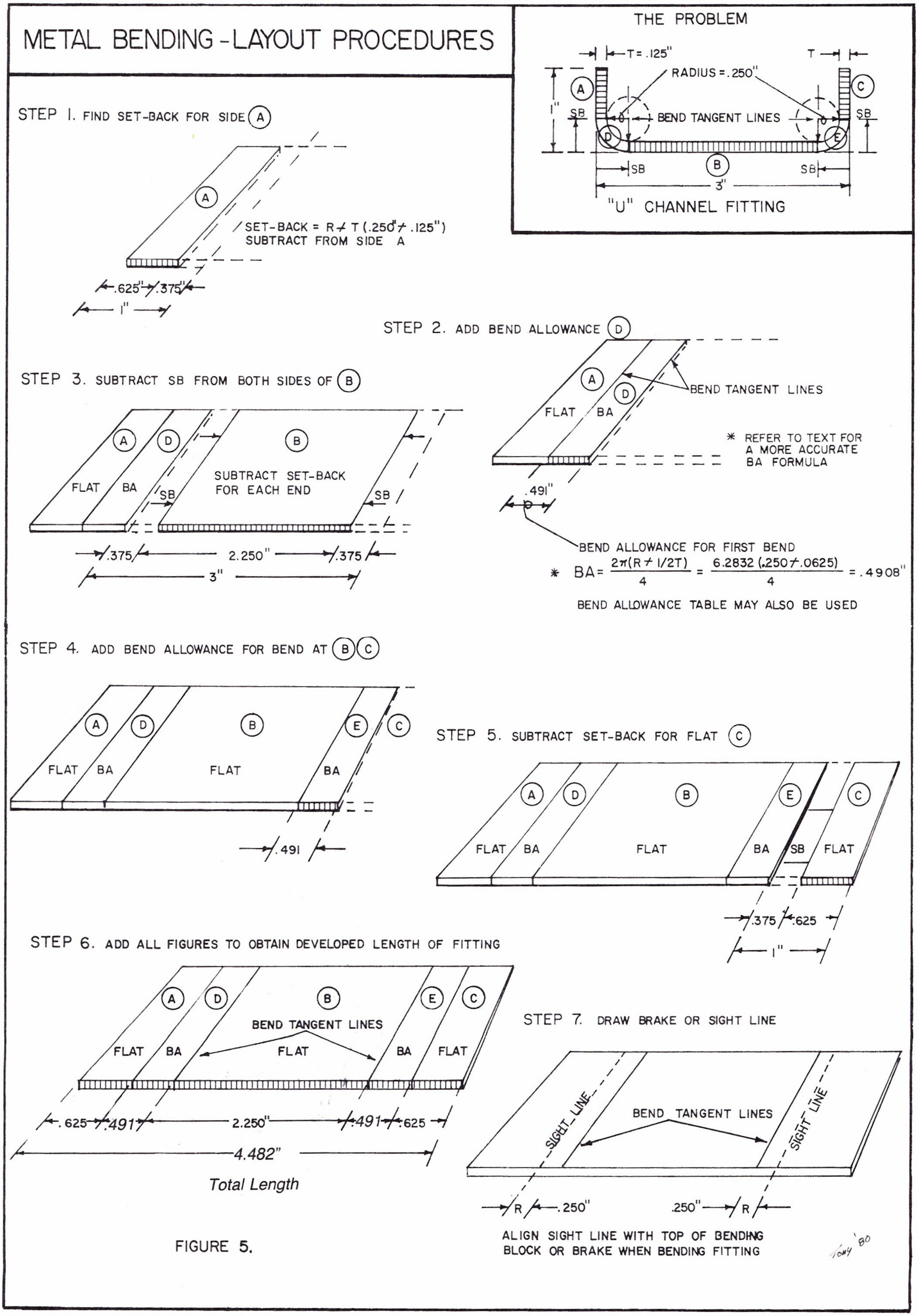

METAL BENDING - LAYOUT PROCEDURES
THE PROBLEM
T = .125"
T
RADIUS = .250"
1"
SB
BEND TANGENT LINES
A
B
C
D
E
SB
3"
"U" CHANNEL FITTING
STEP 1. FIND SET-BACK FOR SIDE (A)
SET-BACK = R + T (.250" + .125")
SUBTRACT FROM SIDE A
.625" .375"
1"
STEP 2. ADD BEND ALLOWANCE (D)
FLAT
BA
BEND TANGENT LINES
* REFER TO TEXT FOR A MORE ACCURATE BA FORMULA
.491"
BEND ALLOWANCE FOR FIRST BEND
* BA = 2π(R + 1/2T) / 4 = 6.2832 (.250 + .0625) / 4 = .4908"
BEND ALLOWANCE TABLE MAY ALSO BE USED
STEP 3. SUBTRACT SB FROM BOTH SIDES OF (B)
SUBTRACT SET-BACK FOR EACH END
SB
.375
2.250"
.375
3"
STEP 4. ADD BEND ALLOWANCE FOR BEND AT (B)(C)
FLAT
BA
FLAT
BA
.491
STEP 5. SUBTRACT SET-BACK FOR FLAT (C)
FLAT
BA
FLAT
BA
SB
FLAT
.375
.625
1"
STEP 6. ADD ALL FIGURES TO OBTAIN DEVELOPED LENGTH OF FITTING
BEND TANGENT LINES
FLAT
BA
FLAT
BA
FLAT
.625
.491
2.250"
.491
.625
4.482"
Total Length
STEP 7. DRAW BRAKE OR SIGHT LINE
SIGHT LINE
BEND TANGENT LINES
SIGHT LINE
R
.250"
.250"
R
ALIGN SIGHT LINE WITH TOP OF BENDING BLOCK OR BRAKE WHEN BENDING FITTING
Tony '80

FIGURE 5.

Making Fittings Part 3

by Antoni (Tony) Bingelis

FITTINGS CAN'T HELP the way they look. I mean, their appearance is determined by how they are fastened to the structure and how they are connected to something else. One end of a fitting, be it a flanged bracket or a simple flat fitting, is generally fastened to a primary structural unit with bolts or rivets. The other end of a fitting, most likely, connects some component part which must be attached to or be supported by the structure. For example, we can easily visualize how typical wing strap fittings, landing gear fittings, engine mount fittings, bracket-like fittings for controls, and other gadgets making up aircraft components and systems are commonly installed and connected. If we were to reduce a fitting to its most elementary function, you would see that its shape is really governed by the location and orientation of its mounting holes, and the hole or holes necessary to connect some component to it. As a result, the ultimate shape of a fitting simply evolves because sufficient metal must be provided around the essential holes to unite the fitting into a single part. See Figure 1.

Actually, the external dimensions of a fitting are not nearly as important as the accurate placement and sizing of the holes. On the other hand, determining the proper specification and gage for the material, from which to make the fitting so that it will be capable of carrying out its function through the life of the aircraft is important . . . and, that is where designers earn their keep.

There is usually only a slight difference between a fitting that is not strong enough to do the job and one that is excessively heavy. Determination of the exact material need really represents a greater challenge than most builders realize. As with most of the basic structure of an airplane, builders should not make fitting design changes or substitutions of materials unless they are able to substantiate those changes through design analysis or testing.

Bushings Vs Edge Distance

The most effective material shape, strength-wise, around a drilled hole is, naturally enough, a uniform radius. But, uniform radius or not, it is still possible, of course, to make a fitting with an insufficient amount of metal (edge distance) around its holes and this frequently happens. As a result, such a fitting might eventually fail with the bolt tearing away from the fitting. A similar consequence may result from a bolt hole that is mislocated during drilling, or one weakened by becoming oversized or elongated. Therefore, any fitting hole which will be subjected to wear from a bolt that pivots, should be fitted with a bronze bushing or made so there is a generous amount of material between the hole and the edge of the fitting.

When wear occurs in a bushed fitting, the bolt and/or bushing can be replaced. On the other hand, if a hole does not have a bushing, the only corrective action you would be able to take would be to replace the fitting or to redrill its hole to take the next size larger bolt. It is apparent that the latter cannot be safely done, however, unless a sufficient amount of metal was originally provided around the hole. Both aluminum and steel parts can benefit from the improved ability to handle friction and wear provided by bronze bushings.

Bronze bushings . . . especially oilite bronze bushings . . . effectively reduce frictional wear to a minimum. Bushings are easy enough to install provided you have the correct bit or reamer. The hole must be slightly undersized so the bushing will have to be pressed into the fitting. If you do not have a small press, you can still press the bushing in with precision by squeezing it in your vise. Place a washer of the correct thickness behind the fitting hole and the bushing, and the depth to which the bushing must be pressed in can be duplicated for any number of identical fittings.

Bronze, aluminum and steel being unlike metals can have a tendency to enter into galvanic action. This is an electro-chemical action which sometimes results in galvanic corrosion. It is the same sort of action that takes place in your battery . . . but this, of course, is just what you want. However, when the same kind of action takes place between two metals bolted to your airplane . . . this you do not want.

Some textbooks on metals contain tables which show the relative tendency for different metals to enter galvanic action. It seems that the greater the voltage difference between two metals, the greater the potential for corrosive activity. Be that as it may, you and I would probably be more likely to learn of the presence of galvanic corrosion by the build-up of a snow-like powder around a bolt and/or the fitting hole. Such activity and corrosion if not treated would probably continue to build to the point where it could eventually become destructive.

These scientific tabulations of metals with respect to their susceptibility toward corrosion are ordinarily considered merely as theoretical indicators of their tendency toward galvanic action.

If you want to be practical, you can reasonably assume that galvanic action (corrosion) will not take place unless water (moisture) is present. Dry fittings will not generally corrode. I have salvaged 20 to 30 year old aluminum fittings from military aircraft that had bronze bushings pressed into a variety of aluminum levers and bell cranks with no sign of corrosion in any of them. Obviously, to avoid corrosion inducing conditions, an aluminum fitting and its connecting steel bolt should be "insulated" against each other and moisture, with at least a light shot of zinc chromate primer. A protective

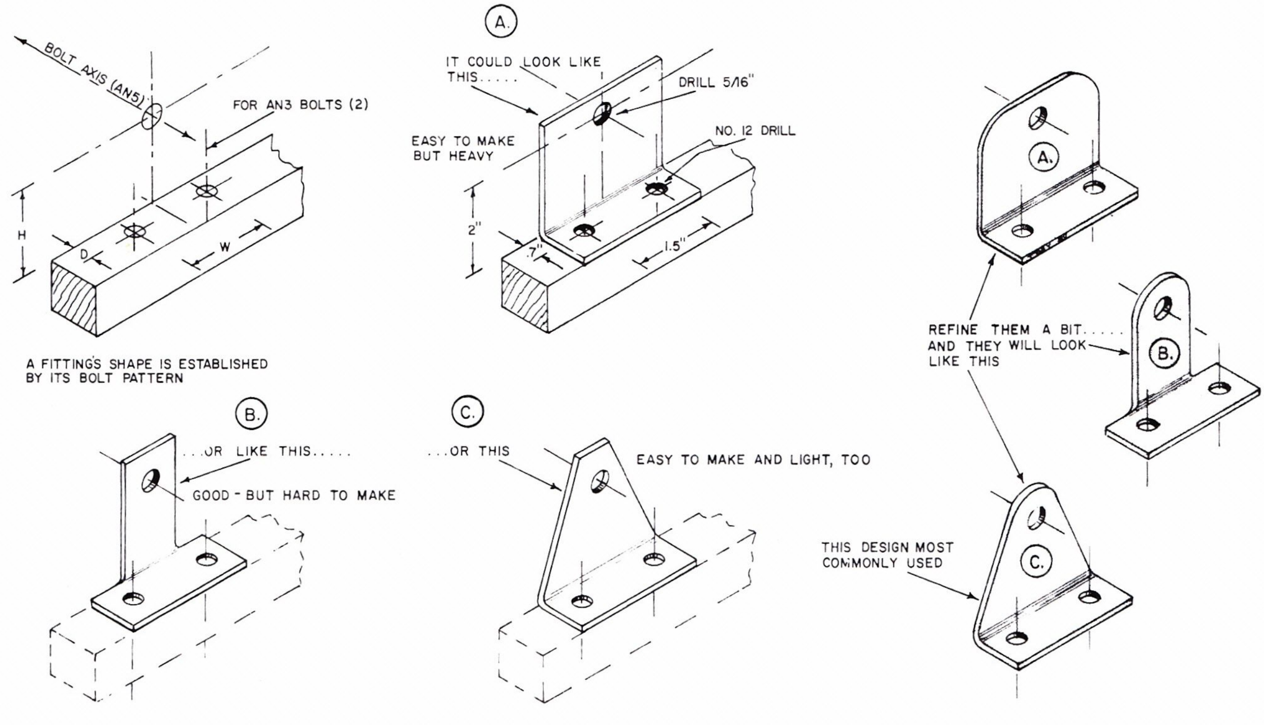


FIGURE I.

ANATOMY OF A FITTING

coating will do much to exclude destructive moisture from the area of contact between the two metals. Bushings pressed into holes might better be sealed by also using "Locktite" in the installation of bushings.

After a fitting installation is completed, polyurethane varnish may be flowed in around the entire assembly. This varnish has a very tenacious waterproof quality and as long as the film is unbroken, it will provide superior protection against corrosive elements.

Completing Your Fittings

Pen or pencil layout markings on steel are difficult to see (try using a silver pencil . . . art supplies) and many builders, therefore, like to scribe their lines on metal parts as an aid to accurate cutting. This is O.K. but only as long as they make no scribe mark on any portion of the metal that will not be cut away.

Never scribe a bend line as it will only create a possible location for a future material failure.

Now that you have obtained the specified material for the fitting . . . laid it out . . . cut it out and bent it as required, you are only half finished with the job.

One chore remaining is to finish your fittings to a uniform external shape making sure that all of their edges are smooth and free of saw and file marks. Surface nicks, scratches and gouges, if present, should be dressed out.

All steel and unclad aluminum parts should be smooth sanded. I use aluminum oxide sandpaper. Smooth finishing a fitting's edges is much easier with the part clamped in a vise. Use a smooth-cut file and follow that up with number 180 (or finer) wet-dry sandpaper on steel parts. Use it dry as wet sanding 4130 encourages rust to form before you can shake up the spray can of zinc chromate primer.

Sometimes we builders will find a piece or two of 4130 steel that has been lying around for years . . . and it shows it in its surfaces which may have varying degrees of rust, scratches and even pit marks. There is no harm in using the material although it should be cleaned up first to determine its acceptability before cutting out parts. This precaution will serve to assure you that you will not have to discard a part after you have spent much time making it. Rust will sand off easy enough provided that corrosion has not eaten into the metal to any degree. **All** rust must be removed, otherwise the residual will keep working away on the metal even after it has been primed and painted. Sanding the surfaces to a nice shiny appearance may or may not prove successful in removing all of the rust. Although the new shiny surfaces might look perfect, the grain of the metal will still have tiny little imbedded specks of rust invisible to the (if you will pardon the immodesty) naked eye. To be sure, treat steel surfaces with a metal conditioner to neutralize the rust. A product similar to

Osphos or any of those put out by DuPont and other paint companies may be used to take care of that problem. (Be sure to read and follow instructions.)

Aluminum oxide sandpaper should be used on aluminum fittings switching from a medium to fine grit in the clean-up process as necessary.

After you have made the surfaces as smooth as a teenager's freshly shaved cheeks, you need to take a close look at what you have. Examine all bend areas closely for cracks or signs of undue stress before you decide that the fitting is good enough to install in your airplane.

Although a lot of builders of metal aircraft like to see all of their internal parts in their natural aluminum shiny state, it is highly recommended that at least the joining surfaces of assembled parts be given a corrosion proofing treatment of some sort.

To most of us this usually means a good cleaning (degreasing) of the part followed by a spray can squirt of zinc chromate primer. Although this means of corrosion control is far from the best, it is not bad at all when you consider that there are builders who do nothing more than install the aluminum parts bare.

Ideally, steel parts should be cadmium plated by a shop that knows what it is doing. It should know of the necessity for, and the process of, a postplating bake treatment to assure relief from hydrogen embrittlement. Hydrogen embrittlement in plated steel parts subjected to vibration and constantly reversing loads, makes them quite susceptible to failure.

Aluminum fittings may be anodized, but this is an electrical process; one not practical for most of us to accomplish in our own limited work area. More likely you will prefer to treat aluminum parts with an aluminum conditioner to improve adhesion qualities for the zinc chromate coating to follow. Once again, the admonishment to make sure the product is suitable for the metal being used and that you follow the manufacturer's directions.

Before You Install Those Fittings . . .

It is a bit annoying to have completed a nice set of fittings only to realize that you cannot immediately install them because the structure hasn't been prepared to accept them.

Aluminum and steel fittings which will be bolted to wood surfaces must be protected from the latent moisture always present in the wood. It is customary, therefore, to coat underlying wood surfaces with two or more coats of varnish, preferably polyurethane or marine varnish, before any fitting is bolted to them permanently. The fittings, too, should be sprayed with at least a light coating of zinc chromate primer, and if you wish, painted. Don't paint them black . . . it's not that bad guys prefer black, but, rather, because black surfaces are simply difficult to inspect for cracks.

Varnish, rather than paint, is always the preferred coating for wood surfaces because it is transparent and the underlying wood's condition will always be visible during future inspections. A painted surface, on the other hand, may hide cracks, dry rot and other defects.

Bolts installed in wood also need protection against the natural moisture present. Even though bolts are cadmium plated, they will, eventually, suffer the effects of rust if not given a little extra help by you. Dip the bolts in zinc chromate primer or polyurethane varnish before permanently installing them . . . sure, you can spray the bolts if you haven't the provisions for dipping them. Some builders use a "Q" tip (a dab of cotton on a stick) and also swab the hole with varnish before installing the bolts.

Everything said for the wood-to-metal protection also applies to installations where steel bolts and nuts are in contact with aluminum alloy fittings. These dissimilar metals must be insulated from each other with some corrosion protection. It's a messy but effective practice . . dipping bolts in zinc chromate and installing them while the primer is still wet.

It is very easy to get a fitting cocked slightly when drilling installation holes. To avoid this horror, clamp the fitting in place checking its alignment. Drill the first hole and insert a bolt. Then recheck the alignment and reclamp the fitting before drilling the second hole. Don't rush! After the second bolt is inserted, any additional holes needed may be drilled with the assurance that the fitting can no longer slip out of alignment.

When two or more 90 degree angle fittings must have matching holes . . . as in control hinges . . . never drill each fitting separately with the anticipation that your skill will prevail.

If you prefer guaranteed accuracy, you might place two opposite fittings on a flat surface, clamp them together back-to-back and drill through both of them at the same time. You can then use one of them to serve as a master jig for drilling the other matching sets. That way you can defer proving your skill and precision for some other more demanding situation.

It is prudent to drill all holes initially undersized. You can always open them to the correct size later by line-drilling through the assembly. Any minor misalignment will usually be corrected in the process. What? You've heard this before? (Must be important.)

. . . They Call Them Relief Holes

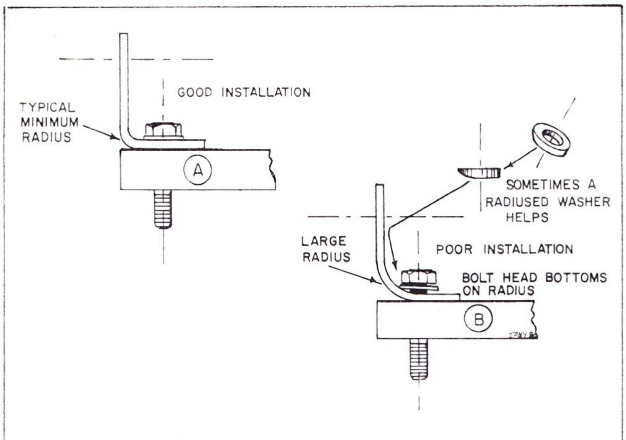
There aren't very many instances when you will have to make corner bends in aircraft work. I can think of only a couple; when you make a metal battery box and when you make a flanged fitting similar to one you might find in an aileron bell crank support. In these instances, should you try to bend the metal to form a corner, the material is crowded and it has no place to go. This crowding is particularly aggravated when the bend is attempted without a fairly large bend radius. As a result, cracks will form, radiating outward from the corner.

There is a simple way to prevent this forming problem from becoming a problem to you. Drill a small relief hole at each bend intersection. The bends will be easier to make and you will have prevented cracks from starting.

Don't be afraid to drill a good sized hole at each of the bend intersections **before** making the bends. I would recommend that the relief holes be at least 1/8" in diameter in thin metal and a 1/4" or larger in the heavier gages. Try a few sample holes and bends in scrap pieces to see the results. By the way, relief holes should have smooth edges, or be given a wisper of a chamfer with a piloted countersink or a larger drill bit twirled between your fingers. Just enough to remove the sharp edges and burrs . . . don't overdo it, remember the metal is probably quite thin. A piece of sandpaper rolled into a long taper will work as well.

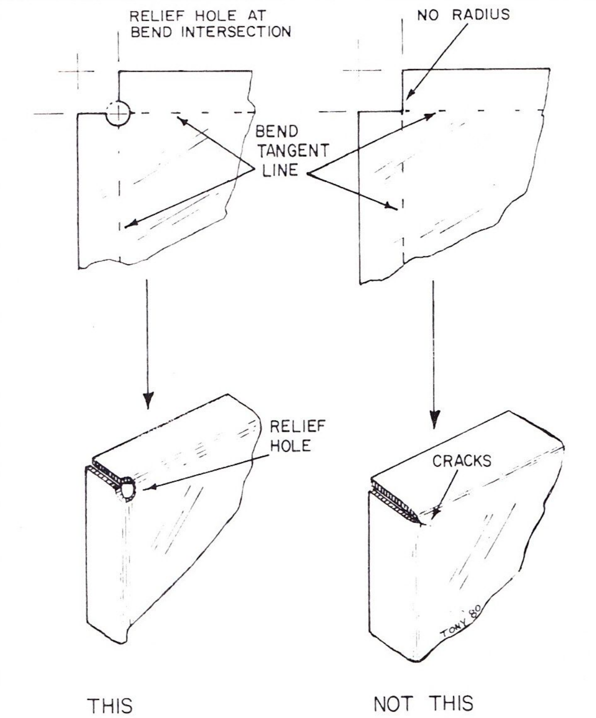
A Word About Piano Hinges

Yes, I would classify piano hinges as fittings . . . at least as used by many homebuilders. We use them to attach ailerons and flaps, trim tabs, inspection doors, cowlings and small baggage doors. They do make convenient easy-to-take-apart fittings for whatever use we are clever enough to devise.



A LARGE RADIUS IS GOOD BUT...

FIGURE 2.



PURPOSE OF RELIEF HOLES

FIGURE 3.

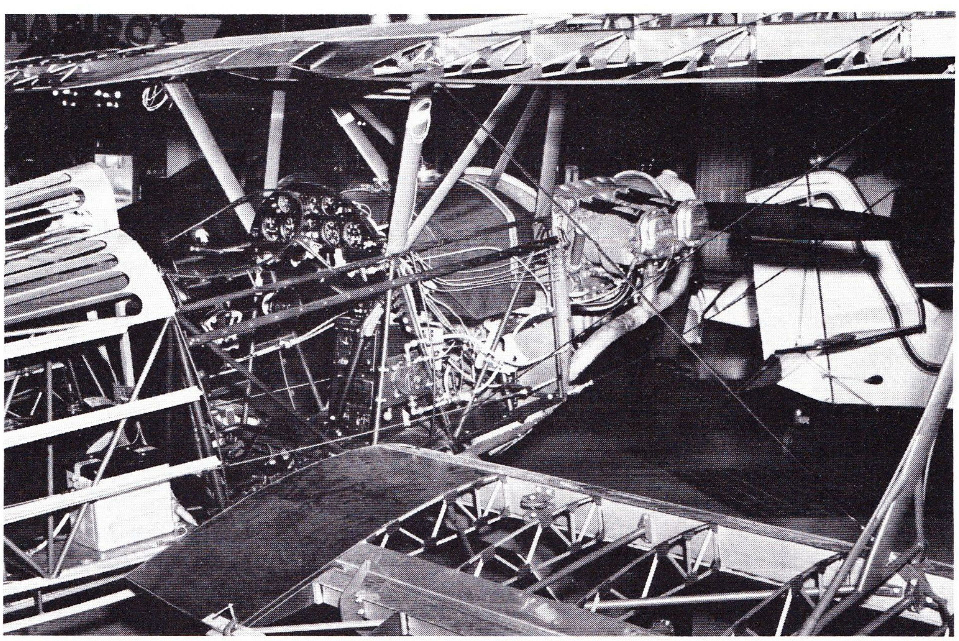
Two common varieties of piano hinges are currently available to you. One is the relatively inexpensive (MS 20257 series), and the other a much stronger extended type with closed hinge loops (MS 20001 series).

The stronger extruded piano hinge is used for structural applications and the weaker (MS 20257 and old AN 257) continuous hinge is used where the strength requirements are not critical. The hinges are normally obtainable in 6 foot lengths although most of your applications will require but short lengths of it.

The wire holding the hinge together is a stainless steel sort going under the name "piano wire". Hobby shops stock several sizes of piano wire if you need replacements.

Retention of the wire insert, in the hinge, is necessary in some installations to keep it from working out. If you would cut the piano wire so it will be about 1/8" short of each end of the piano hinge, you will be able to crimp its ends to keep the wire from working out. Alternatively, using a slightly shorter wire will permit you to drill a small hole in each end of the piano hinge, with a very small drill bit (say number 60) and through each of these holes insert a small wire to form a safety for the assembly. It is very difficult to bend a short end of the protruding wire, so that third method of ensuring the retention of the wire is not used very often.

Everything considered, making good fittings is time consuming but not difficult provided you use at least a minimum bend radius and drill the holes accurately.



Final assembly before covering. Note electrical wiring and fuel, hydraulic and control lines from cockpit to engine compartment. Note too radio stack mounted on floor ahead of the stick. Builder of this Starduster I has done an excellent job which is evident when studying the construction details in this photo.

Jigs for Alignment Accuracy

by Antoni (Tony) Bingelis

A JIG IS a wood or metal frame for holding parts in exact alignment during construction. It is also a dance done by the builder upon his successful return from an initial test flight. The former will assist in making the latter possible, so let's concentrate on the former.

I'm convinced that you cannot build even the simplest of aircraft without resorting to the use of a few jigs. Don't despair, a jig does not have to be a big complex frame welded of 2-inch and 4-inch pipes, angles and the like that one sees inside aircraft factories. In fact, a jig doesn't have to look like anything you have ever seen before as long as it will do the job you want it to do.

A jig can be as simple as a board with a few nails driven in it in such a manner that they hold two parts in alignment for welding; or it can be a larger, more complicated assembly of wood and metal for holding a complete landing gear in proper alignment during the fitting and subsequent welding of its individual parts.

Most jigs by far are simpler, less impressive devices that, for all the world, look like something the builder intends to throw out with the floor sweepings. And this is usually true.

JIG MATERIALS

Many kinds of materials go into jigs. Some defy classification, but of the more recognizable items I would include old 2 x 4's, scrap angle iron, tubing, pieces of U channels, plywood, saw horses, boxes, nails, bolts, C-clamps, wire, bricks, fiberglass, masonite, broom handles, etc., etc.

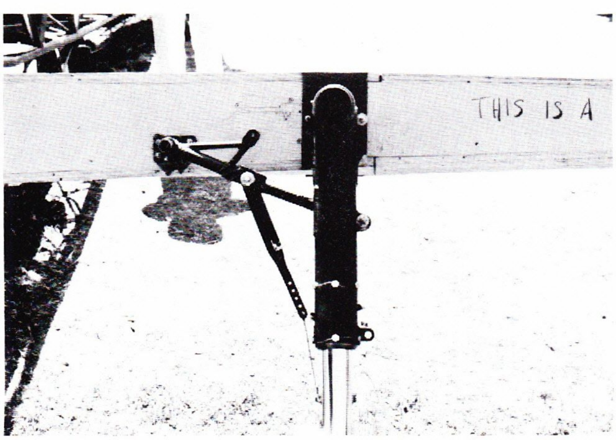
Whatever the materials used, you will need, as a starting point, a level surface such as a board, metal plate, or a workbench top. Equally essential is the establishment of a reference line to work from and to assure yourself frequently of the proper alignment of your work. Measurements in aircraft work are almost always taken from a reference or a centerline.

Jigs and bolts go together like coffee and cream. Not only are bolts used to hold most jig assemblies together, but they are also used to rigidly support the aircraft parts in the jig for whatever work is to be done on them. These bolts, of course, are often subjected to the heat of welding to the degree that scale is formed on the bolt shank and threads. The bushings or tubing through which the bolt sometimes runs also develops a scale build-up which tends to hold the two pieces together making it difficult, sometimes impossible, to remove the bolt. I've heard that the 'old time welders' used to precoat such bolts with white lead diluted about 50% with oil to prevent the formation of the oxide (scale) and, to serve as a lubricant. It might be worth a try if you have any white lead around the shop, or know where to get some. Another thing you can do is to first modify the bolt by grinding a flat surface along its shank before using it. This makes removal of the bolt much easier.

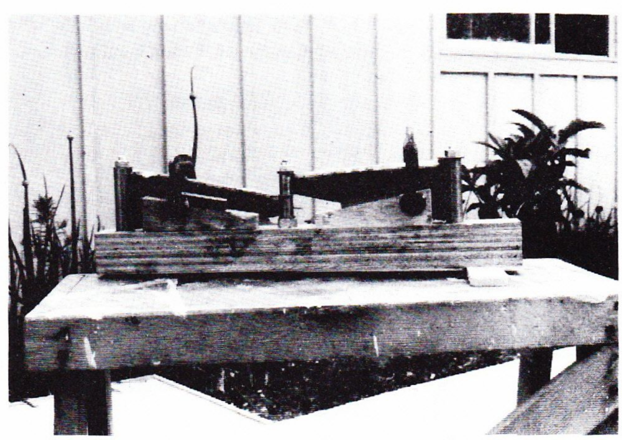
Instead of using nuts on the bolts utilized to support your jigged aircraft parts, you could use wing nuts to speed loading and unloading the jig. Likewise, it might be as expedient to use C-clamps instead of bolts.

PRACTICAL JIG DESIGN

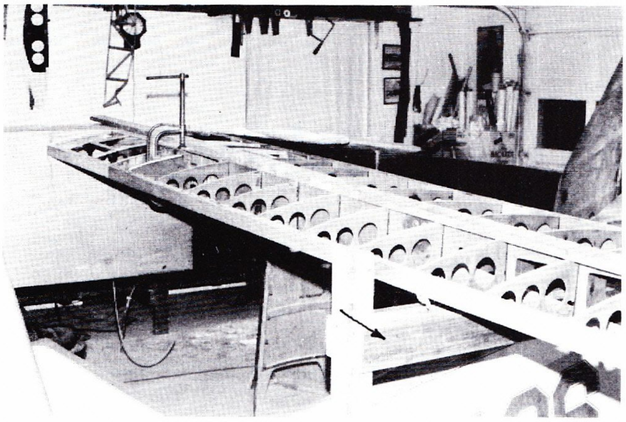
Jigs are categorized according to the part of the aircraft to be built in the jig. Therefore, such terms as wing jig, fuselage jig, control surface jig, wing rib jig, engine mount jig, and landing gear jig are all meaningful terms. Anyone who has been around homebuilders or is interested in such activities will have seen a wing rib jig and possibly others.



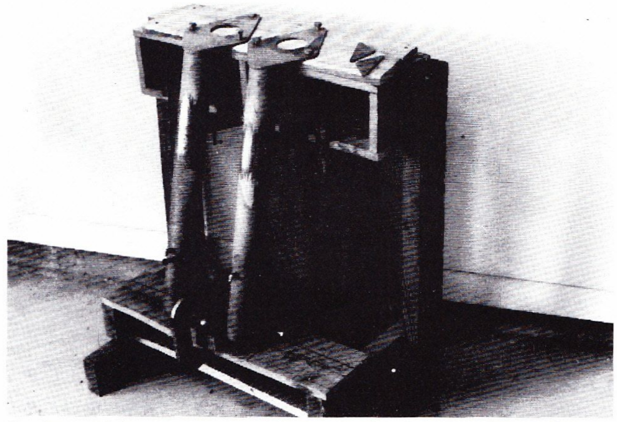
This spar mock-up serves as an assembly jig for working out the retraction mechanism details and operation.



Welding jig for landing gear scissors permits complete access for welding.



Simple jig used to maintain wing free from twist during construction.



Jig for welding upper gear leg attach plates using a dummy box spar for dimensioning and alignment.

The concept and method of executing a particular jig design is limited only by your imagination and the materials on hand. The objective is to design the jig so that the jigged parts are highly accessible and, so that you can do your work while remaining in an upright position. Not only is it undignified but, it is plumb awkward to crawl under a jig to do the overhead work. Even the professional welder finds overhead welding, and welding in other awkward positions difficult and tiresome. Furthermore, doing good work under the circumstances becomes more difficult.

Almost any jig made of wood, especially a large jig utilizing 2 x 4's and wood members, can be made rigid by adding gusseted joints at all corners. A wobbly jig could result in a poorly made and unusable part.

It's worth repeating. During the construction of your jig, as in all aircraft construction layout of parts and components, take your measurements from a reference line to obtain the accuracy needed. A large carpenter's square and a plumb bob will be handy in establishing perpendicular alignment.

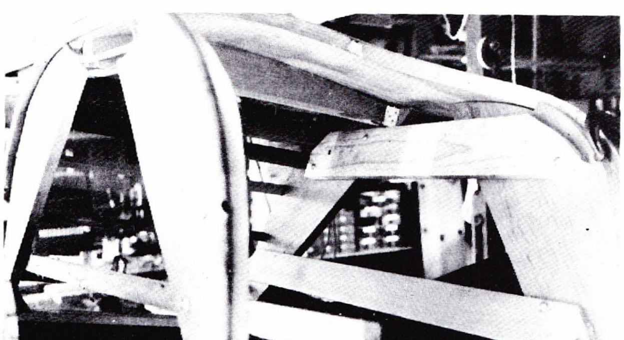
The design of the jig must permit easy access to the parts and to the weld areas. Sometimes you may have to cut holes in wooden jigs to provide the necessary access. But, welding through such cut-outs often permits the welding of the complete joint in the jig, reducing the risk of distortion or possible misalignment of the part due to premature removal from the jig.

Wood jigs used as welding fixtures have the disadvantage of being flammable. They char easily and sometimes burst out in a spectacular blaze at the most inconvenient moment. In your jig assembly strive to minimize the use of wood members close to the intended weld areas.

Metal jigs are not without problems, either. For example, you may have to cope with the problem caused by the heat-sink effect of a poorly designed jig incorporating large metal members adjacent to the parts that are to be welded. A similar problem is encountered when a builder clamps a couple of parts in a heavy vise for welding. He is dismayed when he can't seem to get enough heat to the parts to weld them properly. The heavy mass of the vise serves as an unwanted heat sink which could affect the ductility of the metal in localized areas and contribute to a poor weld.

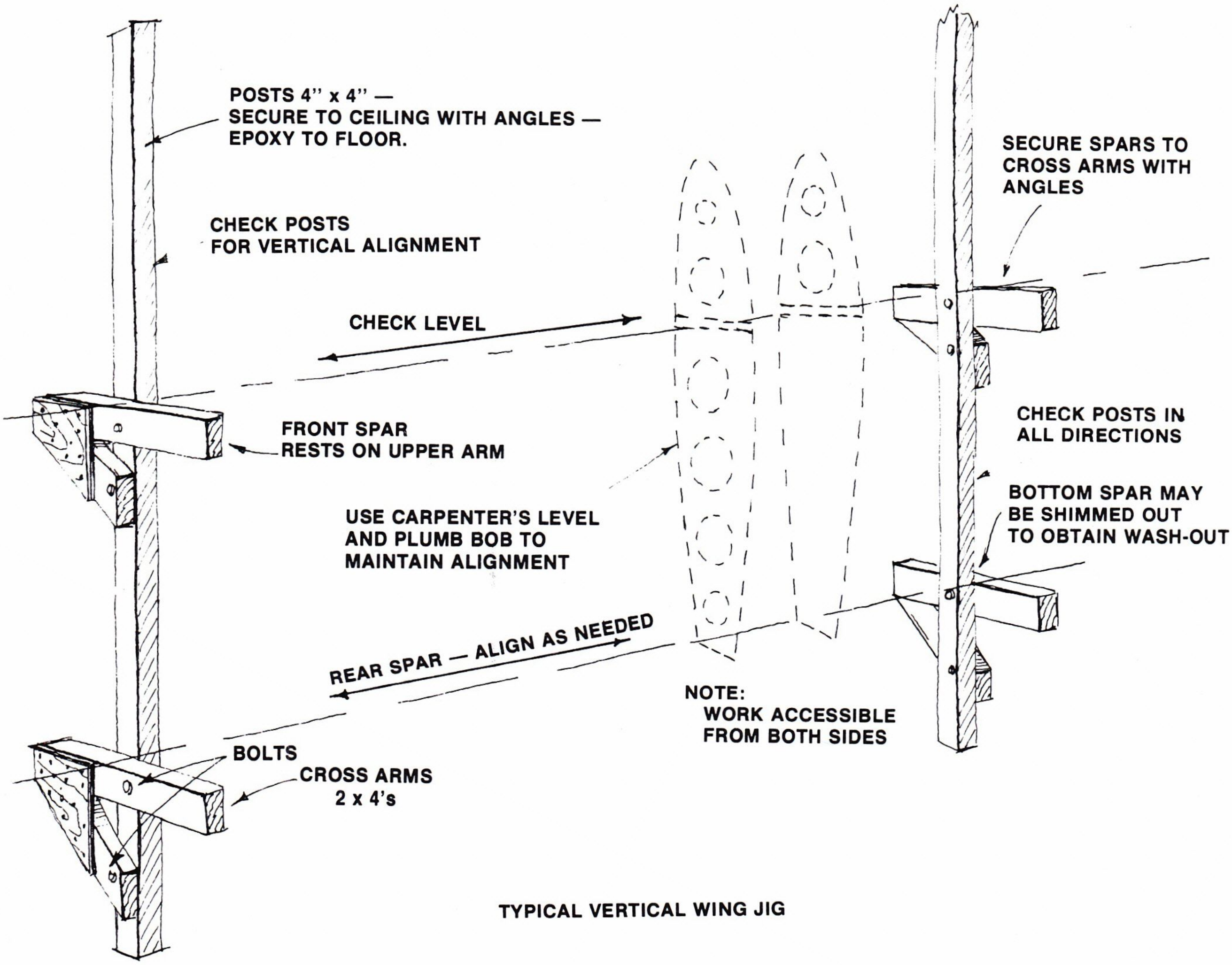
Incidentally, it is important to remember when welding 4130 steel that it is an air-hardening alloy. This means that it could develop cracks if subjected to sudden cooling. Sometimes, even the slightest breeze wafting its way through your work area can result in a cracked weld. Suffer the heat but keep the fan off and the breezes away from your work area.

Jigs constructed by the homebuilder do not have to be as sturdy as those used on a factory production line since the use of his is generally limited to one aircraft. Nevertheless,



Complex cabin jig or form for bending and checking fit of tubing for the large door. It will later be developed into a mold for the stretching of a compound curved window.

Simple wooden form will serve as a jig for forming of the console for a BD-4 instrument panel.



TYPICAL VERTICAL WING JIG

a flimsy wobbly frame cannot be relied on for maintaining accurate alignment. Don't use any more members in its assembly than are absolutely necessary, because the more structure added to the jig, the poorer the access.

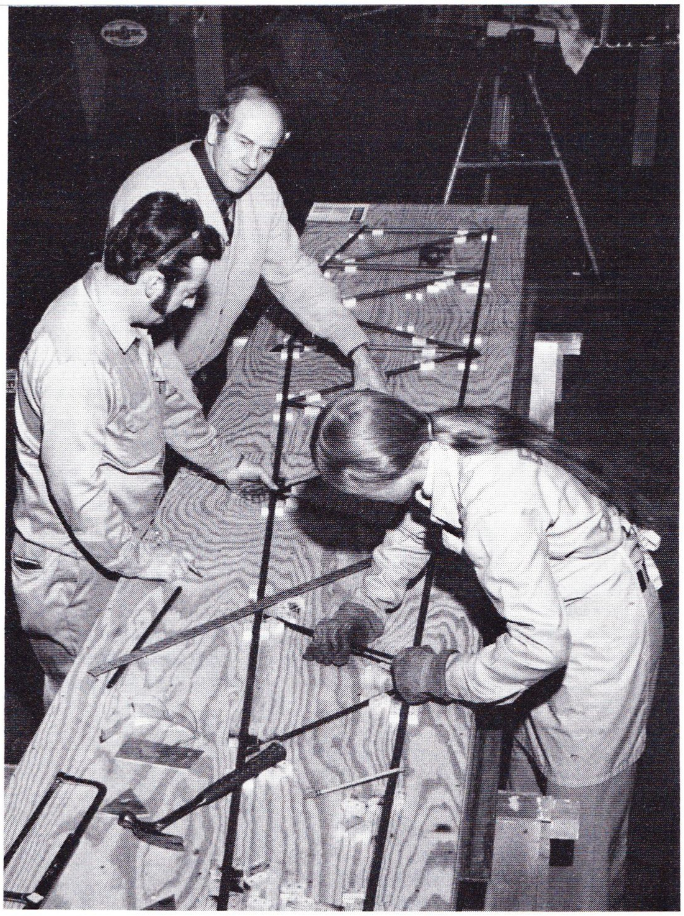
Wood and metal jigs should preferably be assembled using bolts rather than nails. However, metal jigs may also be arc welded or gas welded wherever it best serves your purpose.

Accuracy of measurement must always be maintained at points where the aircraft formers and bulkheads are to be attached to the fuselage jig. Likewise, in other jigs, all attachment fittings and holes require accurate alignment and drilling. Take your time and make your jigs right the first time.

Do not overlook the obvious when building your jigs. Sometimes you must make a left hand part and a right hand part. Making two opposite parts using one jig seems like a quick way to do it . . . and it is, but will it work? Some parts are not interchangeable as a left and a right unit. When making a left and right jig set-up, a common through bolt, if it can be utilized, will insure perfect alignment of the two opposite parts. Landing gear scissors, for example.

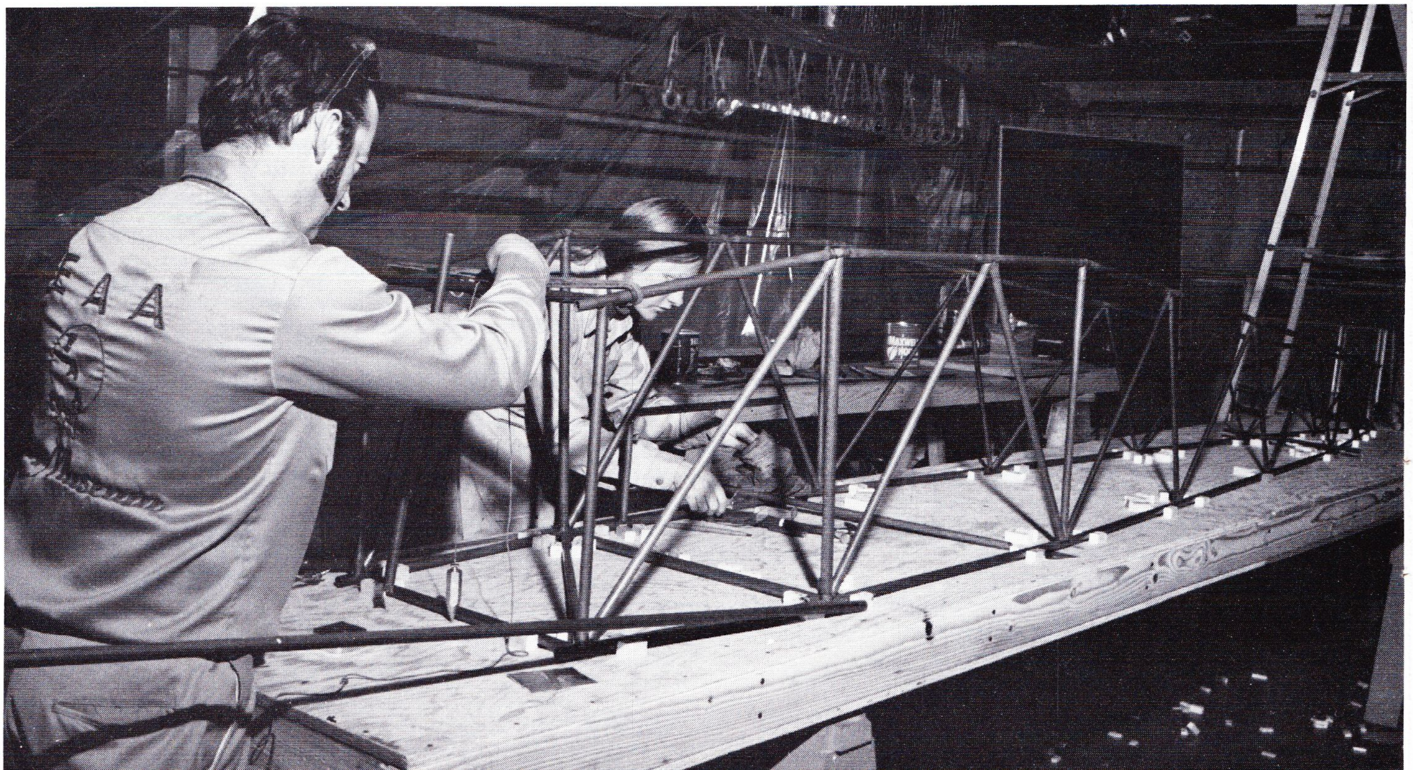
Although making a right hand and left hand fixture (side-by-side) improves your chances for accurate jigging of the work, you will soon find that often it is better to load only one side of the jig at a time for welding. Maximum access to the areas to be welded will then be guaranteed. Before welding, double check that you have it right (and left).

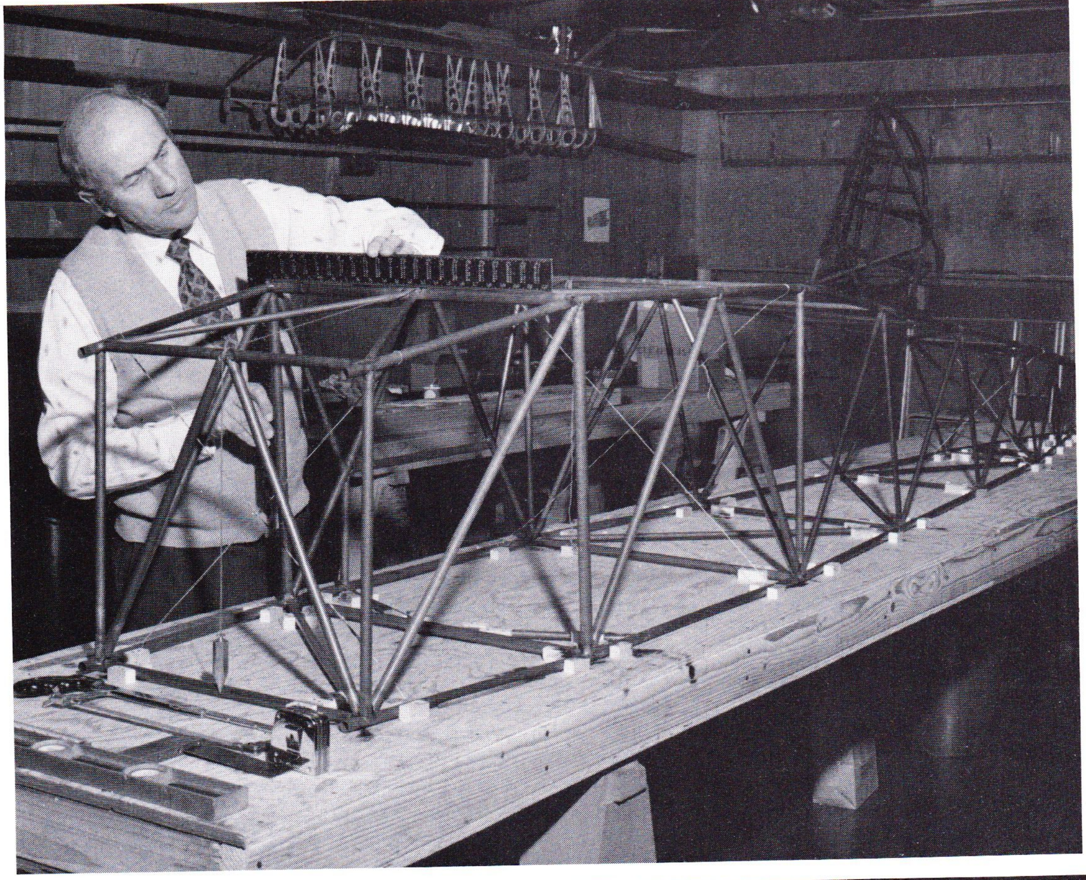
Funny things happen when a builder gets overly involved with his jig. Would you believe that I have seen a jig so well constructed and so effective that the builder could not remove the completed part. Flying an airplane with a left-over jig still attached to it not only reduces performance but is difficult to explain.



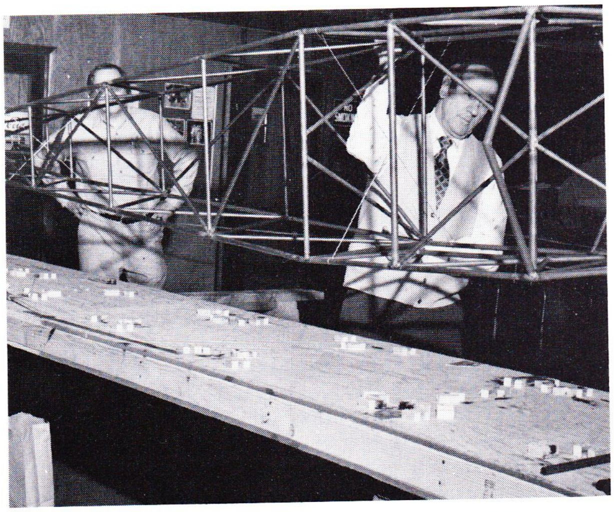
Basic Fuselage Construction

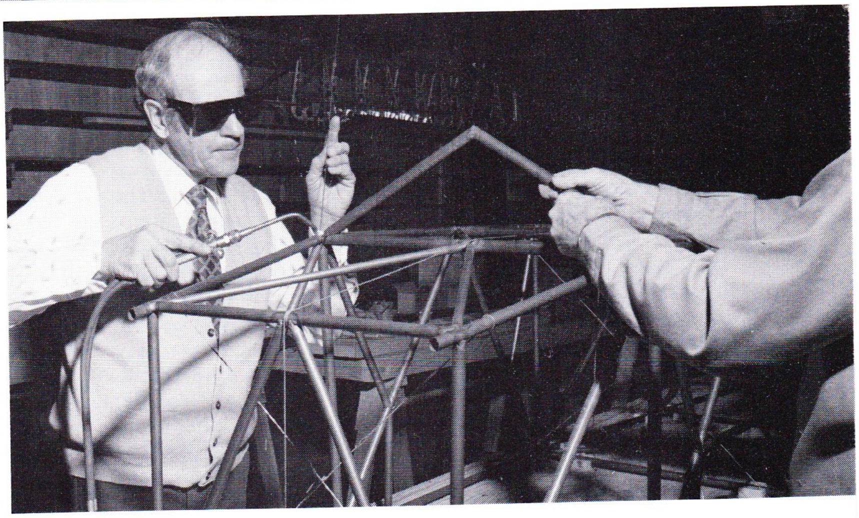
The construction of a flat level table, at comfortable working height, is the first step in starting construction of the basic fuselage. Next, dimensions for the side of the fuselage are transferred from the plans to full size on the plywood table top. Be very accurate in measuring as a mistake at this stage can have serious consequences later. Double check every dimension — then check again! Tubing is then cut and fitted as shown above - left. Tubing is tack welded at this stage. Both fuselage sides are constructed using the same jig. With sides completed the top dimensions of the fuselage are drawn on the table and the sides positioned as shown above. Cross tubes are then fitted and tack welded as shown below.



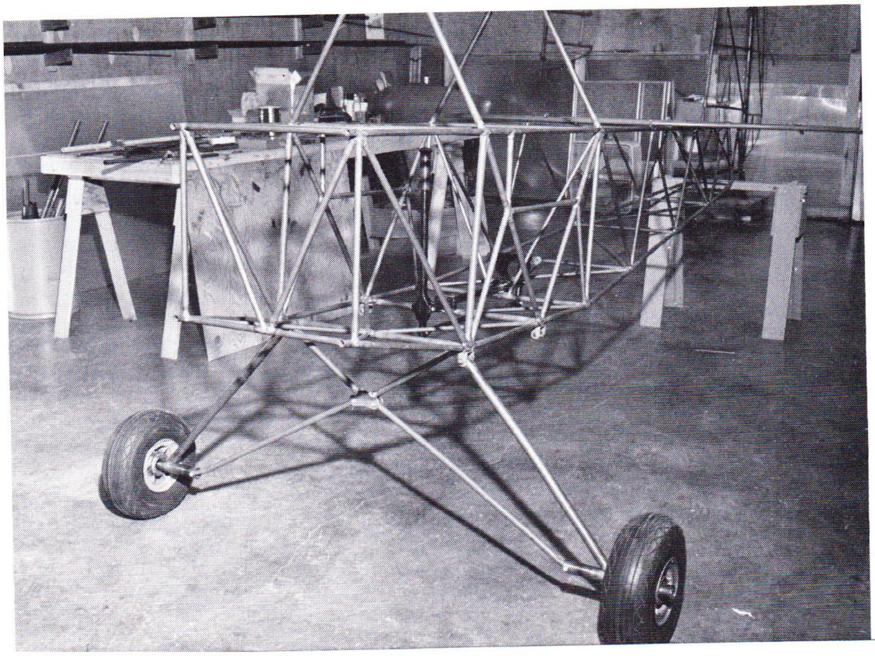


Use plumb line and square to check alignment (left), at every step while tack welding cross tubing so that everything is true. A second pair of hands to hold parts while tack welding is very beneficial (below).





With all cross pieces in position and tack welded, the fuselage frame is lifted out of the jig (above), for final welding of all tubes, fittings, stand-offs and other parts that are to be welded to the basic fuselage frame.



Fuselage on gear (right) with cabanes in position and tail assembly attached. Fuselage shown on these pages is the Pober Pixie, a VW powered parasol. Aircraft is easy to build and is designed for safe, economical fun flying. Plans are available from Acro Sport, Inc., P.O. Box 462, Hales Corners, Wisconsin 53130.

Aircraft Welding

How to Get Good Results

by Antoni (Tony) Bingelis

THE SUBJECT IS controversial. Should the homebuilder try to stress relieve his 4130 welded structures with a torch?

The act of stress relieving a weldment is simple, and although highly recommended by many expert welders, it is poopooed (no such word . . . it just sounds right) by others just as well qualified. The treatment requires that the weld, and the metal areas adjacent to it, be heated uniformly with an acetylene torch to bring the metal to a dull red (approximately 1,000°F) condition and then cooled in still air. That's it. Now, why should this be necessary? When steel is heated as in welding, it increases in size in all its dimensions. While the weld is progressing, a rather narrow zone adjacent to it will reach a plastic condition and ultimately a molten state if the heating continues. This uneven heating sets up stresses in the metal. The metal that is further away from the flame will resist the expansion taking place in the weld area. Meanwhile back at the weld, the tremendous initial pressures exerted by the heated metal become less resistant to the surrounding pressures of the cooler metal. The plastic center begins to yield to the compression force, which is now capable of buckling the plasticized metal in the weld area. This processs continues along the line of the weld. And since all of the pressure or stress is not relieved in the process, these stresses remain trapped, or locked-in as the saying goes. Distortion also is a by-product of these complex changes in the metal. As soon as the welding is completed, the molten metal, if it is permitted to do so, begins to cool down, somewhat more rapidly in comparison to the surrounding areas which will not have been heated much. In effect, this uncontrolled cooling causes an uneven contraction in the metal, as the cool metal further from the vicinity of the weld induces a quenching effect. This effect, of course, would even be greater if there were a nearby weld cluster or a welded fitting.

Anyone who has welded an engine mount or other structure requiring the exact alignment and positioning of mounting holes will attest to the fact that, without rigid jigging, the assembly would crawl around during the welding, as if it were alive. Indeed, the expansion of the metal from the heat of welding and its subsequent cooling and contraction are usually so drastic that the builder must allow for the effect of this distortion.

Ordinarily, such stresses are not as severe nor do they present a problem in simple welded joints that are subjected only to static tension, torsion, or compression. No problem that is, provided the metal's ductility has not been seriously impaired by the welding. It is mostly with larger parts that are highly loaded, and perhaps subjected to vibration during their service life that the prospect of cracking or failure of the weld must be faced.

So, we do have something to think about in regard to the locked-in stresses of welding. Is this a serious enough condition to require some form of stress relief, or should it be ignored because the homebuilder is unable to heat treat the entire assembly in a furnace?

Among those who say that the stress relief of a weld with a torch is not necessary or is not recommended, are some very good welders. Undoubtedly, these welders follow a welding procedure much like this — . . . preheat the metal, make the weld, and complete the process by playing the torch over the entire vicinity of the weld until the molten area has cooled down to a red-heat. Then, and only then, is the torch finally withdrawn. What these welders are doing, in effect, is stress relieving the weldment at the same time it is made. That makes good sense. After all, why leave a newly completed weld where the metal is already thoroughly heated without completing the job? Why should it be necessary to return some time later when the weld and the surrounding metal is totally cold? You would only have to start anew by raising the metal's temperature to that dull red condition necessary for the stress relief you wish to obtain.

It is easy to see that essentially the same results are achieved in both instances except that one welder is more experienced and more frugal with his time and energy. I can understand why such a welder would say that he never stress relieves his welds. Nor is there any conflict in my mind with the procedures adopted and practiced by manufacturers and the professional aerospace engineers as well as factory representatives who believe that the best way to stress relieve a welded 4130 structure is not with a torch but in an oven. Can't argue with that logic. But, I guess their stand is primarily based on the opinion that torch stress relieving is undesirable because the area involved may not be uniformly and thoroughly heated. This is possibly true with some builders who do not take the time to switch to a larger welding tip and those who may not be as careful in heating the areas uniformly and methodically. After all, its easy to inadvertently get some places too hot.

In real life, however, finding an oven to stress relieve an entire fuselage is like finding the pot at the end of the rainbow. So, the option remains, either to stress relieve the completed welds with a torch or to modify the welding technique to assure that the classic pre-heat, weld, and post heat applications serve to accomplish the same end result.

Recently, someone tried to convince me that when one attempts to stress relieve a weldment with an acetylene torch (as opposed to using an oven) he simply moves the stresses outward from the welded area, but does not relieve them. That argument concluded with the observation that it would therefore, be more desirable to have these stresses in a welded cluster where the structure was the strongest as opposed to moving them outward on the tubing where the structure was weakest. I don't know why but the remark was added . . . "this, of course, is based on the assumption that 4130 steel was being used in a properly designed structure."

I find that supposition faulty for the most part. It might be true if there were some sort of heat sink a short distance away from the weld which might have a

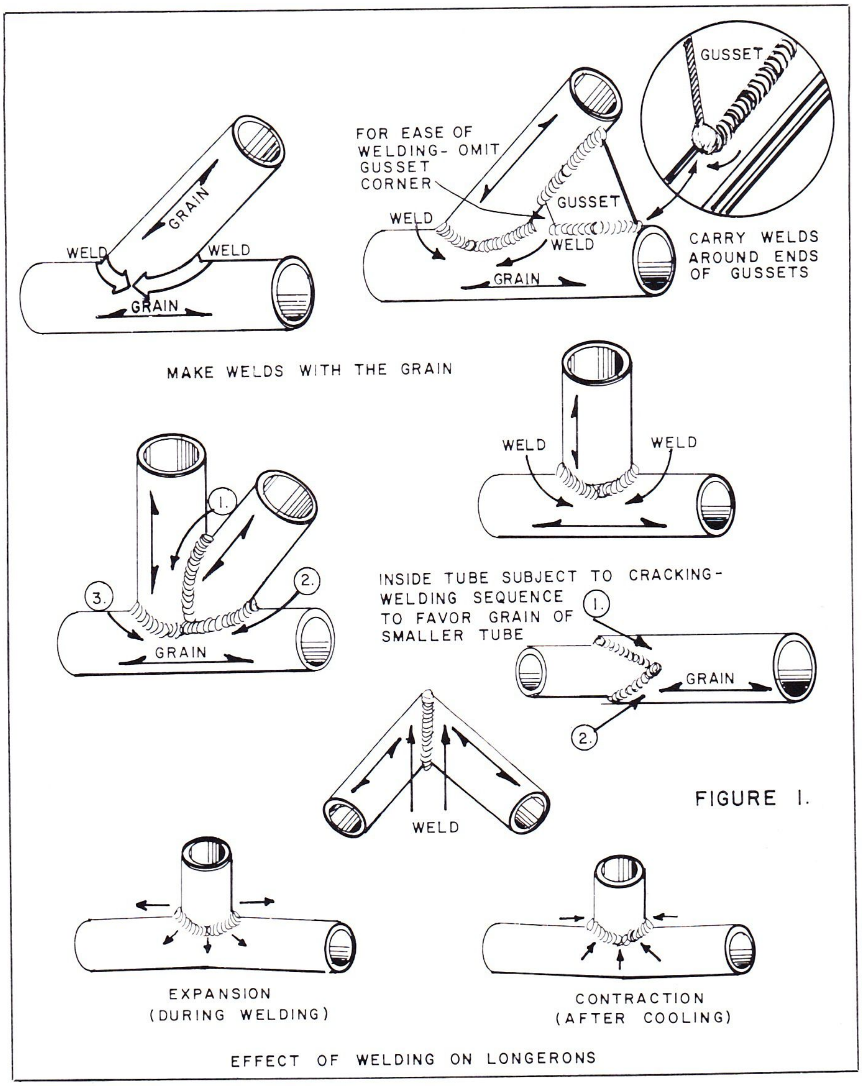


FIGURE 1.

quenching effect on an unevenly heated weldment. However, it seems that during a properly executed stress relief effort this would not be true. Here's why. The weld area is thoroughly pre-heated and brought up to a dull red condition and, therefore, the heated areas of the metal will range outward to an almost red, very hot, hot, not so hot, to a relatively cool and ultimately cool condition some distance away from the weld. How could such a gradual thermal change in the metal from the weldment to the remainder of the metal cause serious stresses to be moved further outward on the tube as these folks suggest? Again, an exception might be if there were an adjacent welded cluster that was not included in the heating process.

The fact remains that people who obviously have much experience in this area do honestly disagree on this particular point. Maybe the real disagreement is not so much whether to stress relieve or not, but with the technique utilized in making welds.

Other Matters Involving Stress In Welds

The Matter of pre-heating — What is the best way to begin a weld in 4130 steel? Certainly, not with a concentrated application of the flame directly to the joint. Such a modus operandi (that's Texas talk for . . . technique) may result in committing certain critical welds to a short-lived future even though a fairly good looking uniform weld was obtained. Additionally, a welding procedure like that introduces internal stresses in the adjoining metal in the manner discussed earlier.

The proper starting procedure is to always take the time to pre-heat the metal before starting to weld. The work should be approached with the flame in a playful manner, if you will, playing the flame over the entire area until it is evenly heated. This pre-heating is especially important when there is a nearby welded joint. It doesn't mean though, that the surrounding metal must be raised to a red hot condition . . . not at all.

Weld With the Grain? — Metal does have grain, you know. Somewhat like that in wood. It results from the manufacturing process and is a factor to consider whenever bending metal or welding it. The grain in tubing is noticeable and runs the length of the tube in straight lines. The grain in flat steel stock is likewise visible to the eye and is further delineated by the orientation of the lines of painted specification numbers and letters across the sheet.

Experience has shown that cracks tend to develop in welds made against the grain. Therefore, whenever possible welds should be made in the direction of the grain and not against it.

Examples shown in Figure 1 illustrate several exam-

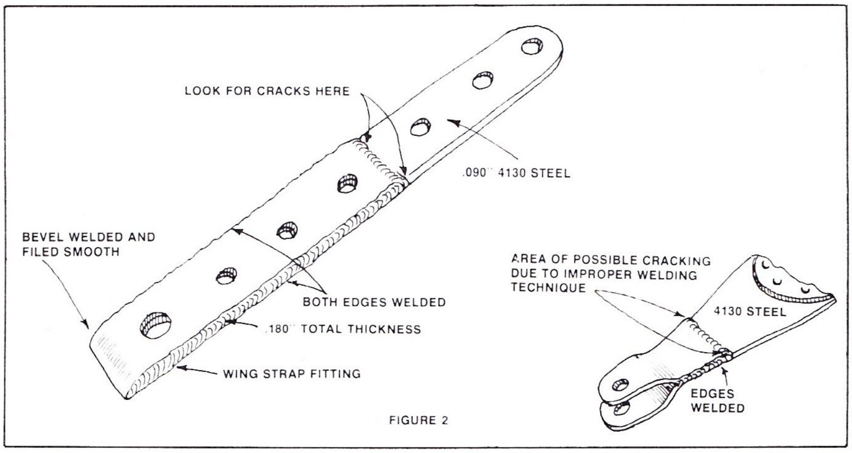


FIGURE 2

ples of this little heeded peculiarity.

Protect the Weld Against Oxidation — Once the metal is heated to a molten state and the welding puddle forms, air should not be permitted to reach the white hot metal at any time. Use the outer envelope of the flame as a protective blanket against oxidation. This protective blanket must not ever be totally removed even when changing to a new welding rod or readjusting the flame. Certainly, not until the weld is completed and the heated metal has been allowed to cool down to a red heat.

End the Weld Properly — Do not immediately withdraw the torch and marvel at the good looking weld you just completed. Instead, take your time and play the flame over the completed weld area until it cools to a red heat condition. The gradual withdrawal of the heat after the weld is completed minimizes the likelihood of cracks developing, or more likely, the appearance of small pin holes in the cooling puddles where the welds terminate. Furthermore, this procedure improves the ductility of the weld and minimizes the quenching effect the adjacent cooler metal may have. If all this seems familiar to you by now, I would hope so.

Beware of Breezes — Those gentle caressing breezes drifting through your workshop during those hot sultry summer days may be great for you, but they are bad for your welding. When welding 4130 steel do not expose it to any cooling by air in motion. This is an air hardening steel and it will develop cracks when subjected to any sudden cooling, however gentle it might feel to you. That means you should close any door near the welding area and shut off those fans, too, while you are welding. For that matter, you better make sure that your dog doesn't wag his tail, either.

Precision Rigging

By Bill Mann (EAA 22718)

Do your plans call for a 1½^0 angle of attack, or a 2¼^0 dihedral angle . . . and you're wondering how to accurately accomplish this? Do you need a $40 Bubble Protractor?

Note! Joe Pfeifer, well known California builder and restorer, has been measuring angles precisely for many years following the method shown below. This method is **much** more accurate than using a small protractor, usually resulting in a hands-off first flight.

Example For A 1½^0 Angle Of Attach

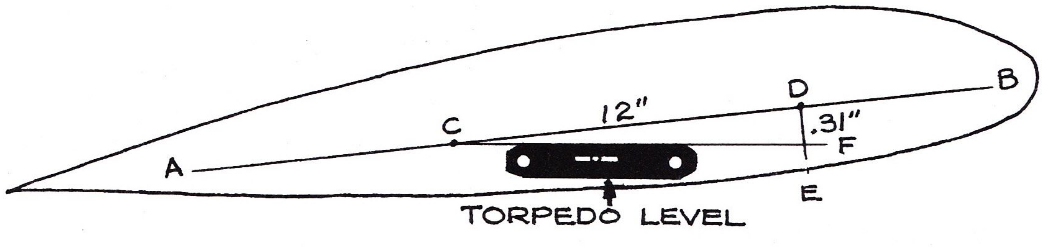
1. On a butt rib (or easily accessible rib) draw a chord line . . . or a line parallel to the chord line. (Line AB)
2. Mark off a 12" segment. (Line CD)
3. At the forward end of the segment (D), draw a perpendicular line downward. (Line DE)
4. Carefully measure off a length of the perpendicular line — downward from Point D the distance shown in the chart below. In this example, .31^0.

Our Example
Use Sears 6" Rule #9GT 40996

½^0	= .10"	3^0	= .63"
1^0	= .21"	4^0	= .84"
1½^0	= .31"	5^0	= 1.05"
2^0	= .42"	6^0	= 1.26"

(Interpolate For Other Values)

5. Draw line CF. This is a line exactly -1½^0 downward.
6. Clamp a Torpedo Level (Sears #9A 39823 — $4.97) to the negative 1½^0 line (CF), then raise the lead-edge until the torpedo level bubble centers.
   Your angle of attack is now exactly 1½^0
   It is important to use a torpedo level because it has a straight glass tube and is very sensitive. Don't use a carpenter's level with the curved tube.



Random Notes on Welded Steel Tube Structures

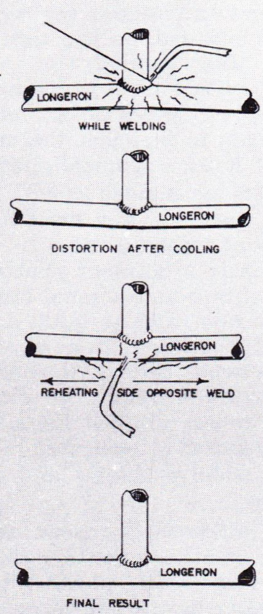
by Antoni (Tony) Bingelis

THE PROBLEMS WE most frequently encounter in building steel tube fuselages, or for that matter most welded components, are those resulting from the welding process itself.

Here's what happens everytime you weld a tubular joint.

As the tubing is heated, tremendous pressure is exerted in the area of the weld by the expanding hot metal; at the same time just a bit further away, the metal is cooler and unyielding. It resists the expansion. As a result, as soon as the heated area becomes plastic (molten), it succumbs to the resisting pressures around it and the molten area compresses and thickens in the process. This relieves the pressure in the expanding weld area.

When the weld is completed the heat of the torch is withdrawn and the metal starts to cool. Contraction takes place as the joint area tries to return to its original shape and dimension. But because the weld area was compressed during its molten state by the surrounding cooler metal, and because the metal now is no longer molten, the tubing will contract beyond its original configuration in making up for the diminished metal area caused by the original thickening that took place during welding. The resultant contraction is shown in Figure 1.



EFFECT OF HEATING AND COOLING ON LONGERONS

FIGURE I.

Let's Get It Straight

It seems to be a common belief that if you normalize a weld the tube will relieve itself of both the internal stress and the distortion. This is not so. Although the internal stress will be relieved, the distortion will not be. The distortion, if allowed to remain uncorrected, can endow your airplane with a bad case of the uglies or cause other difficulties depending on the locations where they take place.

For instance, you may have noticed after completing the fuselage welds that the longerons are bowed-in between some stations. This little cosmetic problem can be corrected by playing the torch flame along the outside portion of the longeron. Get the tube red hot and the longeron will probably return to its proper straight alignment. But what if it doesn't? In that case, the friendly persuasion of a rubber mallet may be exercised. For slight bends a rubber mallet's gentle influence (on the cold tubing) should be sufficient. Take care, however, not to dent or damage the tubing!

Try to remember that anytime you heat metal, it will increase in dimension . . . both in length and in breadth. Conversely, as it cools, it will contract but, because of the process described earlier, welded areas tend to contract a little more than they expanded.

Once you realize that the expansion/contraction process can no more be eliminated than the resulting localized shrinkage, you will learn to allow for it.

Fuselage Assembly Practices

The accepted assembly practice is to tack-weld a fuselage together before undertaking the completion of the welds at each tube cluster. This permits you to at least begin with a good alignment of everything. Nevertheless, continuously check the alignment during and after welding each bay, to determine what effect, if any, has been transmitted to other tack-welded areas.

I'm sure that one of the first lessons learned regarding fuselage assembly is the discovery that it is virtually impossible to insert diagonal tubes in place once the fuselage cross members are fitted and tacked. The obvious procedure is to fit and position the diagonals at each bay before installing the cross members in the next bay.

Incidentally, if you intend to treat the fuselage interior with a rust preventative treatment — don't forget to drill ⅛" holes in the longerons at every point of intersection with an upright tube, cross member, or a diagonal. The idea is to interconnect the entire structure with a passageway for the introduction of a rust preventative fluid. More on this later.

The Welding Sequence

Always start to finish-weld a tacked fuselage at the firewall and work toward the tail end, a single bay at a time. Complete welding each cluster before moving to the next bay. This method should minimize the amount of distortion and misalignment resulting from the welding process.

I would advise against installing and attempting to align any fittings until **after** the basic tubular structure has been completed. Accuracy in the alignment of components such as landing gear lugs, wing attachment fittings and the tail attachment fittings is then possible.

Try The Sub-Assembly Method

One way to reduce the undesirable effects of contraction resulting from the welding is to pre-fabricate portions of the structure as sub-assemblies.

Certain tube clusters are very difficult to reach when an attempt is made to assemble them along with the main structure. Trying to finish-weld clusters in confined areas can be frustrating. It may be better, therefore, to jig such assemblies on a workbench or in some other convenient welding location to finish-weld, straighten and normalize the sub-assembly beforehand. Then when you do install it in the primary structure the only welds remaining to be made are the legends attaching it to the main frame. Some landing gear trusses fall in this category.

About Splicing Longerons

Sometimes longerons must be spliced because the designer calls out a tubing size reduction in the longerons just aft of the cockpit. Designers often do this because loads and stresses are lower nearer the tail.

To effect the dimensional reduction in the longerons called for, use either scarf joints or fish-mouth joints. These joints will, when properly made and welded, result in greater strength than the original tubing. The angle of cut for either type of joint is made at 30 degrees to the centerline of the tube. For my part, I think the fish-mouth splice is the better joint for longerons.

I would highly recommend that you make the splice and complete the welding of each as a sub-assembly before inserting the longerons in the fuselage assembly jig. This assembly technique should outwit the "shrink gremlins" and allow you to maintain dimensional accuracy in the fuselage.

In making these longeron splices a smaller diameter tubing is telescoped into the larger a short distance, approximately equal to the diameter of the smaller tube. Someone is sure to ask how good a fit is needed for this splice. Well, in making a fish-mouth splice, the fit between the smaller and larger tube may be somewhat on the loose side. However, for the scarf-joint type of splice, the fit between the telescoped tubes must be fairly close. Use the next size smaller tube and it will be just about right.

Controlling Warpage

To attach tail surface hinges, a fairly heavy weld must be made along the centerline of the stabilizer spar and likewise on the facing side of the elevator torque tube spar. Each of these tubes will warp due to the welding shrinkage at the point of each hinge weldment.

So, weld those hinges first . . . finish them before inserting the tube into the tail assembly jig. By prefabricating the tail spar tubes separately they can be straightened easily by applying heat to the side opposite from the welded hinge.

I guess the general rule, if there is one, is to look at each assembly and determine if it might best be welded up as a sub-unit.

Similarly, an engine mount requires the maintenance of accurate alignment throughout the welding process because, as the tubing is heated and welded, it "walks around" quite a bit. It is not unusual to complete welding an engine mount only to find that the mounting bolt holes are misaligned . . . sometimes by as much as 3/8". Rigid jigging, therefore, is a must for engine mount construction.

The basic alignment problem, I find, occurs because some builders will not take time to build a rigid metal jig. Instead, they use wood and plywood. Both will char and burn during welding. The charring usually causes the bolt holes to become oversized or elongated . . . and that is when problems and errors multiply.

Most all-wood European designs feature engine mounts welded to rather large metal plates (fittings) which serve as attachment points for bolting the mount to the firewall. The large steel fittings do an excellent job of distributing localized loads in a wood structure but they are difficult, very difficult to weld to thin-wall engine mount tubes. You learn this quickly because by the time you get the steel plate to a molten state, the thin wall of the tubing has been overheated and has started to disappear before your eyes. And, try as you may, it is difficult to lay a good bead without burning away the tubing.

Then later (assuming you were fairly successful), when you turn the mount over for welding the flip-side, the challenge becomes just too much because then you have the just completed weld on the reverse side contributing a temperature-robbing-mass to your problem of getting enough welding heat in the right place. What to do? Well, it would be nice to have somebody heliarc weld the mount, of course. However, your best course of action is to arrange to have someone play another torch over the metal fitting to preheat it and to keep its temperature up while you concentrate on making a good weld. It is the differential in the heat required that causes you to burn through the thin wall tubing. Alternatively, you might switch to a heavier wall tubing. Welding .049" tubing is much less demanding than using .035" wall thickness. Even easier to weld would be tubing having a wall thickness of .065" but here we go with a significant increase in weight. At any rate, remember that preheating the heavier metal areas and keeping them up to red heat will afford you the best chance for making successful welds in this kind of a welding situation.

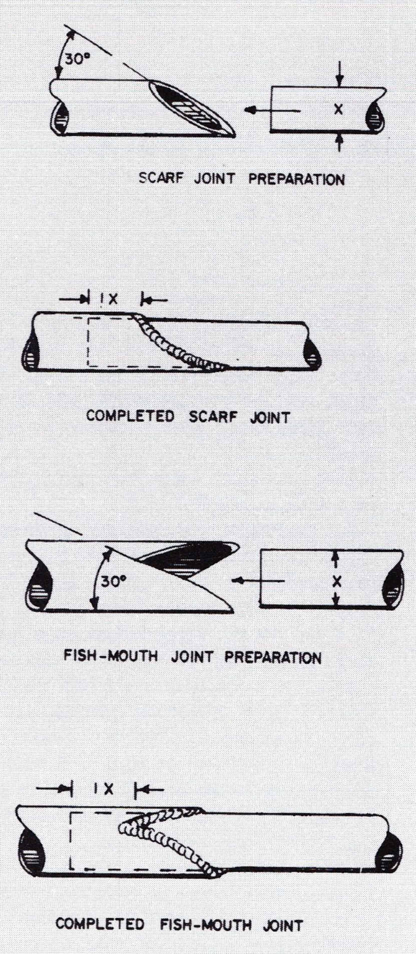


FIG. 2 JOINTS FOR REDUCING LONGERON SIZE

A Turn-Over Fuselage Stand Is A Must

You don't have to have a bum back or a trick knee to appreciate the usefulness of a rotating stand. Think of the convenience of having your fuselage supported at just the right height and providing free access to all parts of the structure. But best of all, a turn-over stand can be