

## Metal Etching Principles & Rules

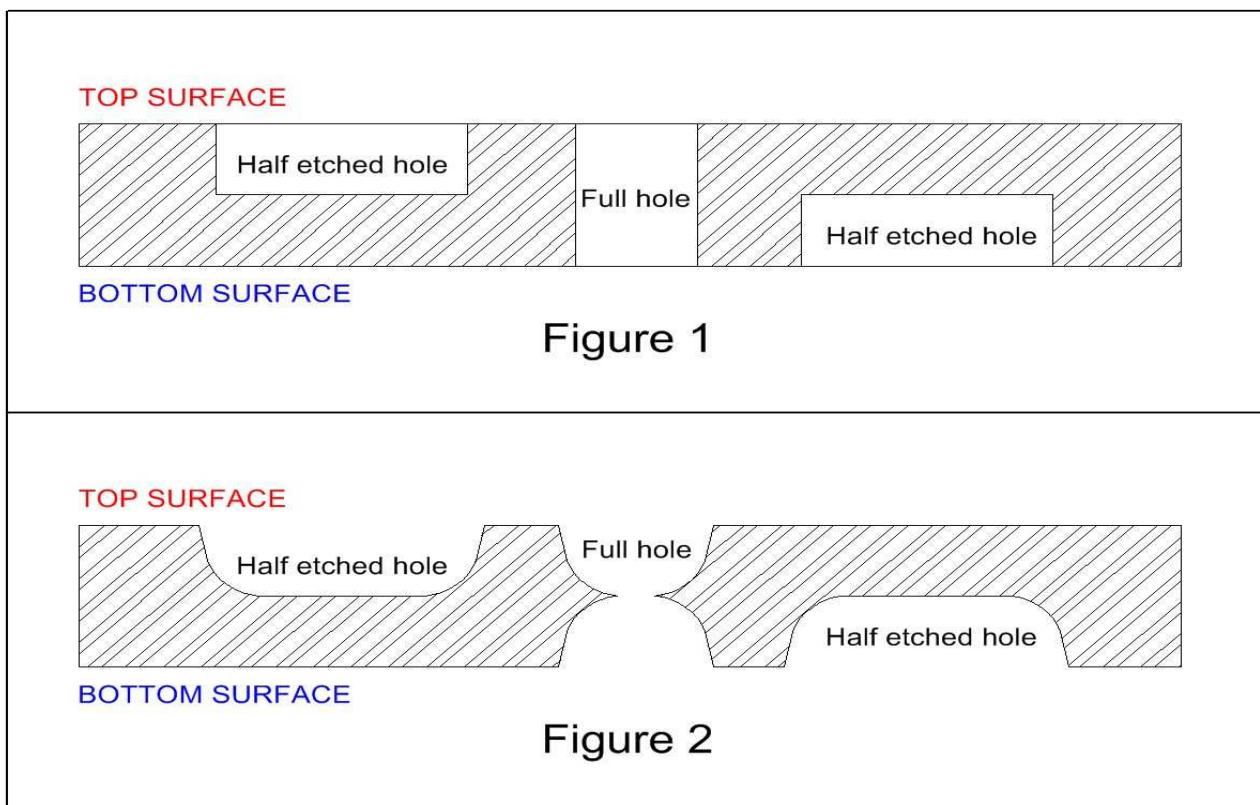
This paper explains the principles of metal etching and the behaviour of metal when it is subjected to etching. The paper is intended to be read by someone who already knows what metal etching is, but is not necessarily conversant with the etching principles and needs to know more.

The first paper in this series explains the basics of metal etching, and the third paper shows how to go about drawing items for etching.

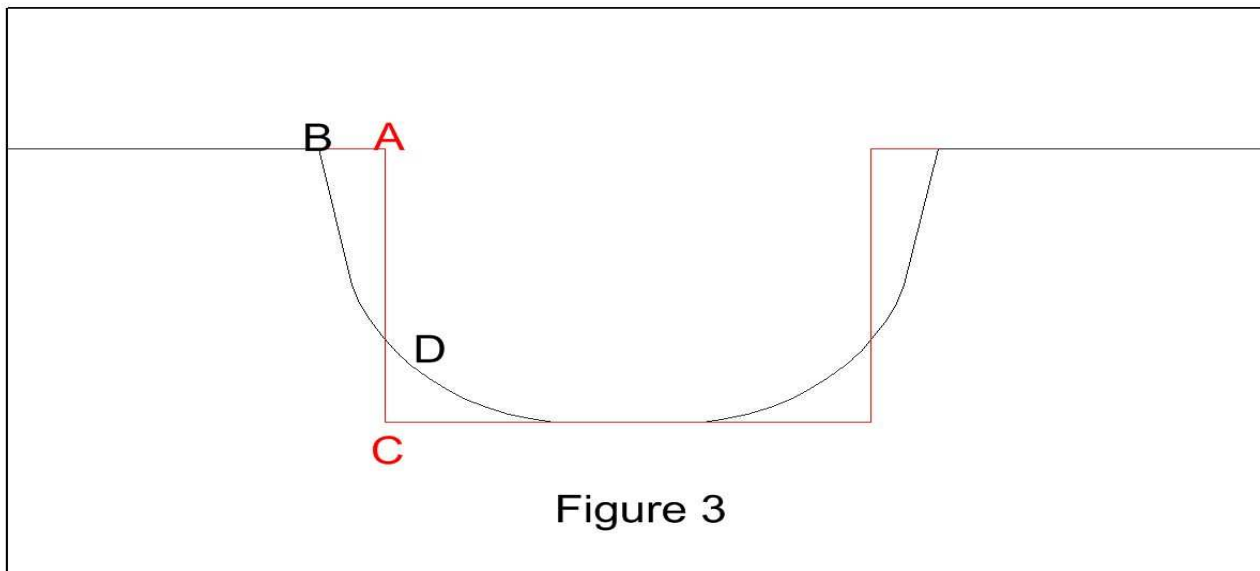
### ***Etching Behaviour - Cusping***

When a metal is etched it exhibits some strange behaviour that needs to be understood and taken into account when designing a model.

Figure 1 shows a simple two sided etch with a half etched hole on the top surface, another on the bottom and a hole that goes all the way through the material. What you would *expect* to get, when the pattern is etched, is shown in Figure 1, but what you really get is shown in Figure 2.



The bottom of the holes becomes rounded, and the sides slope in slightly from the top. Notice that the full depth hole now has a restriction in the middle. This feature is called 'cusping' and needs to be kept in mind when designing etch artwork. The effect of cusping is that **objects get smaller at the edges, and holes get larger**. This is better demonstrated in the following diagram.



The red lines show the hole as you intended, but the black lines are what you get after etching. The original top edge, A has now etched a larger hole out to B, while the bottom of the hole, which should have been shaped to C, now is rounded off to form a curve at D.

The main reason is that because the etching process takes some time to complete, the top of the hole has been exposed to the etchant for longer than the bottom of the hole. While you actually would have preferred that the etchant worked in a strictly vertical direction, of course it can also work *sideways*. So while the etchant is producing a vertical hole in the metal, it also etches sideways on the hole to make it wider therefore creates a sloping side to the hole.

This is why **objects get smaller at the edges, and holes get larger**. The amount of change is approximately 15% of the material thickness, so for a 0.25mm brass material, the average distance from A to B is 0.0375mm. However, a good etching company can minimise the cusping of the etch by careful control over certain factors in the etching process.

Most modellers need not be too concerned about the effect of cusping, after all 0.0375mm is almost negligible. A hole that gets a little too big and has the restriction in the middle can easily be enlarged by passing a twist drill through it, easy.

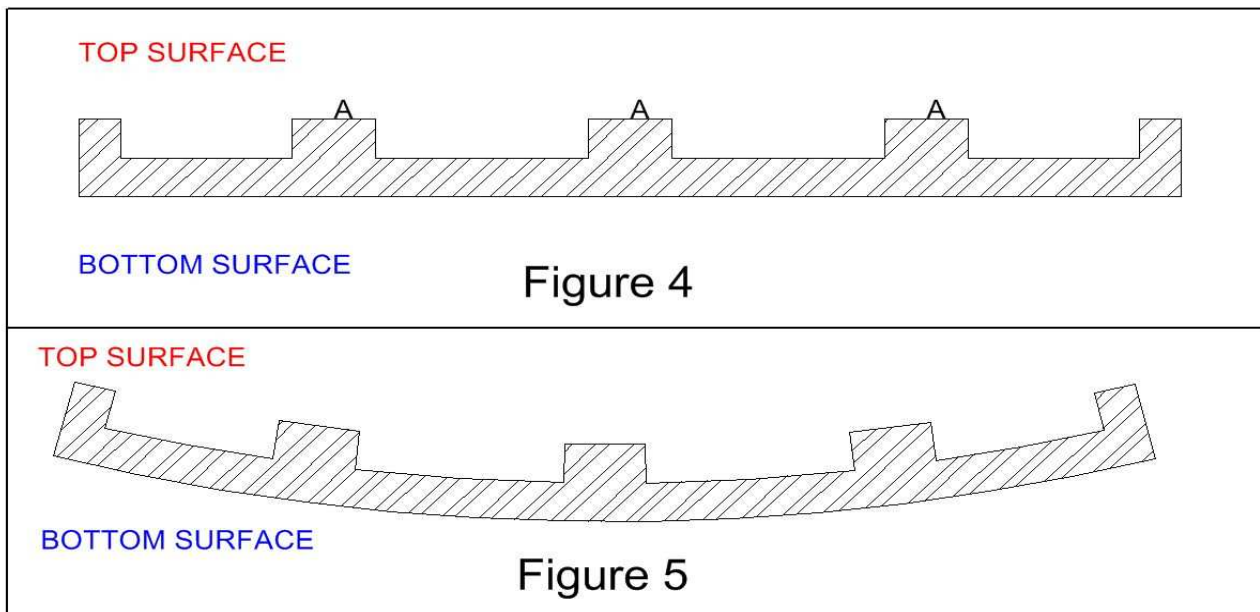
But if you have designed a piece that has tab and slot construction, where the hole is very narrow and long, then you might be in trouble. Have you ever tried to assemble a model that has tab and slot construction only to find the tab does not fit into the slot properly? This generally means the designer has not taken cusping into consideration when designing the kit. Unlike a round hole, a long thin slot is extremely hard to open out, and also extremely annoying to the modeller when it is too narrow.

### ***Etching Behaviour – Etch Annealing***

Many of the common metals used for etching have already been work-hardened when rolled into a sheet. Brass suitable for our modelling purposes is usually termed 'Half-hard Brass', meaning it has been cold reduced 20% from its annealed condition. This means it has some stiffness and can be further formed retaining tensile strength. The hardening process is primarily by rolling the brass and this tends to compress the structures of the metal near to the outer surfaces.

If you etch the material with a more or less balanced pattern on either side of the sheet, the result is predictably normal. But one technique that is frequently used in modelling is the thin overlay, where most of the metal is etched off one side leaving small raised features like rivets.

This usually means the opposite side of the metal sheet is not etched at all, and this then causes a small problem. The side that is etched has the majority of its surface etched away, this surface containing the work-hardened structures. The effect is such that the etched side of the metal relaxes, while the non-etched side retains its tension. The result is shown in the following diagrams, where Figure 4 is what you expected to get, and Figure 5 is the actual result.



In figure 4, the majority of the surface area is etched half way down, leaving raised 'rivets' shown as A. In Figure 5, the metal has curved towards the patterned side of the sheet as a result of the principles mentioned earlier.

This is not a desirable condition, as most overlays created by modellers are intended to be sweat soldered or glued to another sheet to create additional layers of features. There is little you can do to correct this condition, except keep the object that is half etched as small as possible. The degree of curvature seems to be proportional to the surface area of the etched part.

It is possible to straighten the part using a simple rolling technique. Place the part on one of those self-healing cutting mats with the etched surface down. Using a round metal bar about 12mm diameter, roll over the part, checking frequently to see if it has straightened out the curvature. Do this gently, as it is possible to distort the part if you use excessive pressure. Whatever you do, do not be tempted to try correcting this problem by heating the part to anneal it. I tried this several times and ended up with the most horrible twisted 'thing' as a result.

### ***Etching Behaviour – Minimum Feature Size***

A feature is anything that is created on the surface of an etch. It may be a hole, raised or sunken line, rivet etc. There are certain minimum sizes for features, related to the thickness of the metal. The etching companies will usually give quite generous minimum sizes, but from experimentation, I can advise that you are able to bend their rules to some extent.

In general, these are the rules:

Minimum diameter of hole = material thickness.

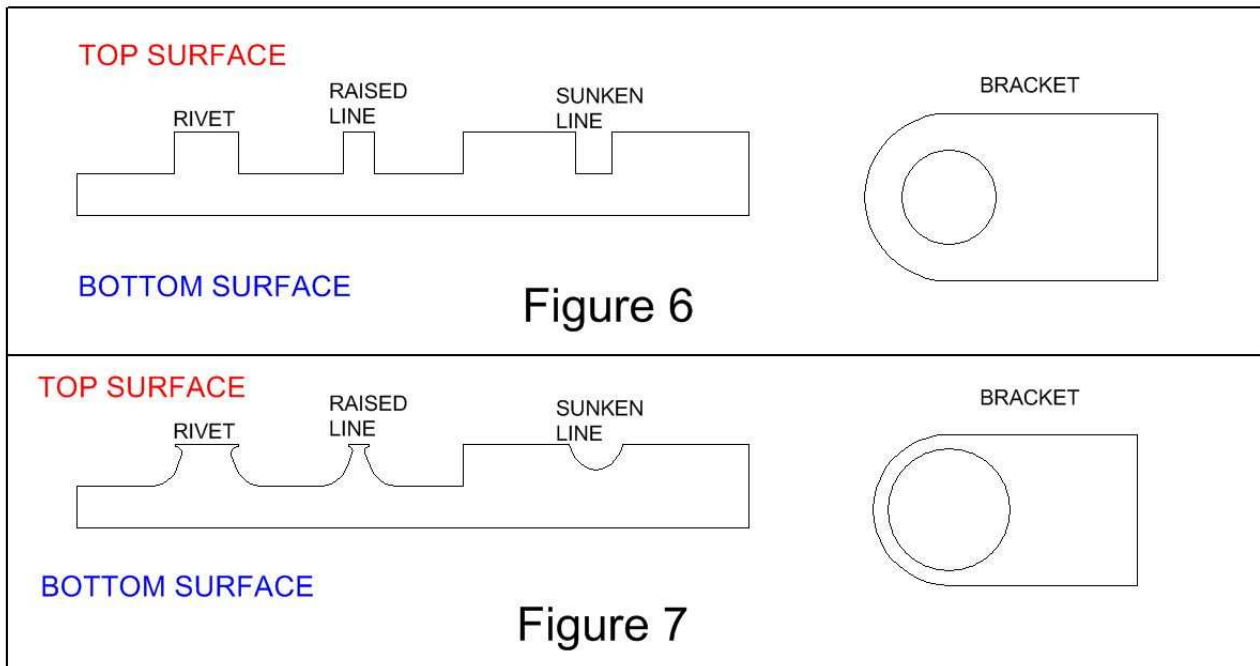
Minimum rivet diameter = 1.4 times material thickness (for best definition rivets).

Minimum width of raised or sunken line = 0.8 times material thickness.

Fold Line width = material thickness.

In Figure 6, three features and a small bracket are shown as they would have been drawn. Figure 7 illustrates how they actually would be formed after etching. The etching characteristics have been slightly exaggerated to make the point, but you can see that the rivet and raised line have been eroded quite considerably from the intended shape. The sunken line has ended up much shallower than intended, and is etched to about one third the depth intended and has become slightly wider. The raised features have a sort of 'cap' on the top, caused by the photo-resist.

The bracket has suffered from the rule: **objects get smaller, holes get larger**. But in this case it can be quite detrimental, as it is in danger of being etched away at the rounded end entirely.



If in doubt about whether an object such as the bracket will work out, then consider adding 15% to the outside diameter of the bracket and reducing the diameter of the hole by 15%. Just to make it a bit easier, these are the 15% figures for popular metal thicknesses.

0.125mm material (5 thou.) = 0.019mm

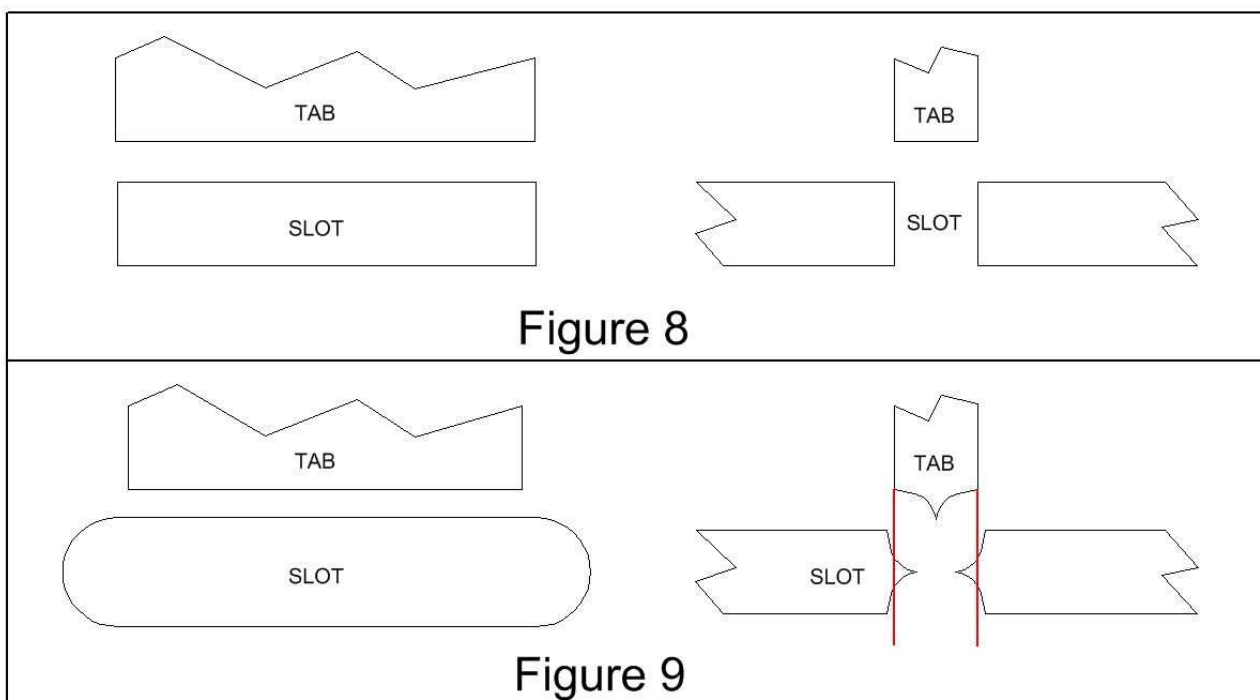
0.25mm material (10 thou.) = 0.038mm

0.5mm material (20 thou.) = 0.075mm

### ***Etching Behaviour – Tab & Slot Construction***

Tab & slot construction presents a unique case of etching behaviour and warrants a special section to deal with it. It can be very frustrating to assemble a kit where the designer has not taken the etching behaviour into account, and the tabs simply do not go into the slots.

The cusping behaviour affects all etching, but when you design a tab and slot it needs to be remembered that the thickness of the tab is not affected by cusping or any etching at all, while the slot is.



Once again, figure 8 shows the tab and slot as you would imagine it should be drawn, and Figure 9 depicts how it actually turns out. Notice that the length of the tab in figure 9 has reduced by 15%, while the ends of the slot have become rounded. This is not necessarily a problem, as it slightly increases the clearance between the tab & slot. But in the view on the right side, the cusping in the middle of the hole does present a problem.

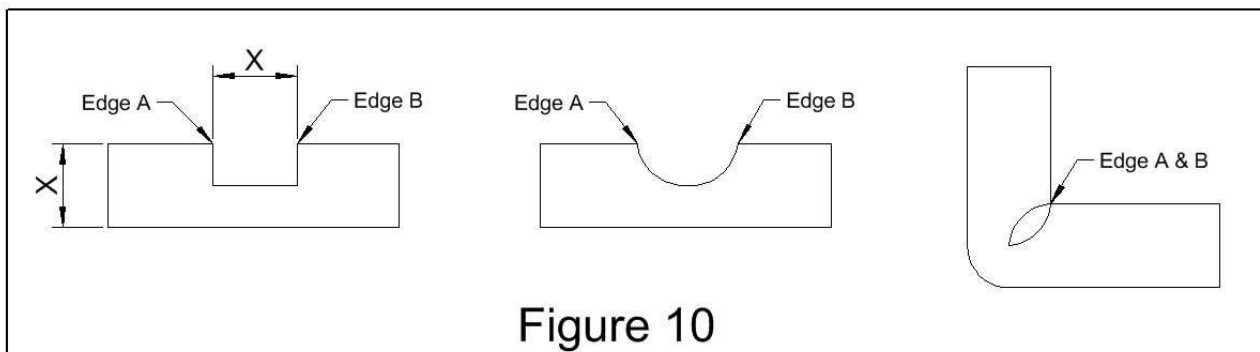
The width of the tab on the right has not been affected by the etching process at all, while there is a small amount of cusping in the slot. The red lines show that the tab would not pass through the slot. Now this can be a real pain to fix, as there is virtually nothing small enough to insert into the slot to make it larger or remove the cusping. A fine scalpel blade will fit into the slot, but can distort the metal if used too much.

Experience has shown that the best way to deal with this occurrence at design time is to increase the width of the slot by 15% on each side, but leave the length the same as the tab.

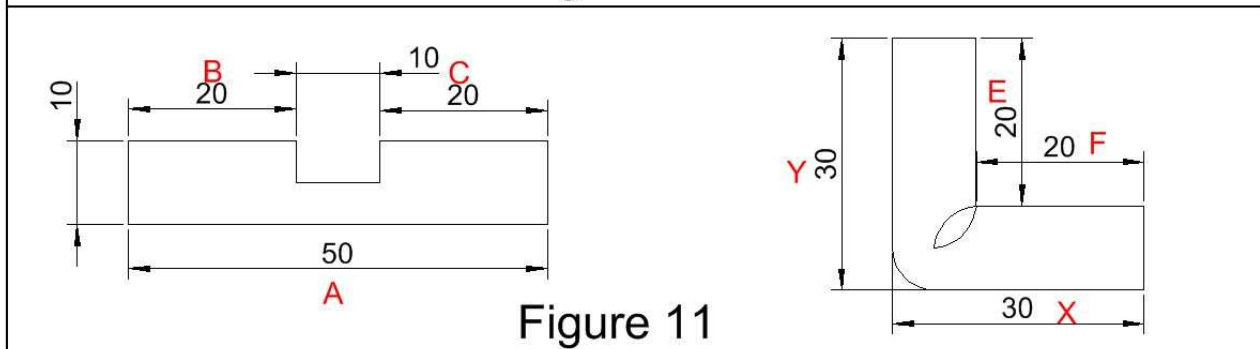
### ***Etching Behaviour – Fold Lines***

Most objects designed for etching have at least one fold in them, and it is important to understand how a fold works, and the principles behind designing them into a part. There is a rule that I consider absolute: **All fold lines should be drawn at the thickness of the material.**

Figure 10 illustrates how a fold works. The fold line has been designed to be the same width as the material, shown as X in the left hand drawing. The centre drawing in Figure 10 shows how the material actually ends up after etching. The right hand drawing shows how the fold works, note that the two edges, A & B now meet each other, with a small elliptical cavity contained in the fold.



**Figure 10**

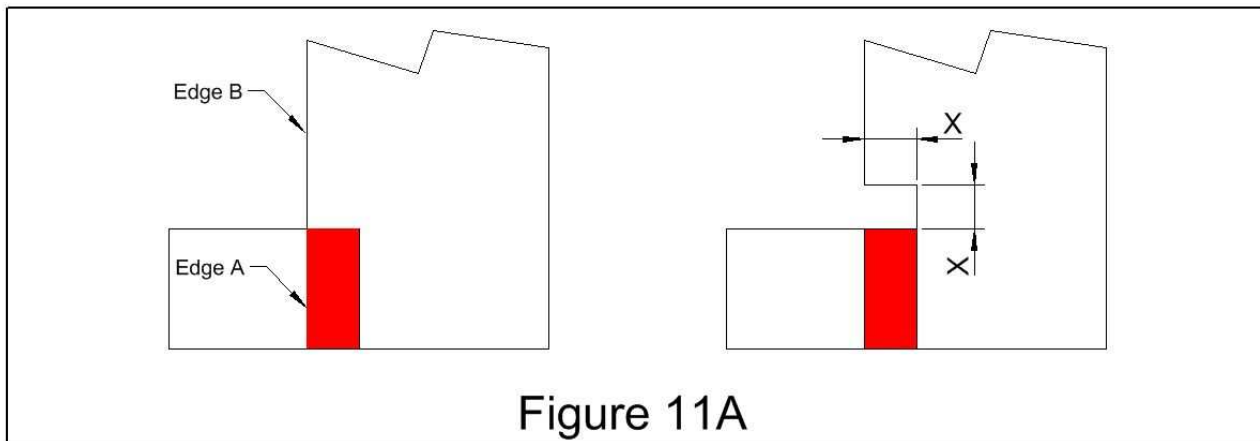


**Figure 11**

Figure 11 shows how the fold affects the dimensions of the part. Because the two edges meet as depicted in Figure 10, the internal dimensions E & F are pretty much as expected, 20 by 20. However, note that the external dimension, X & Y are both 30, so you would expect the length of the material, A, to be  $30 + 30 = 60$ . But it is actually 50, comprising  $B + C + \text{Material thickness of } 10 = 50$ . The dimension X equals dimension C + material thickness of  $10 = 30$ , and similarly for dimension Y, it equals  $B + 10 = 30$ .

So, the general rule is that a fold line always **ADDS** to the width of the drawn object, and this must be allowed for in the design. If you were to create a strip object say, 20mm in length with 5 folds in it, then for a 0.25mm thick material, the overall length must now be 21.25mm, or  $20 + (5 \times 0.25) = 21.25$

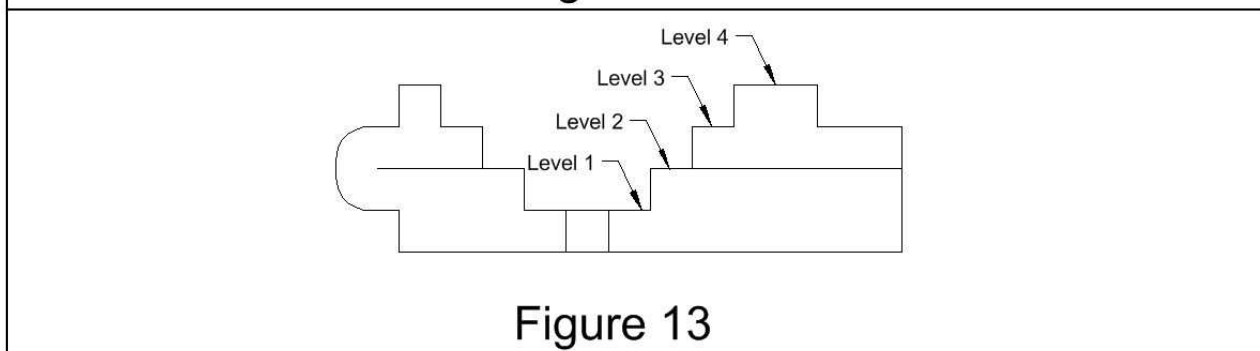
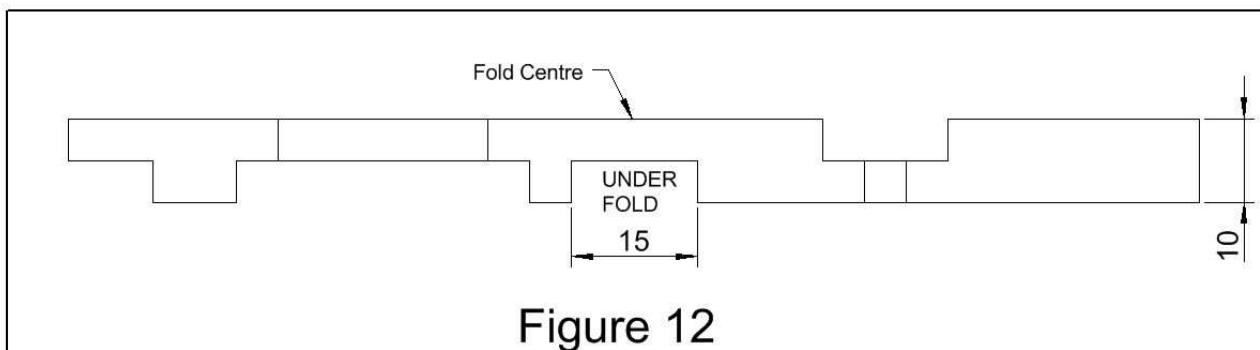
Often it is necessary to create a fold line that brings the folded section in line with the edge of the material, so you would then produce a part similar to that shown in the left hand drawing of Figure 11A. The fold line is shown in red.



But this would not work very well at all, as you need to create a cut-out in the material to allow it to fold correctly. The right hand drawing shows a small notch X by X in size, where X should be equal to the material thickness. This allows the metal to be folded without distorting the part.

As stated earlier, my preference is that all fold lines should be drawn at the thickness of the material. You may wish to make a fold where the sides are not folded at 90° to each other. It might occur to you that the fold line can therefore be reduced. This is not really a good idea, as the vagaries of etching will probably produce a metal distortion at this point that you really did not want.

As a general rule, all folds are inwards, so that the material closes the gap of the fold line. Occasionally you may want to fold the material the other way so that it folds back flat on itself. This technique is illustrated in Figure 12 & 13.



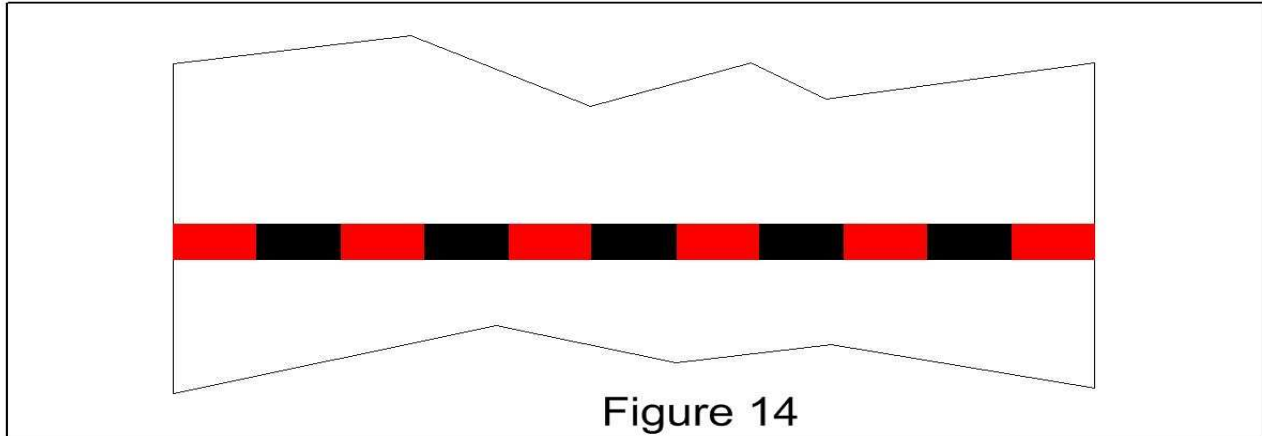
The section on the left side of the fold centre in Figure 12 is folded over towards the right so that it lies on top of the right hand side. The result is shown in Figure 13.

This technique yields 4 distinct layers of levels, while doubling the thickness of the material. It is a very useful technique where you need a lot of layers to accurately depict the surface of a model, such as the panels of wooden passenger vehicles. The doubling of the material thickness is a handy by-product of the technique as it stiffens the sides of the model and removes the need for any underlying structure to support the side.

It is also preferable to simply laying another etched layer over the bottom sheet in that, if drawn correctly, it keeps the surfaces in perfect register.

To produce a fold-back of this type, you must increase the width of the fold line, otherwise you risk the material fracturing when folded back. The recommended width is 1.5 times the material thickness.

Long folds also introduce some problems, especially for fold-backs as previously described. So another technique is to produce a slotted fold. This is illustrated in Figure 14.

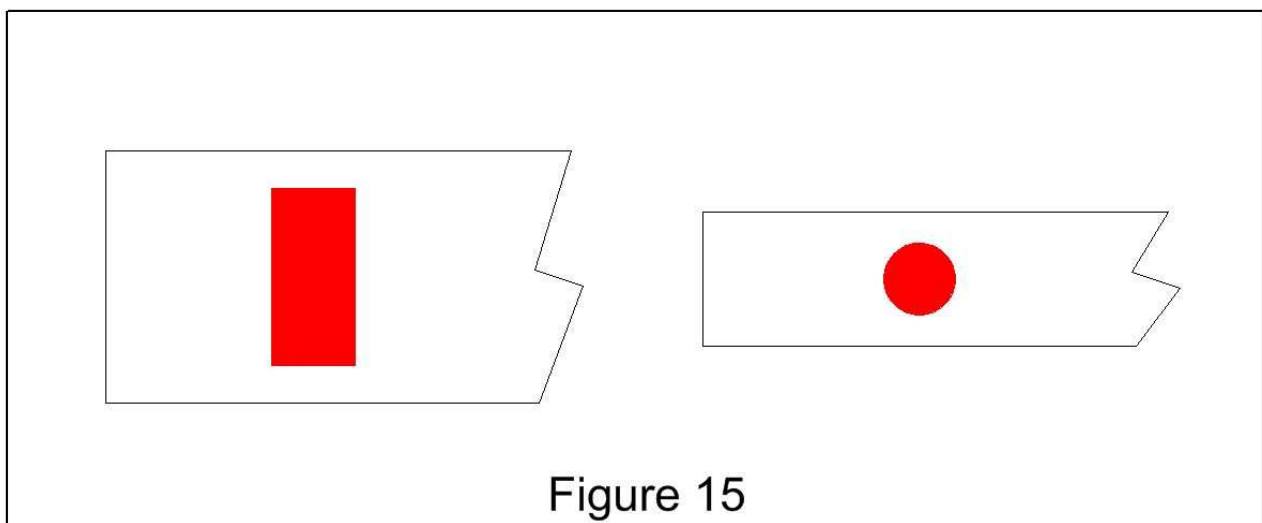


The red sections indicate half-etched tabs, while the black sections are through holes. This makes folding the material much easier, but does produce a ragged edge.

This idea is also often used where the material on one side of the fold is very narrow. Simulated edges of sole plates are a common use of this technique. With a narrow side, it is very difficult to get hold of the narrow side and bend it if it is a normal fold, even with the use of devices like a Hold N' Fold.

However, a slotted fold leaves the red tag sections protruding and there is a little distortion at the tab corners, all of which produce a rather undesirable effect. It can be quite difficult to clean up the results of a slotted fold, so my recommendation is to avoid this technique unless absolutely necessary.

It should be kept in mind that a fold weakens the part to some extent. It is a good idea to strengthen the fold by running solder into the cavity in the fold during assembly of the model. But sometimes the part may be very narrow and does not survive very well because of the weakness introduced by the fold, so an alternative to the fold line is a fold dimple, or partial line. This is shown in Figure 15.



A shorter fold line that does not extend to the edges of the part is used for the narrow part on the left, while the very narrow part on the right has a simple etched dimple to create the fold point. This is especially useful for things like strap-iron shunter's steps and the like. The left side part keeps that extra bit of strength by having a full depth edge on either side of the fold line, while the objective of the dimple on the right is to simply weaken the strip sufficiently to allow a fold, while retaining the majority of the metal's strength.



### ***Useful Techniques – Push-through rivets***

A handy way to produce rivets in a section is to use the technique of push-through rivets. This involves placing a dimple, similar to that shown above, on the reverse side of the sheet to where you want the rivet to be. A half-etched dimple should be used with a diameter equal to the material thickness.

The rivet is then created by using a sharp object and pressing in the centre of the dimple to force a raised bump on the other side of the part. I have found that the best object for pushing the dimple is a low-cost drawing compass with a hardened spike tip. The diameter of the dimple, equal to the material thickness, is important as any larger and you run the risk of punching a hole, any smaller and you risk distorting the metal.

The best surface for making rivets I have found is a moderately hard piece of wood. If the material the part sits on is too soft, then the rivet is not crisp and clean, whereas if it is too hard, the rivet is not deep enough.

### ***Useful Techniques – Hinged Laminating***

It is often necessary to produce a part that is thicker than the material you are working in, perhaps twice the thickness. A common requirement is locomotive connecting and coupling rods. To complicate matters further, these rods have several levels to them and are quite often fluted.

The solution is to create a double thickness part that is connected by a narrow under-fold, allowing the part to be folded under while keeping the part in precise registration. The part can then be sweat soldered to bond the two halves together, and then the edges of the under-fold can be filed away.

This is demonstrated in Figure 16.

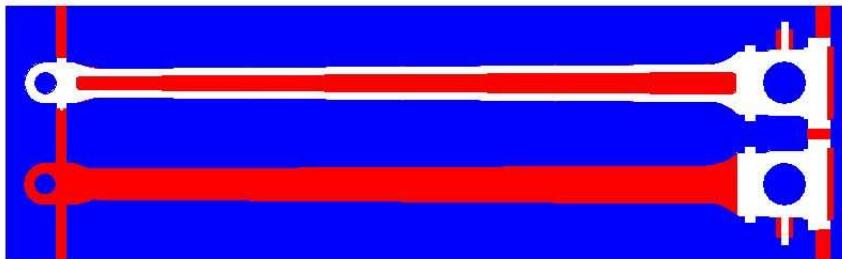


Figure 16

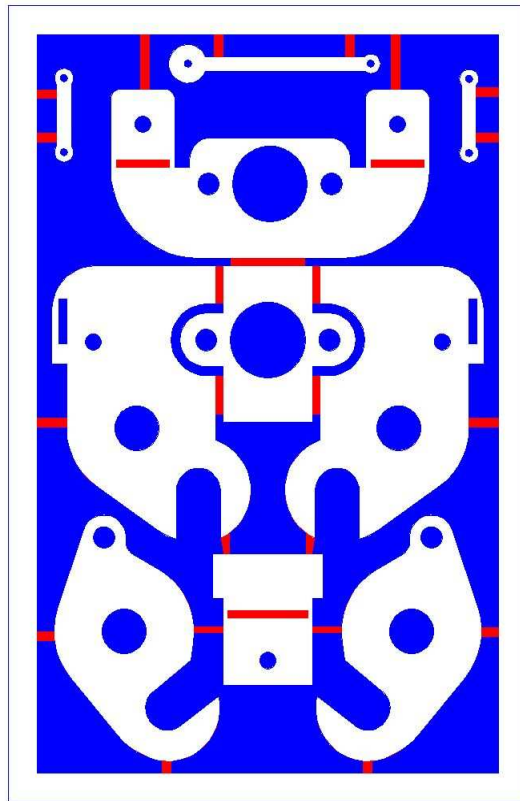
Notice that the fluting of the connecting rod is etched into the top surface of the top half, while the rear surface of the bottom half is half-etched to create the thinner stepped profile of the back of the connecting rod, while maintaining full double thickness at the big end.

### ***Useful Techniques – Fret Tags***

You place your part in a sheet, usually termed the Fret, containing a number of parts in close proximity to each other. The closer these parts can be fitted to each other, the more efficiently you use the available space. But the parts must be able to be separated from each other, while at the same time, being held securely in the fret.

So a sort of 'moat' is constructed around the part, and small sections, called fret tags, are provided to hold the parts in place.





This drawing shows a small etched gearbox and its various components designed for production in 0.45mm nickel silver. The white areas are the parts, the blue area is completely etched away, and the red sections are half-etch fold lines and fret tags.

The blue area also represents the 'moat' around the parts. At a minimum this moat should be at least twice the thickness of the material. Note that the fret tags are placed in several positions around the parts to securely hold them in the fret. When it comes time to cut these parts out of the fret, you do not want to make the job difficult or arduous, so keeping the number of fret tags to a minimum is desirable.

At the same time, you need to be able to safely remove the parts from the fret without damaging them or causing distortion of the part. This is best done on a flat surface with a sharp hobby knife. To make it easier to cut the tags, they are half-etched to start with, making them only half the thickness of the material and the width is kept to a minimum, usually 1.5 times the material thickness as a guide.

Do not make too few tags or too thin a tag. Nothing cranks an etching company off more than parts that fall out of the fret in the etching bath. And of course, they are not there when you receive the sheet back, which can then crank you off.

### ***Useful Techniques – Name & Revision Text***

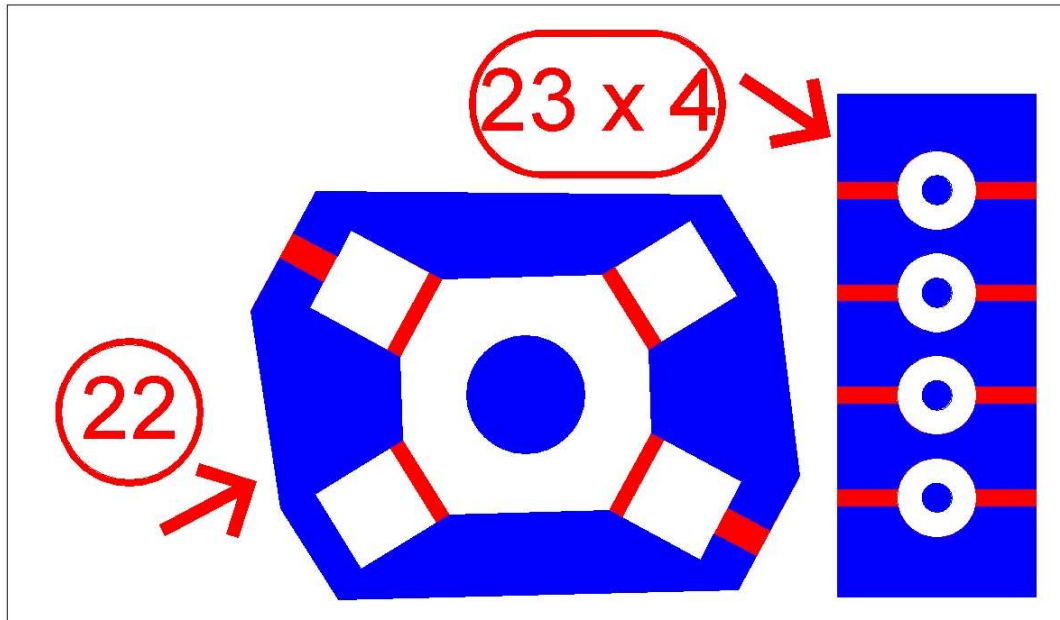
Any etched part you produce needs to be identified for your own purposes. It is recommended that you put the following in a non-visible part of your etch, Item Name, Your Name and Revision number. Eg.

AV Car  
Hollywood Foundry  
Revision 1

When placing identification on a part, please use simple or default fonts. If you choose a fancy font, it is most likely that the photo-plotter at the etching company will not have that font anyway, and all you will get is a simple segmented CAD font.

## Useful Techniques – Part Identification

When placing a large number of parts on a fret, you will need to communicate to the modeller which part is which. Two common methods are to produce a photo or drawing of the fret with text added to identify the parts. However, it is much better from the modellers point of view to incorporate the legend on the fret itself, and this is one way to do that.



The part numbers are etched into the front or top layer of the fret with an arrow to point to the part. Note that the small circles are marked '23 x 4', meaning they are part number 23 and there are four of them. It is also a good idea with tiny parts like these to put spares on the fret, as they are easily lost.

## Summary of Rules

1. Objects get smaller at the edges, and holes get larger. Remember the effect of cusping and make adjustments if necessary. These are the 15% values for common material thicknesses:
  - 0.125mm material (5 thou.) = 0.019mm
  - 0.25mm material (10 thou.) = 0.038mm
  - 0.5mm material (20 thou.) = 0.075mm
2. Minimum feature sizes:
  - Minimum diameter of hole = material thickness.
  - Minimum rivet diameter = 1.4 times material thickness (for best definition rivets).
  - Minimum width of raised or sunken line = 0.8 times material thickness.
  - Fold Line width = material thickness.
3. All fold lines should be drawn at the thickness of the material, except for:
4. Under-folds should be 1.5 times the material thickness.
5. Increase the **width** of slots for tab & slot construction to ensure tab will fit in slot.
6. Fold line always **add** to the width of the drawn object, and this must be allowed for in the design.
7. Provide an adequate number of well placed tags on your parts.
8. Create a 'moat' around your part with a width of at least twice the material thickness.
9. Identify your parts if possible with item name, your name and revision number in an inconspicuous position. Use plain fonts.