Making it Dead Flat and Square

By R. G. Sparber

Introduction

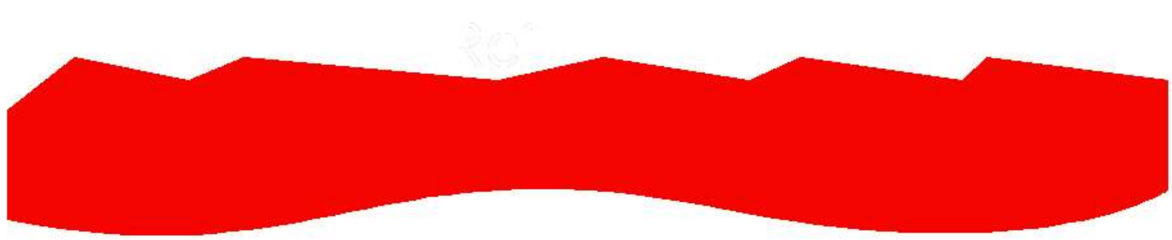
Open up your favorite machine tool catalog and you can find precision straight edges accurate to a degree to please almost anyone. Same goes for buying a square. Pay more money, get closer to perfect. Have you ever thought about how some ancient machinist made the first precision straight edge and precision square? It turns out to be amazingly simple.

Background

This article was inspired by a piece in "The Machinist's Second Bedside Reader" by Guy Lautard entitled "How to Make a Master Reference Square". I own the complete 3 book set and re-read it every few years. He focuses on the practical side but is light on the theory. To compliment his fine work, I have decided to present mostly the theory.

The Precision Edge

When I start to make my precision edge, it will be far from straight.



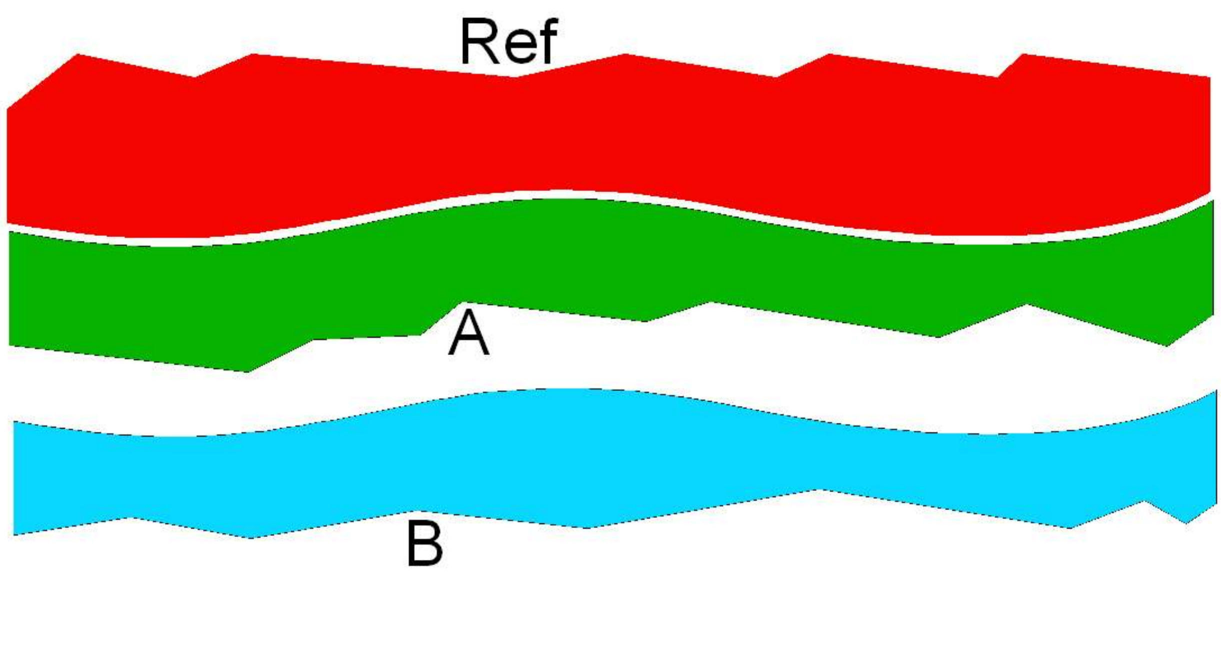
If I had a precision straight edge, I could lay it up against the edge I'm making and figure out where to shave away metal.

But where did I get this precision straight edge?

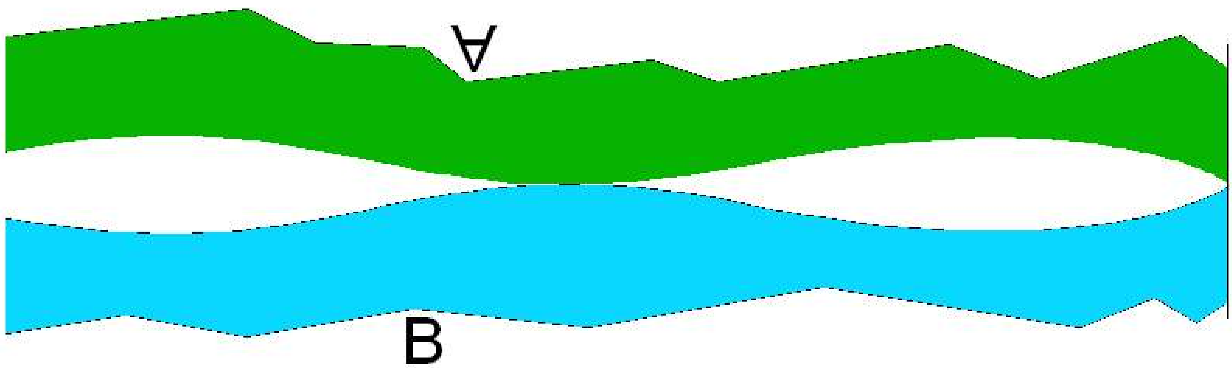
I have fallen into what is called circular reasoning. If I had a precision straight edge, I could make another. But where did the first one come from? Unlike the dumb chicken and egg joke, we actually have a rather satisfying answer for this one.

I will call the edge I am making my Reference edge because when I'm done, it will be a precision straight edge.

Now, say I made two exact copies of this edge. Call one of these copies "A" and the other "B". Both have been carved to fit the contours of Ref without a gap.



Now flip the “A” copy over and butt it up against “B”.



Note the vertical black line on the right side. It is essential that the two edges are aligned so they touch at the same point traceable back to Ref. If B slid over and meshed with A, we would get the wrong result.

I now have one point where the edges touch and plenty of length where they don’t touch.

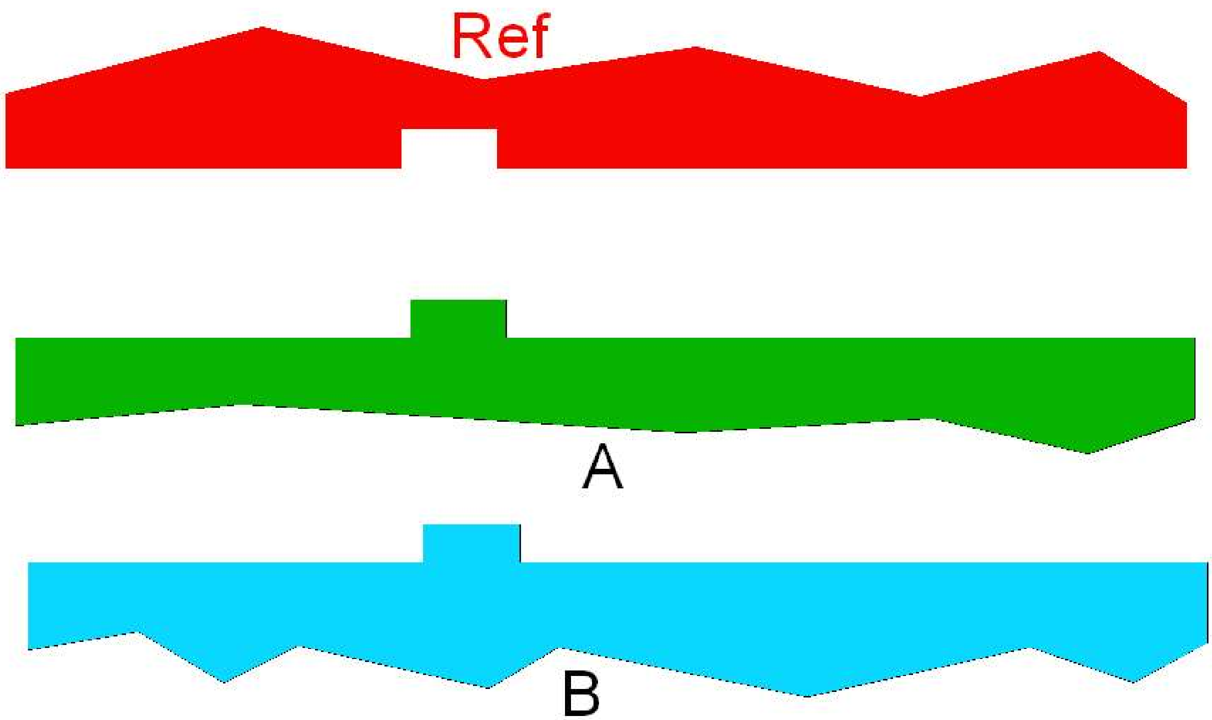
At each place they ***don’t*** touch, my Ref edge sticks out too much. This might be kind of counter intuitive at first but please bear with me.

If I shave down these Ref parts that stick out, I will get my precision straight edge.

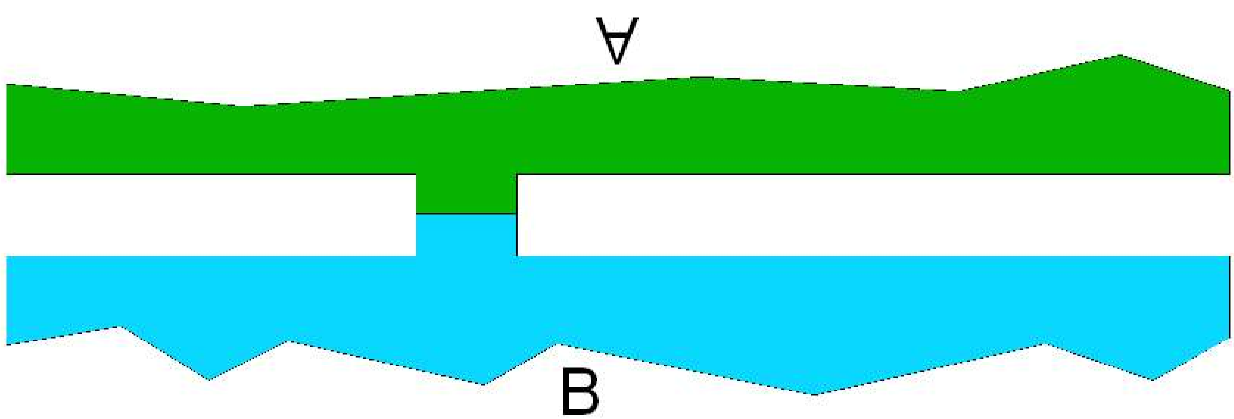
But how much do I remove? It turns out the separation between flipped A and B at any point along this edge equal twice the amount the Reference edge is over the line.

It is hard to see with this wavy line so consider an edge with a notch in it.

I make two copies of my Reference edge



and then flip "A" over.

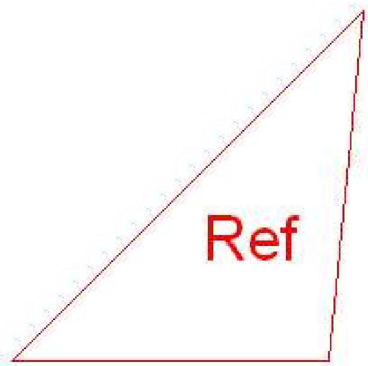


Now I see a gap between A and B. Compare this gap to the part of Ref below the black line.

If I shaved off the Ref material below the black line and fitted A and B to match Ref's new contour, we would find no gap as I butted flipped "A" and B.

This technique tells us when we have arrived at a precision reference edge but not how we get there. I defer to Mr. Lautard's book for that detail. I want to move on to how the above relates to making a precision square.

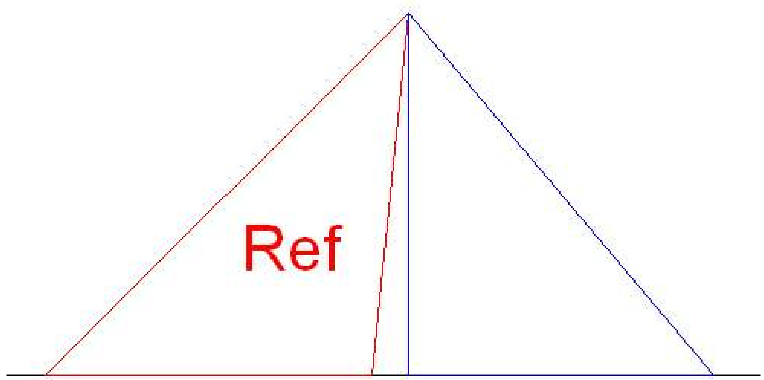
The Precision Square



Say I have a triangle with straight sides but it does not contain a perfect right angle in it.

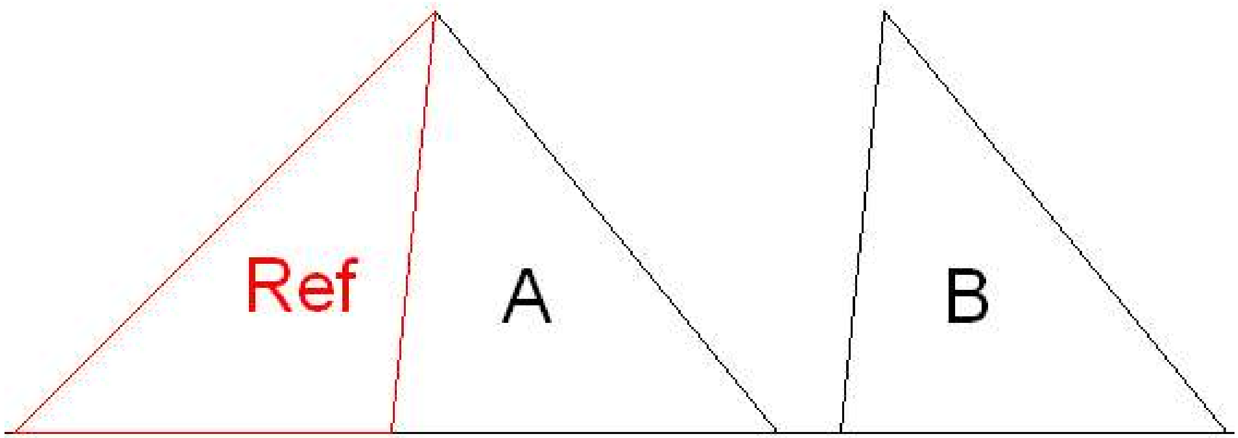
I will call this my Reference triangle because when I'm done, it will be a perfect right triangle or "square".

Now, if I had a perfect right triangle, it would be easy to see how to adjust Ref to also be perfect.



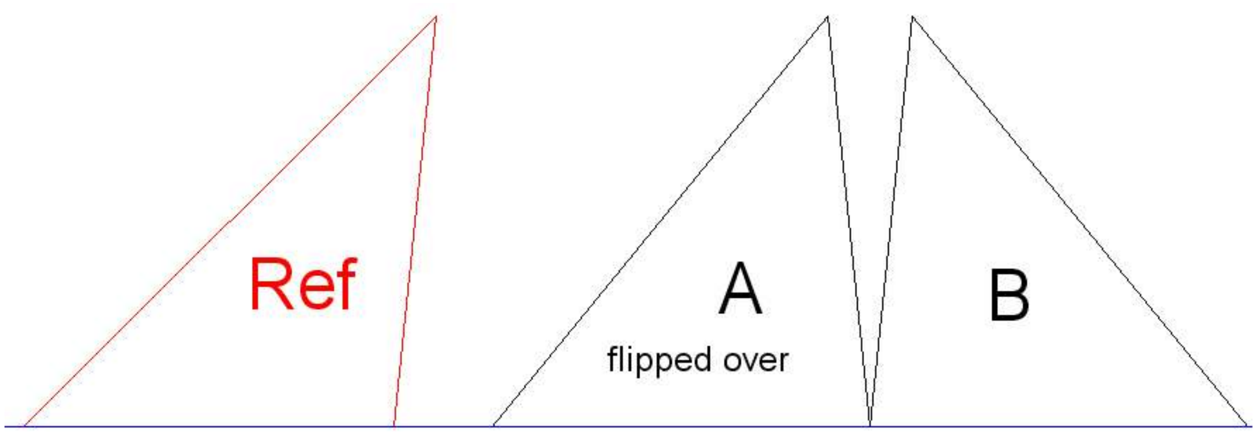
I have again fallen into circular reasoning. If I had a perfect right triangle, I could make another. But where did the first one come from? The answer is similar to how we can make a precision straight edge.

I will make two more triangles called “A” and “B”.



With Ref placed on a straight edge, I will adjust triangle A until it perfectly matches the almost vertical side of Ref. Then I will take triangle B and do the same thing. So now triangle A matches triangle B on its almost vertical side.

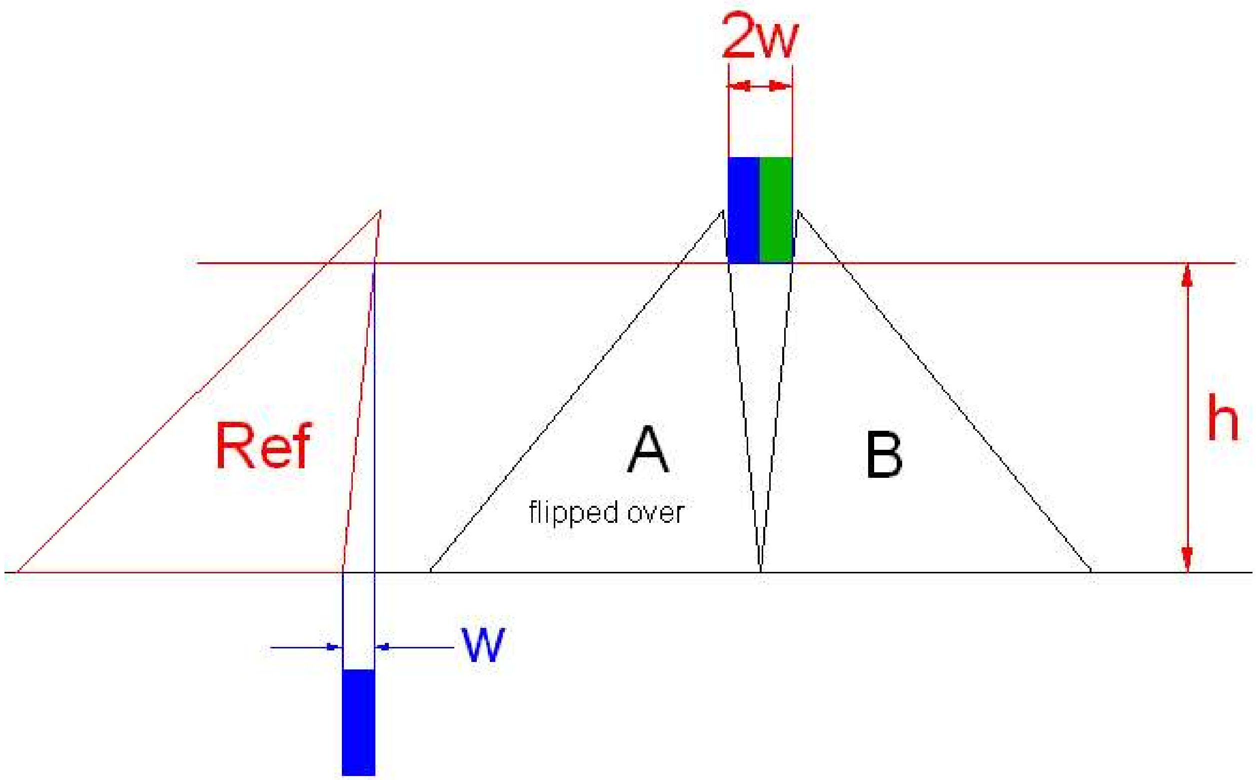
Next, flip over triangle A and put A and B together.



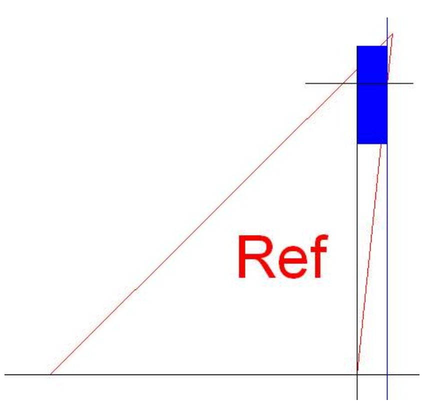
See that gap between A and B? It wouldn’t be there if Ref was a perfect right triangle. So although we don’t have a right triangle, we can tell when we get one. As with the challenge of making a precision straight edge, the gap at any point equals twice the error in Ref.

Let's creep a little towards the practical.

Say I take a piece of metal with a thickness of "w" and cut it in two and deburr the edges. Then I stack them up with the bottom edges lined up. I now have a thickness of 2w. Then I slide the stack down the gap between flipped over A and B. If I chose w wisely, the stack will contact both A and B at some height "h" along the almost vertical edges.



If I then mark vertical height "h" on Ref, I know that this point is a horizontal distance "w" from true.



Taking one of the two strips of metal, I have my width "w". I change my almost vertical Ref edge by this amount and will arrive at my precision right angle.

If A, B, and Ref have a pivoting vertical edge, the above process should be reasonable. The problem with Ref being of this design is that it can be easily knocked out of alignment. Precision squares are made with parts permanently fixed together. Machining, filing, grinding, and scraping are used to get the required straight edges and alignment. Drop the precision square on the floor and you might have to start all over again. If you are the one that made this instrument, I suspect it would be a rather dark day.

What's Next?

If you want to make precision straight edges or squares, I encourage you to buy Guy Lautard's book. In fact, I suggest you buy the entire set.

Questions and comments are always welcome. All of us are smarter than any one of us.

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