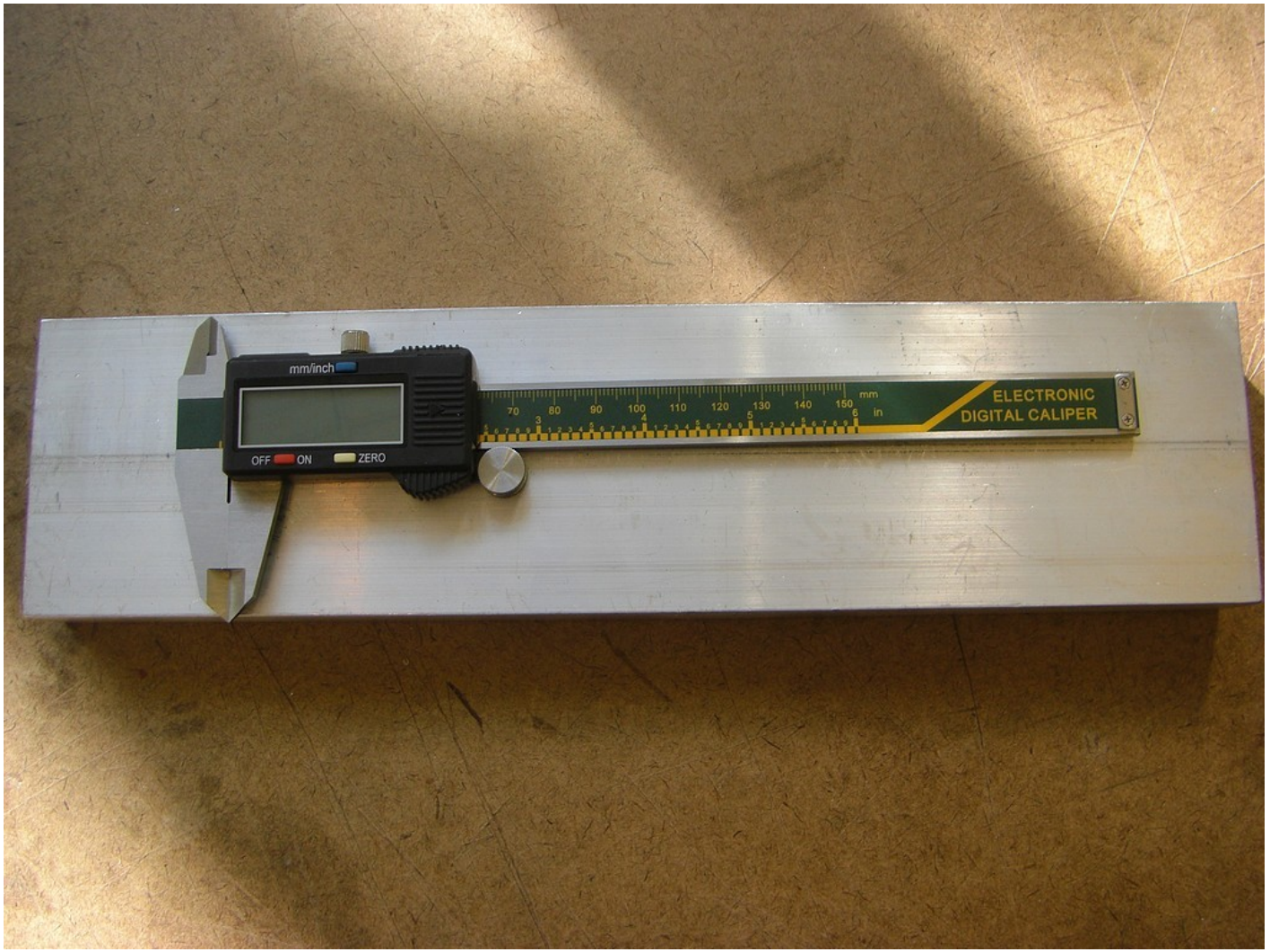
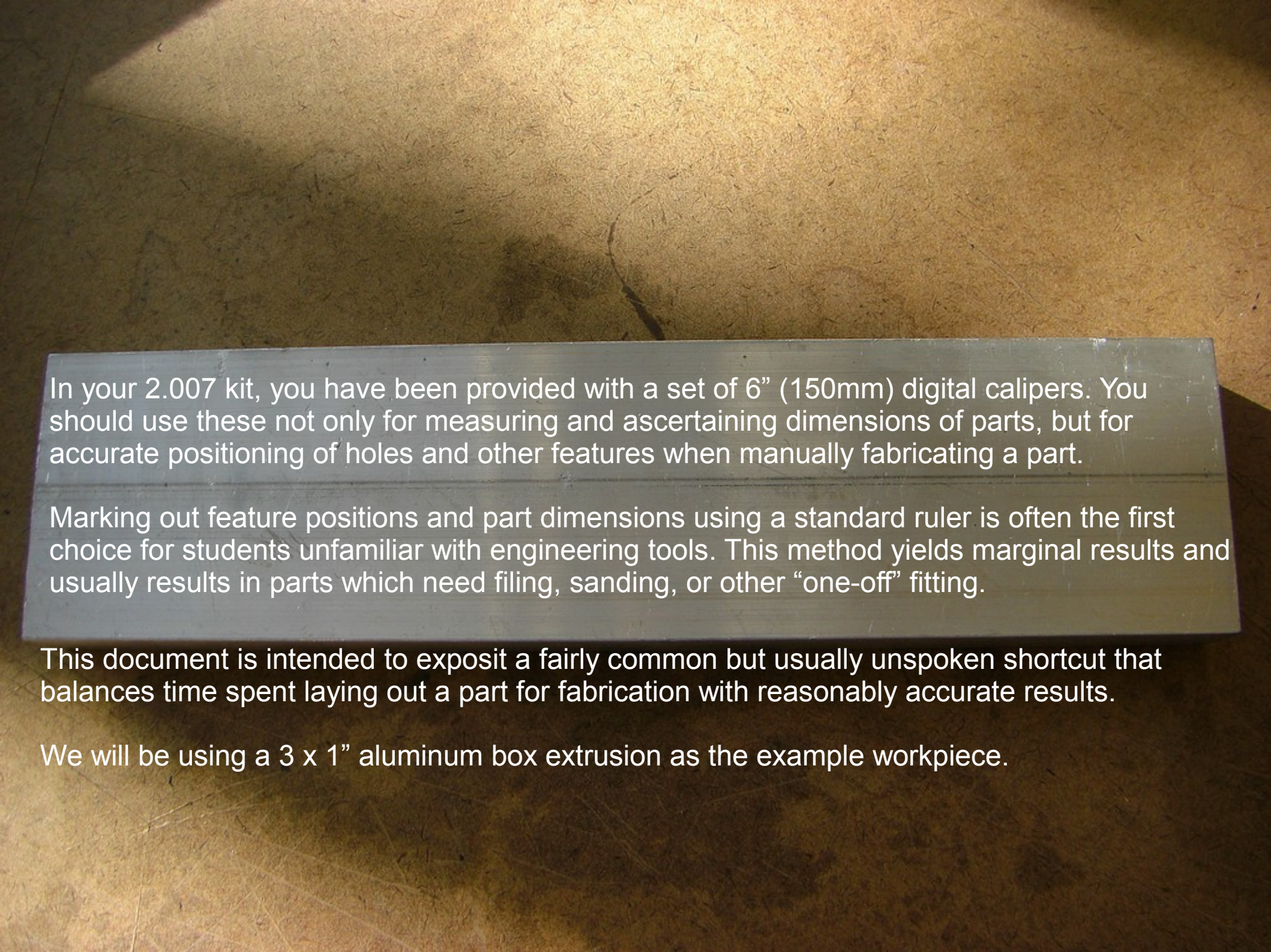
Caliper Abuse for Beginners

A Guide to Quick and Accurate Layout Using Digital Calipers



charles z guan productions

21 Mar 2010



In your 2.007 kit, you have been provided with a set of 6” (150mm) digital calipers. You should use these not only for measuring and ascertaining dimensions of parts, but for accurate positioning of holes and other features when manually fabricating a part.

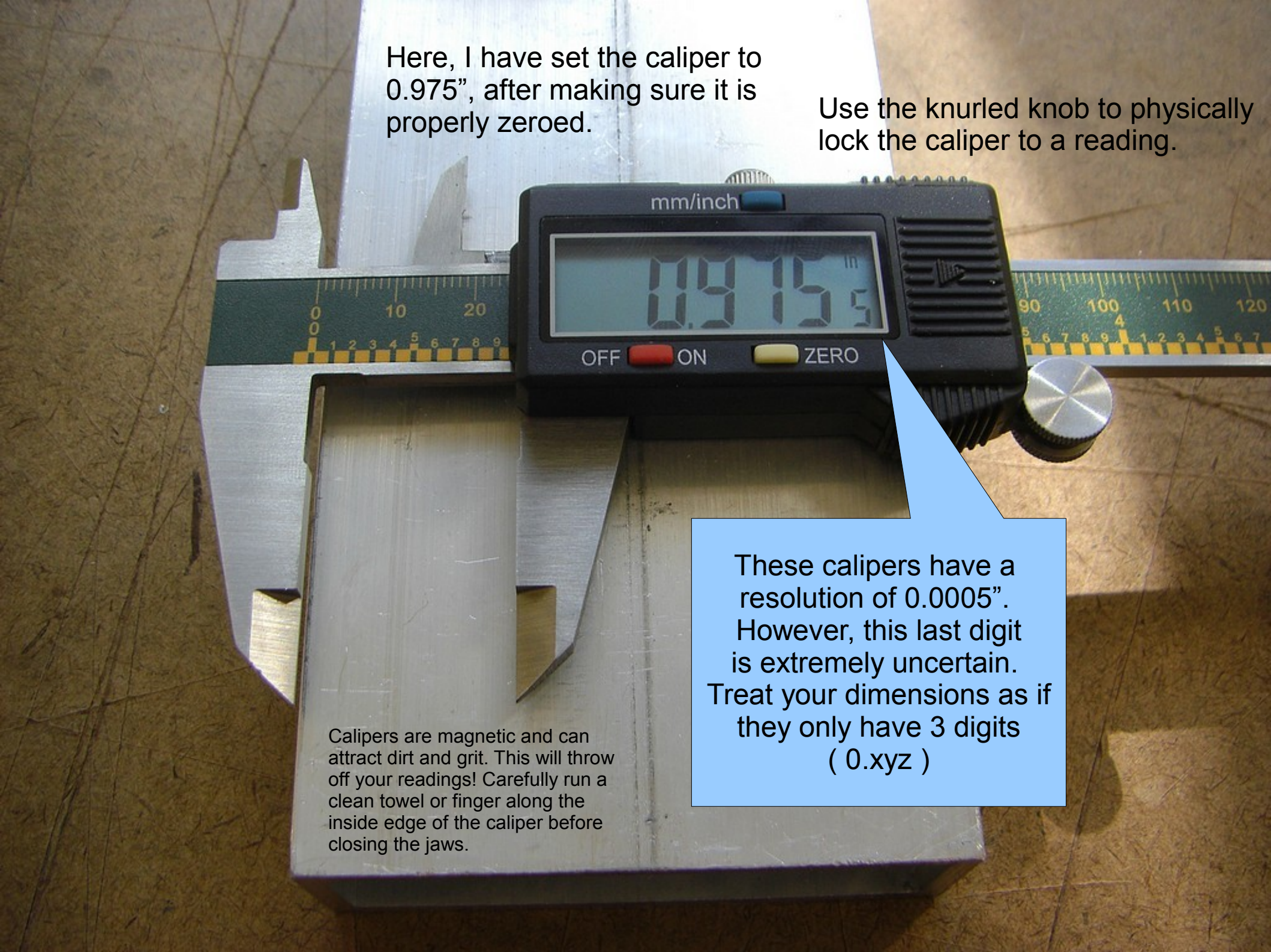
Marking out feature positions and part dimensions using a standard ruler is often the first choice for students unfamiliar with engineering tools. This method yields marginal results and usually results in parts which need filing, sanding, or other “one-off” fitting.

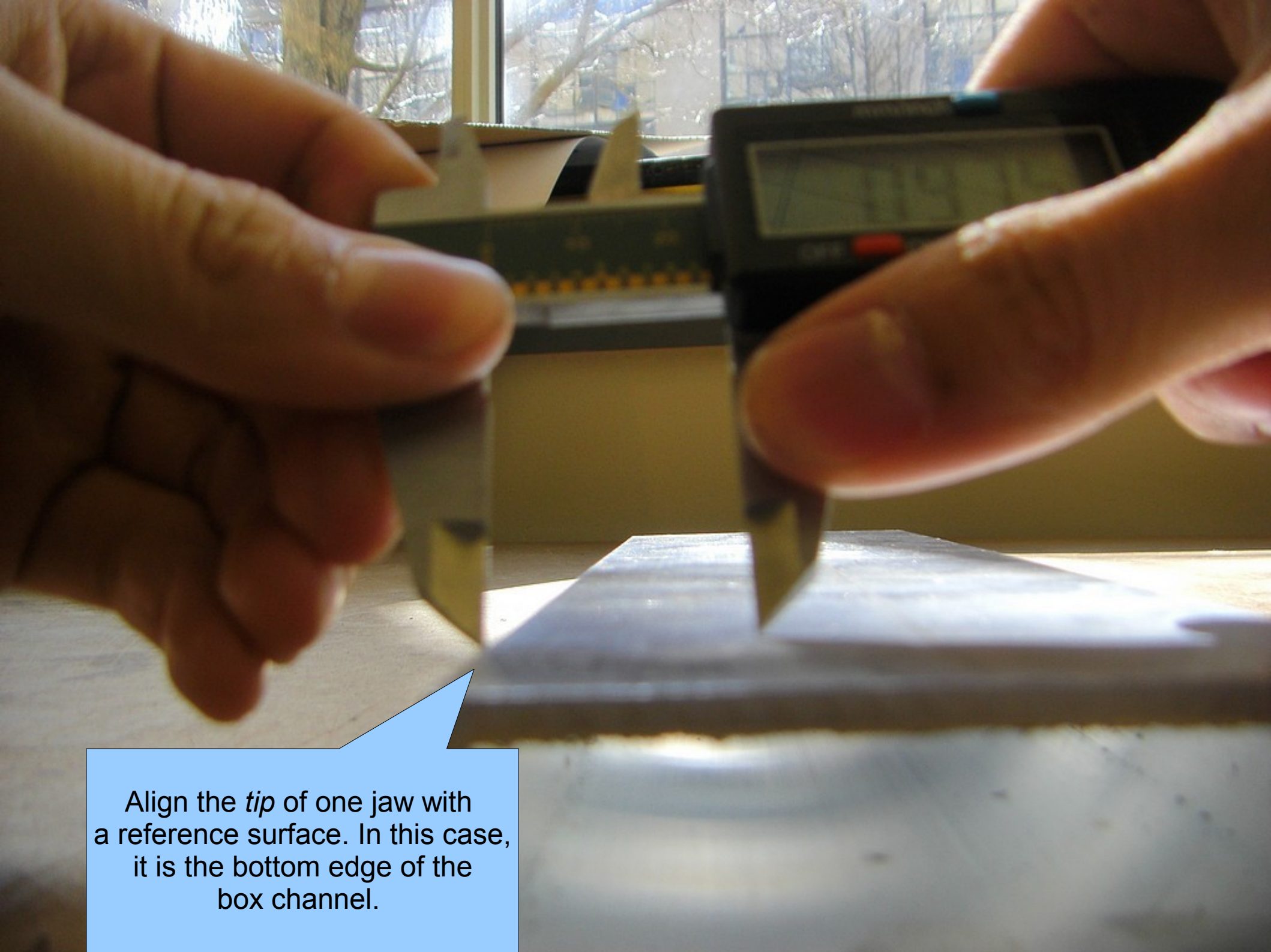
This document is intended to exposit a fairly common but usually unspoken shortcut that balances time spent laying out a part for fabrication with reasonably accurate results.

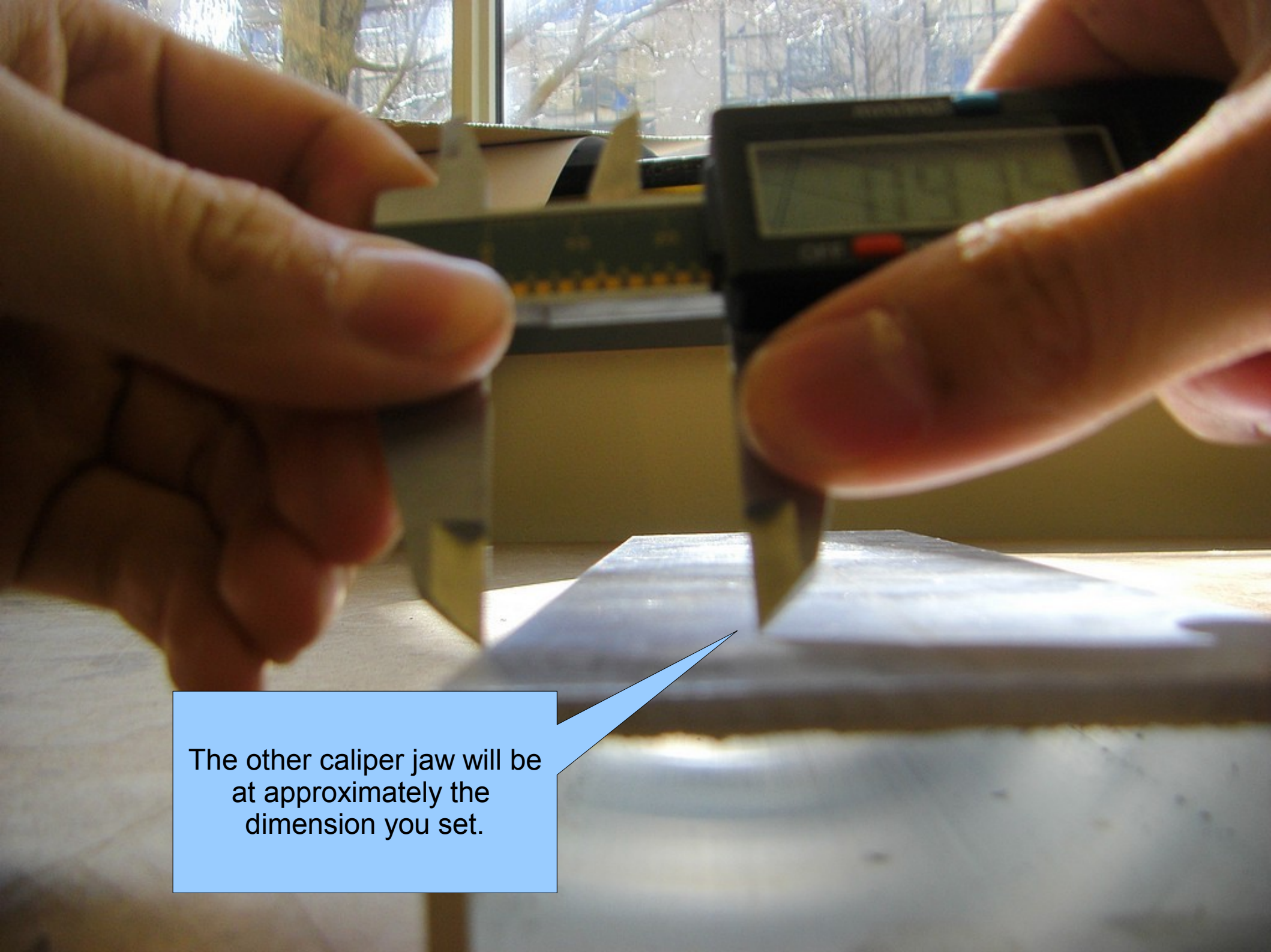
We will be using a 3 x 1” aluminum box extrusion as the example workpiece.

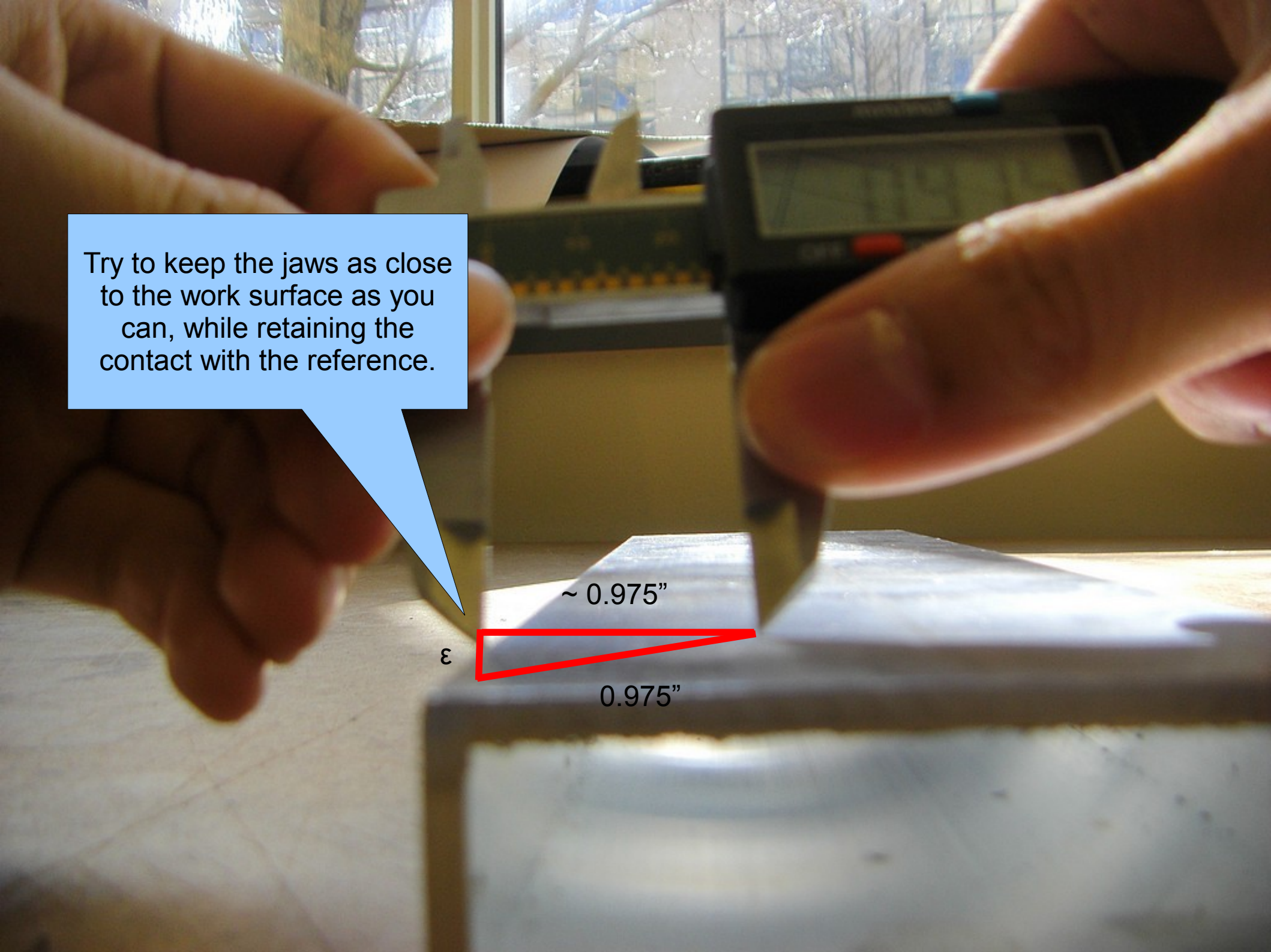
Let's say that we wanted to drill a hole that is 0.975” above the bottom edge of this piece and 1.150” from the right edge.

Neither dimension is a common fraction, nor a demarcation found on most rulers. How would we drill such a hole on the drill press?

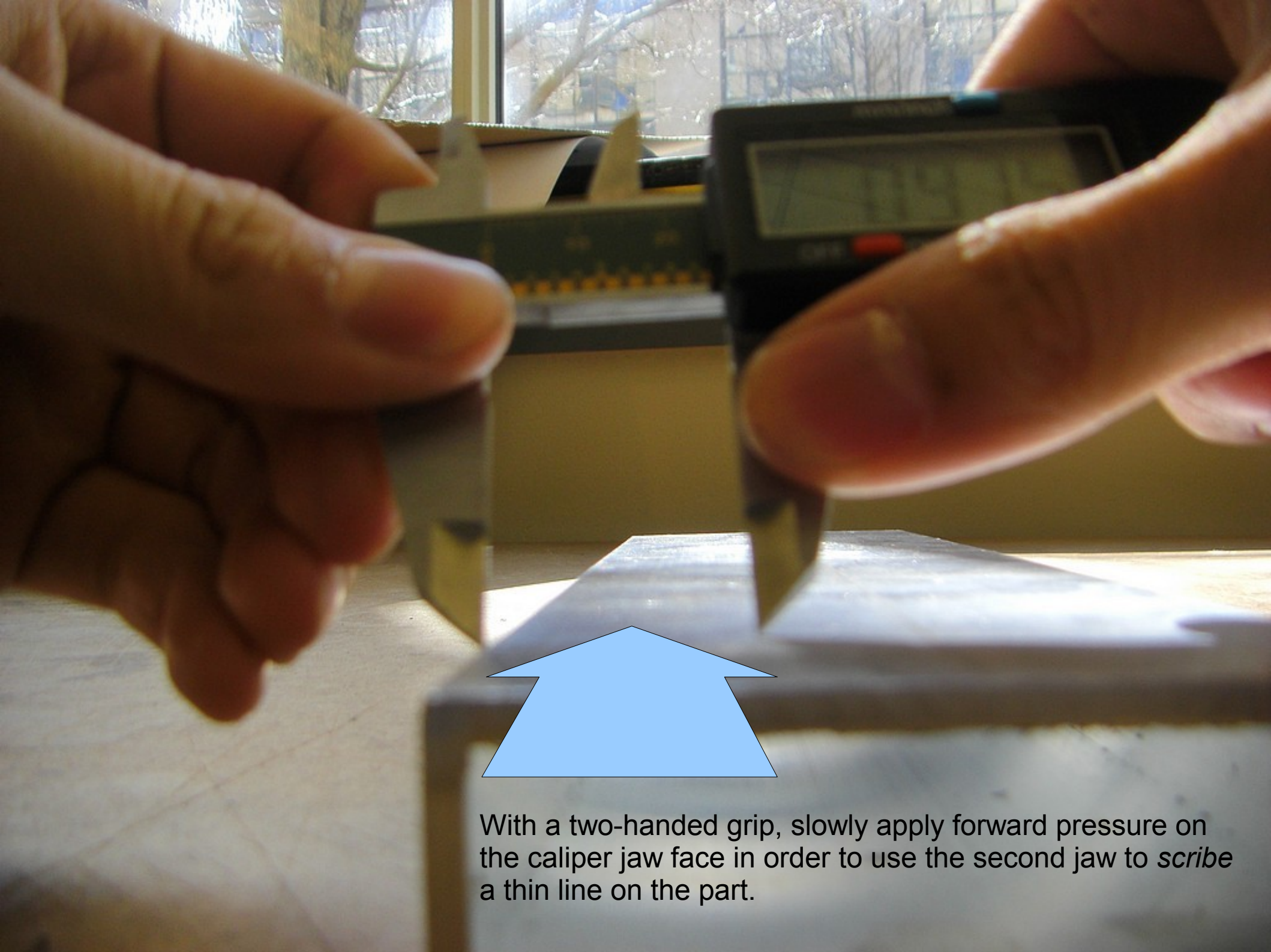

Here, I have set the caliper to 0.975”, after making sure it is properly zeroed.
Use the knurled knob to physically lock the caliper to a reading.
mm/inch
0.975
OFF
ON
ZERO
These calipers have a resolution of 0.0005”. However, this last digit is extremely uncertain. Treat your dimensions as if they only have 3 digits (0.xyz)
Calipers are magnetic and can attract dirt and grit. This will throw off your readings! Carefully run a clean towel or finger along the inside edge of the caliper before closing the jaws.


Align the *tip* of one jaw with a reference surface. In this case, it is the bottom edge of the box channel.


The other caliper jaw will be at approximately the dimension you set.


Try to keep the jaws as close to the work surface as you can, while retaining the contact with the reference.
~ 0.975”
ε
0.975”


Use both hands to grip the calipers. Keep the thumbs firm in one position on *both* jaws. You should have a steady grip, but do not *squeeze* the caliper in this manner, as it could damage them.



With a two-handed grip, slowly apply forward pressure on the caliper jaw face in order to use the second jaw to *scribe* a thin line on the part.

The result should be a very faint line that is approximate 0.975 inches from the reference edge.

Very little downpressure is required! Do not *carve* a line with your caliper tips! Gliding them is often enough.

STOP

Do **not** perform this with any toolroom, metrology, or inspection calipers, or any calipers that are not explicitly yours. This activity degrades the point of the caliper and results in accuracy loss. Calipers are first and foremost measuring tools, not cutting tools.

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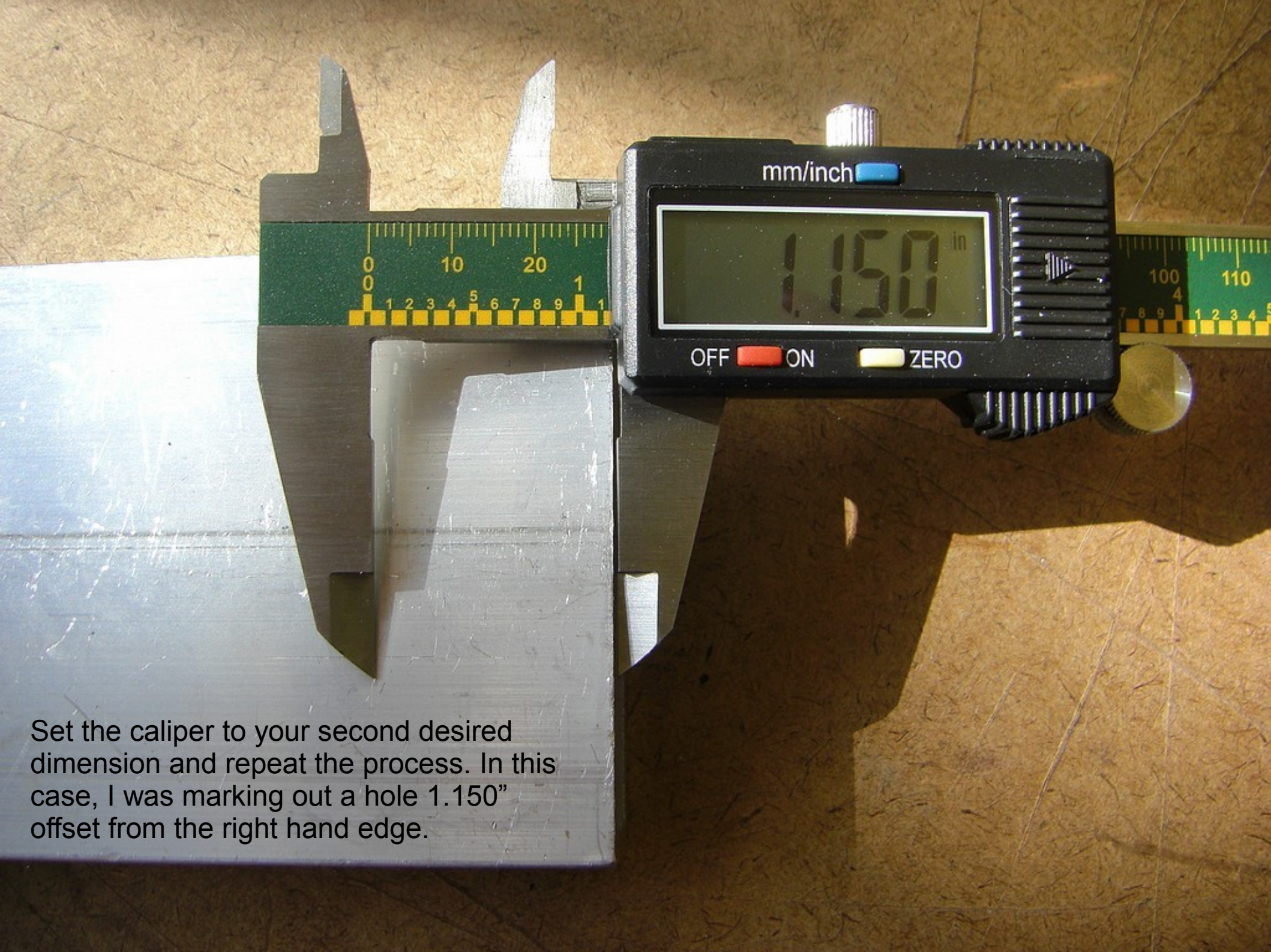
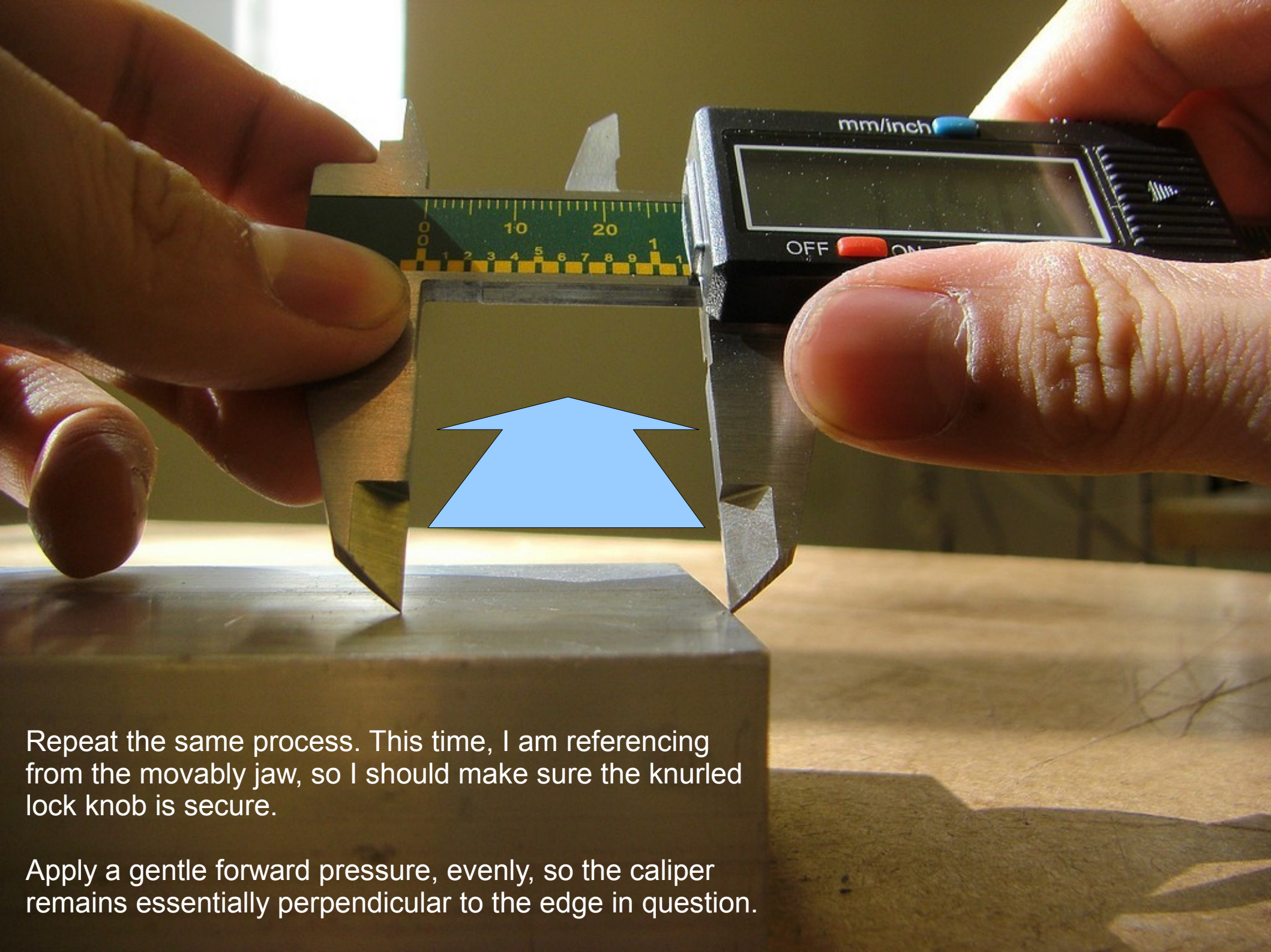
I consider this method a shortcut for when I need something built in the heat of battle, and the calipers I have are “cheap” (import grade), such as the ones provided in the 2.007 kits. Using expensive (highly precise) calipers as scribing tools is a violation of engineering tolerance principles.

c.f. Using sandpaper to clean your computer monitor.



Set the caliper to your second desired dimension and repeat the process. In this case, I was marking out a hole 1.150” offset from the right hand edge.



Repeat the same process. This time, I am referencing from the movably jaw, so I should make sure the knurled lock knob is secure.

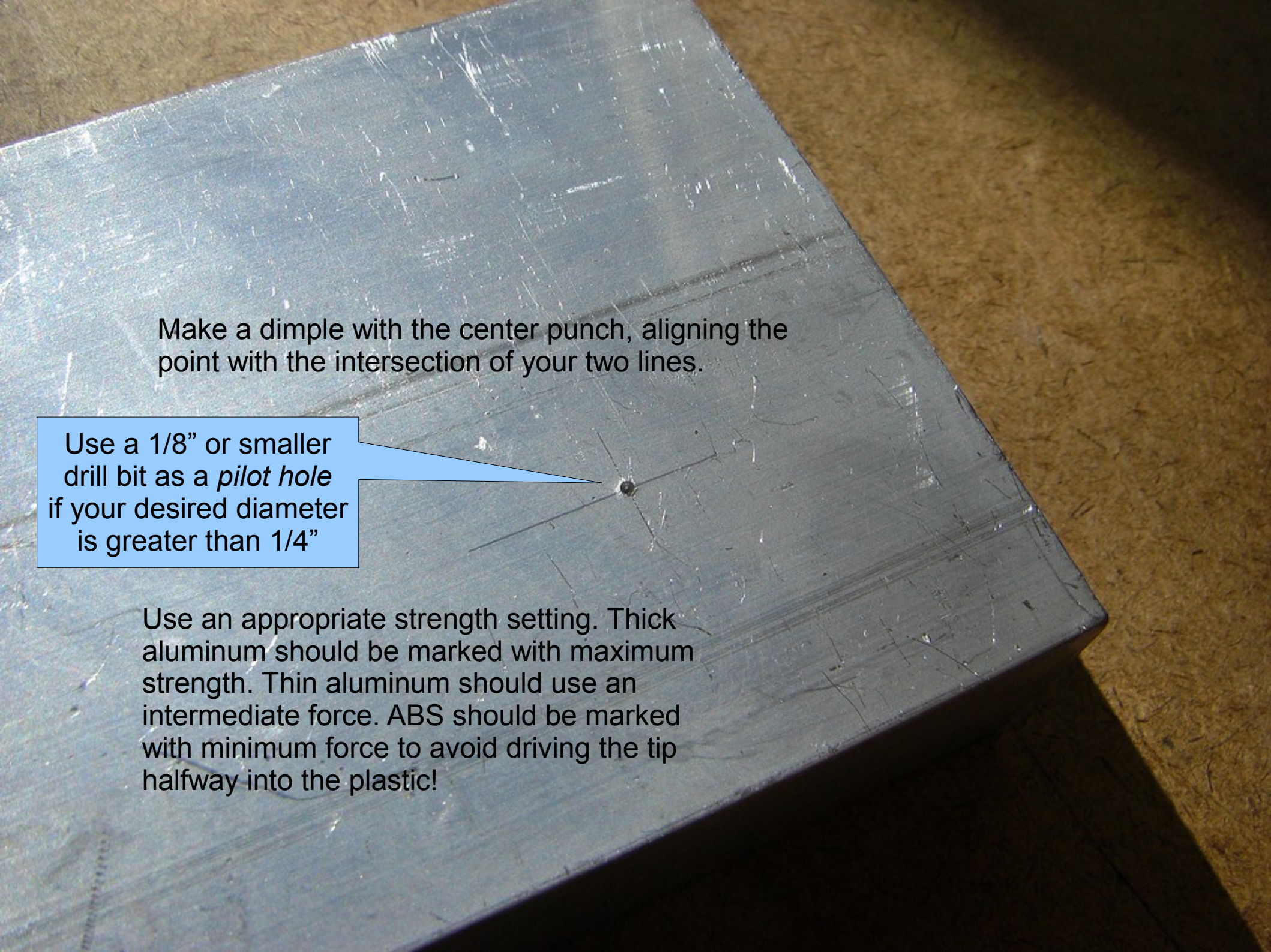
Apply a gentle forward pressure, evenly, so the caliper remains essentially perpendicular to the edge in question.

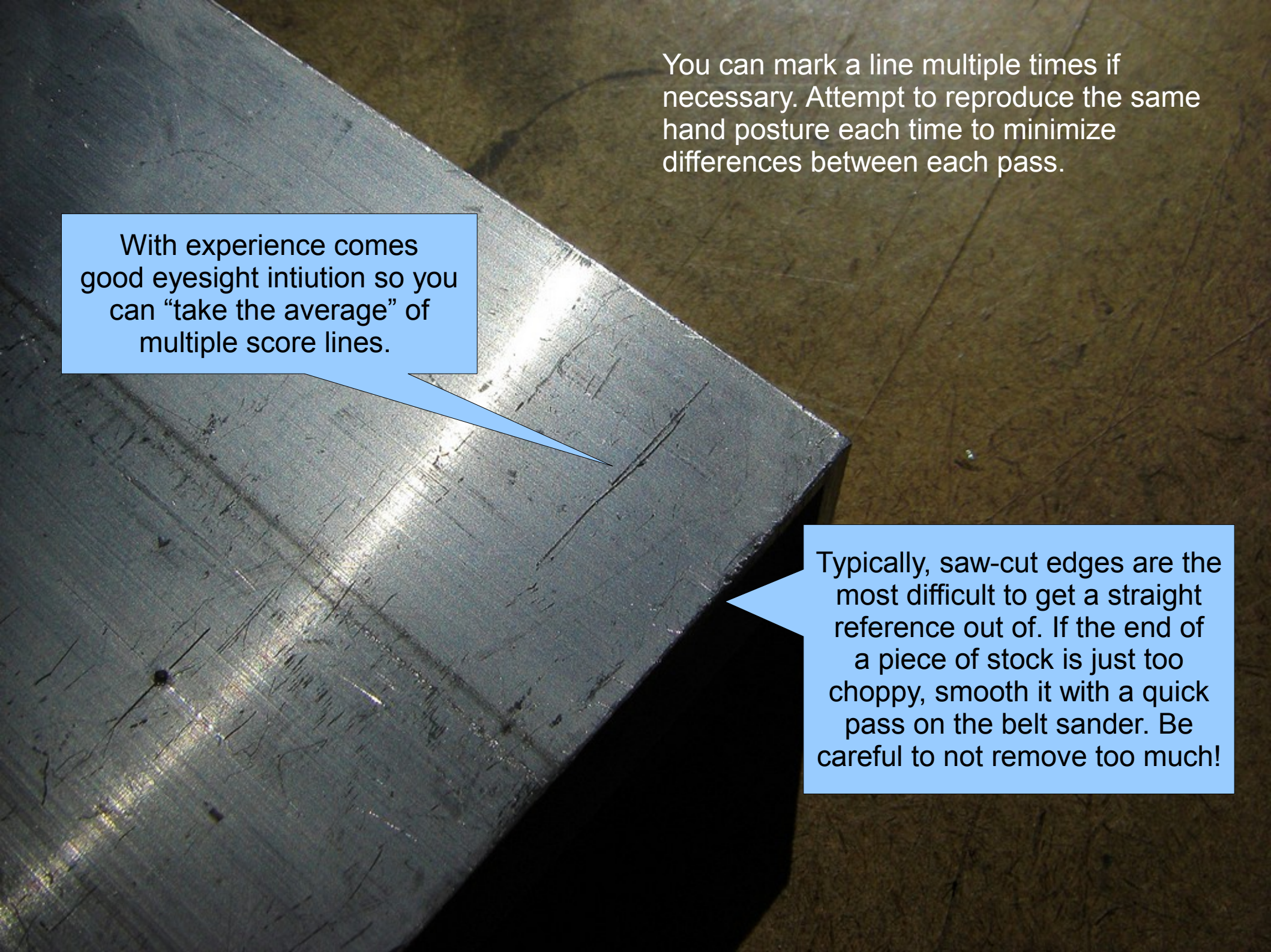

The two lines intersect at (-1.150 , 0.975)
as referenced from the lower right corner.
You can realistically get tolerances of ± 0.003”
with practice. This is sufficient for gear mates!

The other tool you will find useful is an **automatic center punch.**

If you have made it this far in 2.007 and **not** used one yet, go try one out in lab ASAP.

This endcap tightens and loosens to set the punch force

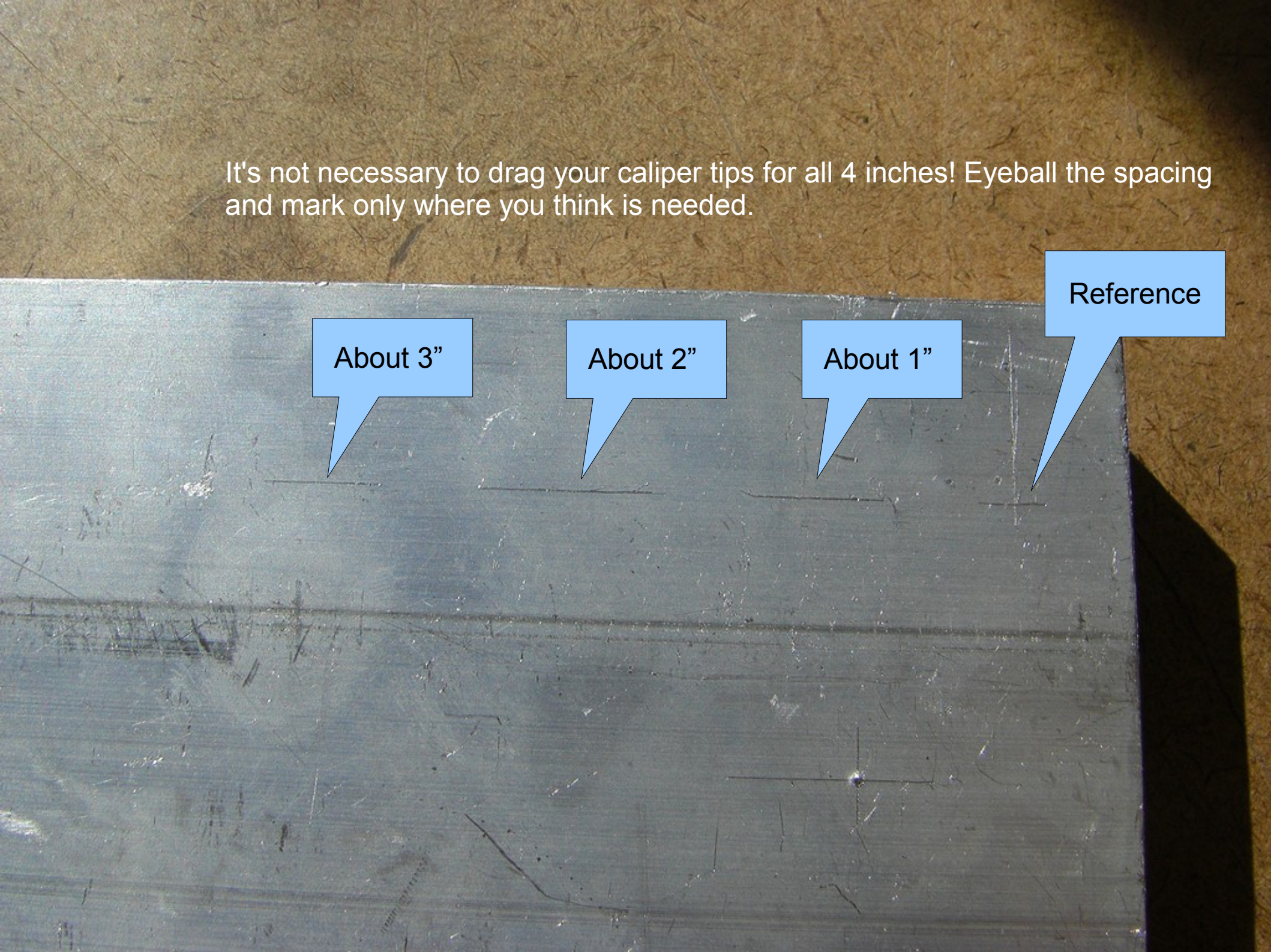

Make a dimple with the center punch, aligning the point with the intersection of your two lines.
Use a 1/8” or smaller drill bit as a *pilot hole* if your desired diameter is greater than 1/4”
Use an appropriate strength setting. Thick aluminum should be marked with maximum strength. Thin aluminum should use an intermediate force. ABS should be marked with minimum force to avoid driving the tip halfway into the plastic!

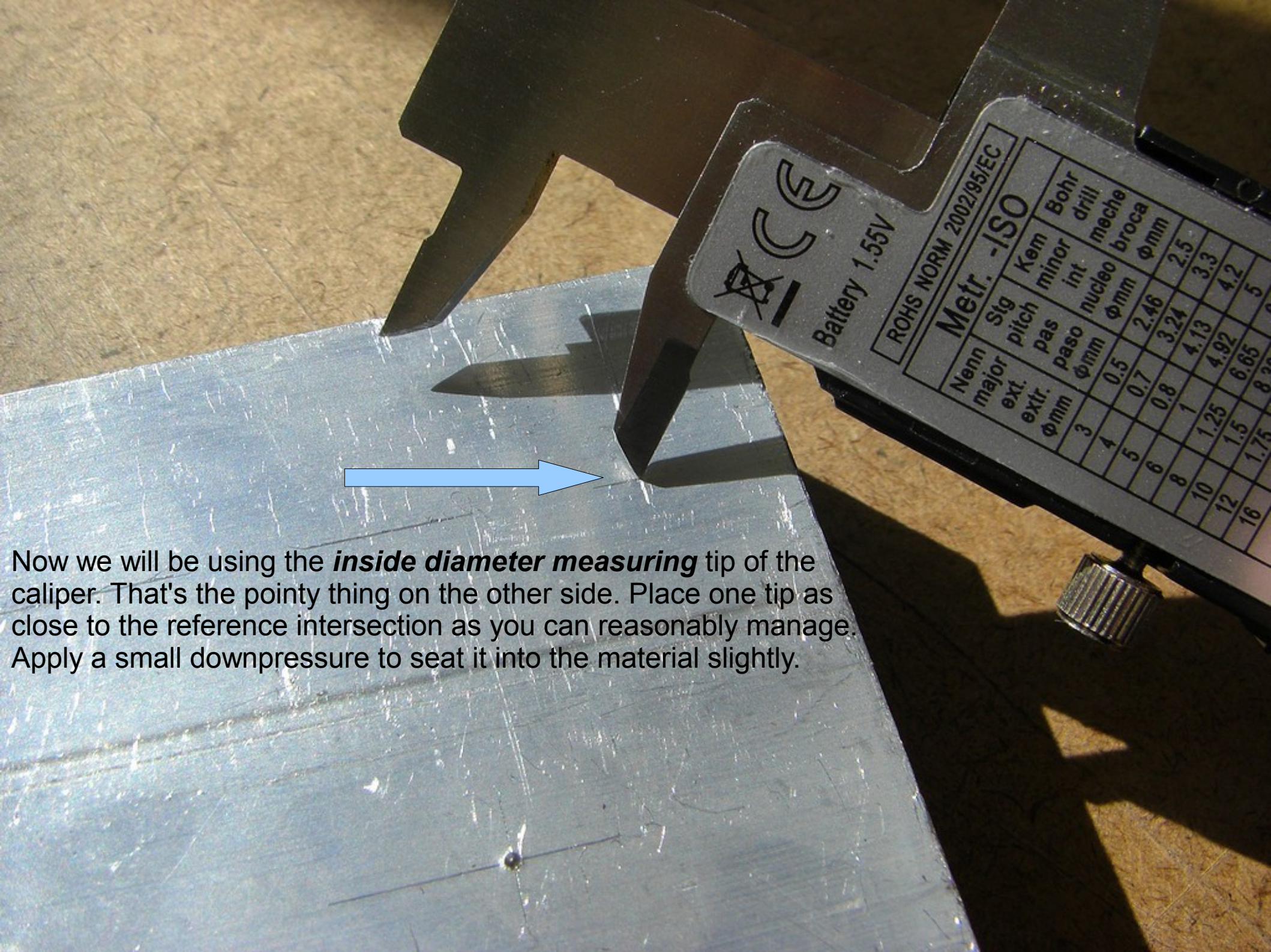

You can mark a line multiple times if necessary. Attempt to reproduce the same hand posture each time to minimize differences between each pass.
With experience comes good eyesight intiution so you can “take the average” of multiple score lines.
Typically, saw-cut edges are the most difficult to get a straight reference out of. If the end of a piece of stock is just too choppy, smooth it with a quick pass on the belt sander. Be careful to not remove too much!

Next, we will explore how to mark out a linear pattern.

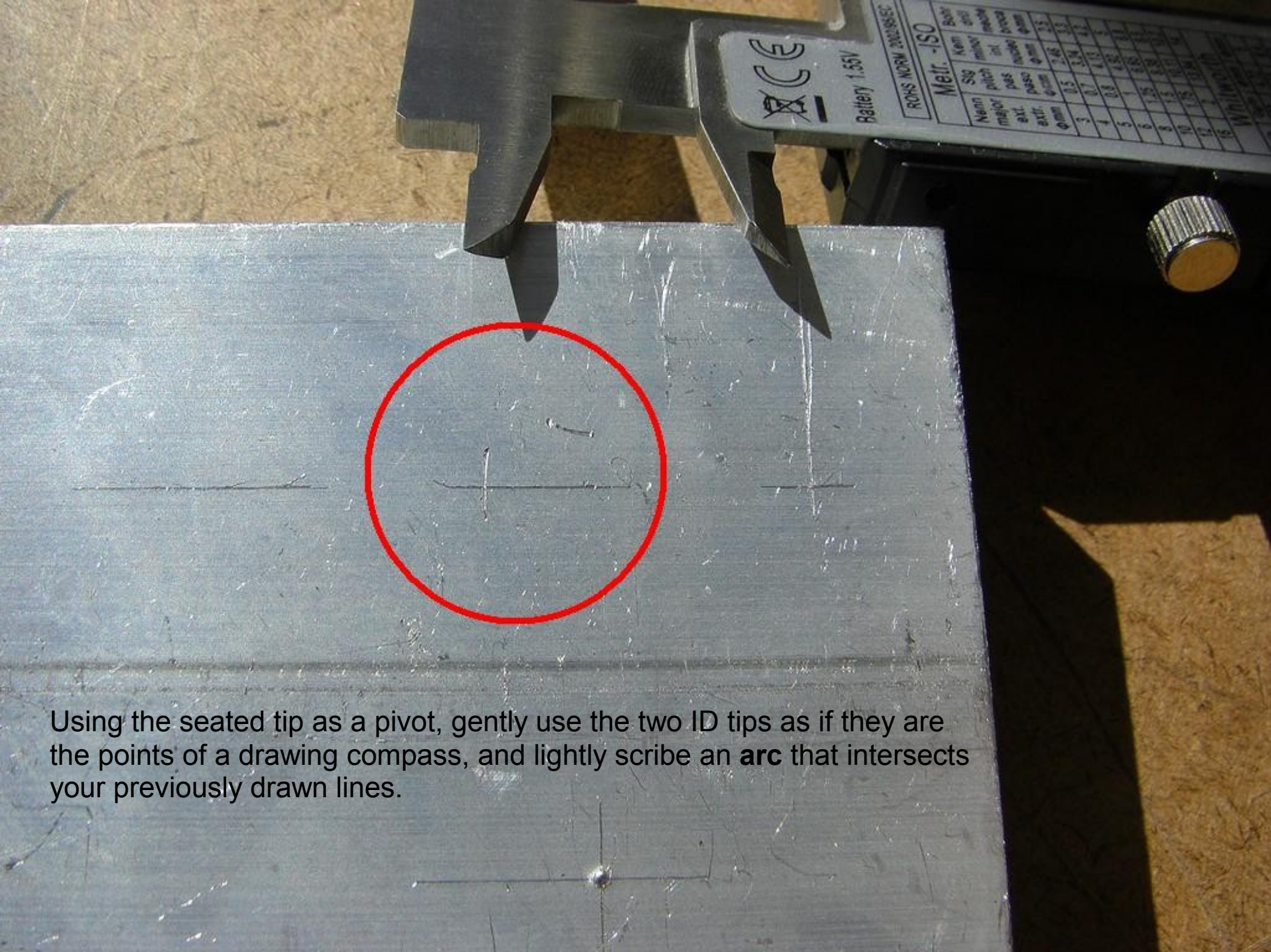
I have placed an arbitrary starting point at (-1 , 0.5) from the bottom right edge in this picture.


Let's say I want to place a hole every 1 inch, 4 in total. All the holes must be offset from the right (the top in this picture) by 1 inch, as marked previously. Set the readout to the desired spacing.
mm/inch
1.000
OFF
ON
ZERO

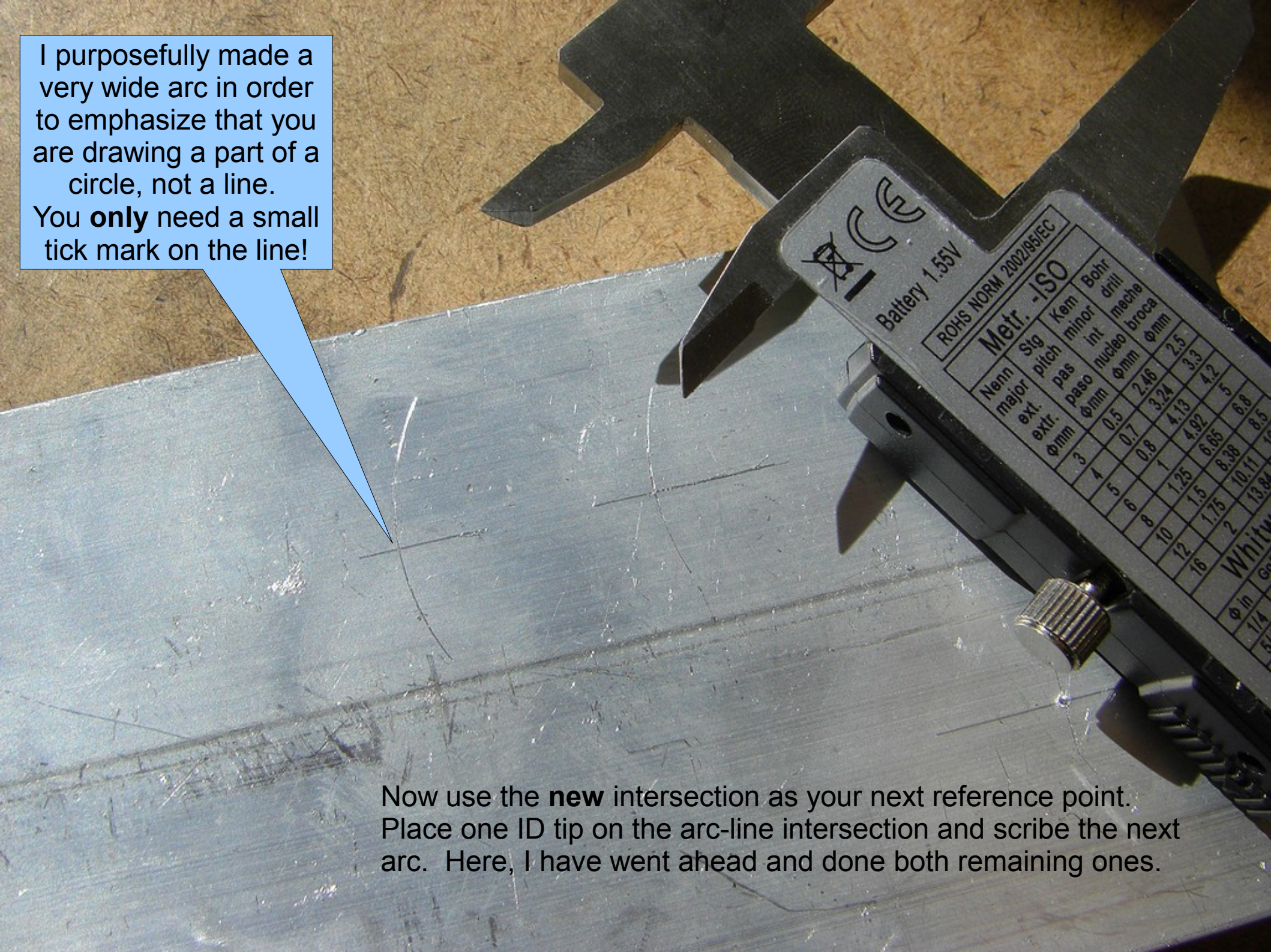

It's not necessary to drag your caliper tips for all 4 inches! Eyeball the spacing and mark only where you think is needed.
About 3”
About 2”
About 1”
Reference

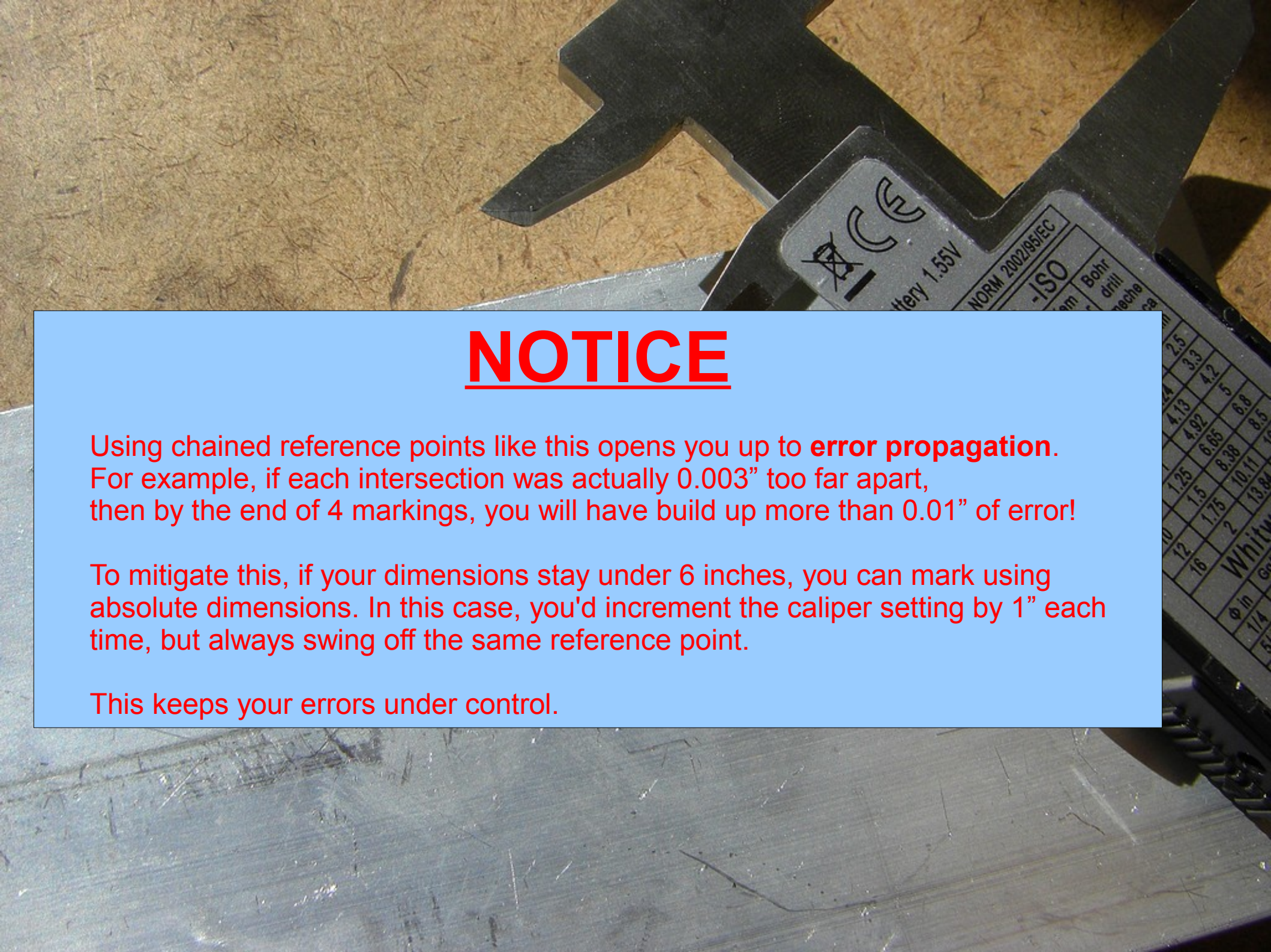


Now we will be using the ***inside diameter measuring*** tip of the caliper. That's the pointy thing on the other side. Place one tip as close to the reference intersection as you can reasonably manage. Apply a small downpressure to seat it into the material slightly.



Using the seated tip as a pivot, gently use the two ID tips as if they are the points of a drawing compass, and lightly scribe an **arc** that intersects your previously drawn lines.


I purposefully made a very wide arc in order to emphasize that you are drawing a part of a circle, not a line.
You **only** need a small tick mark on the line!
Battery 1.55V
ROHS NORM 2002/95/EC
Metr. -ISO
Now use the **new** intersection as your next reference point. Place one ID tip on the arc-line intersection and scribe the next arc. Here, I have went ahead and done both remaining ones.

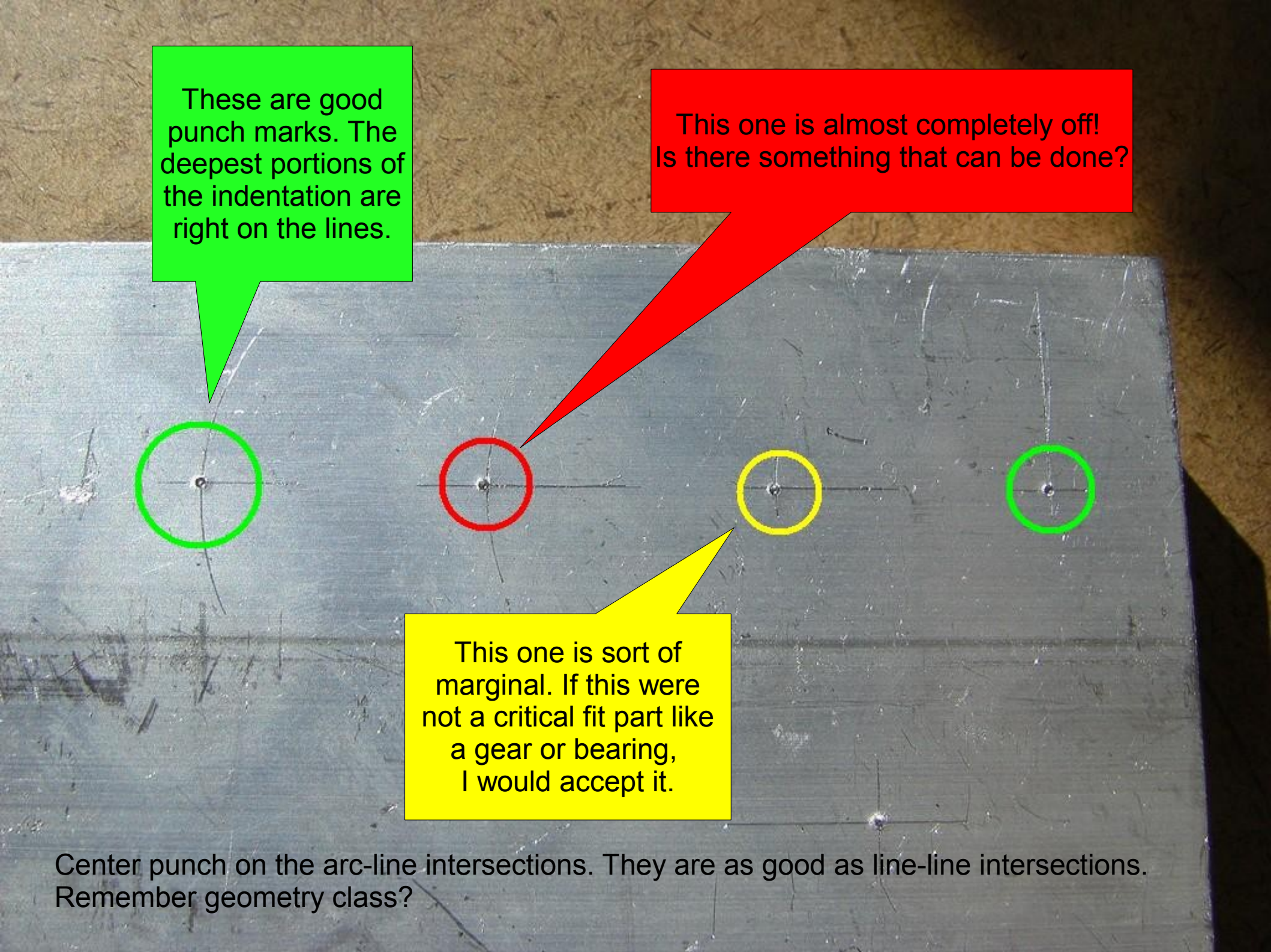


NOTICE

Using chained reference points like this opens you up to **error propagation**.
For example, if each intersection was actually 0.003” too far apart,
then by the end of 4 markings, you will have build up more than 0.01” of error!

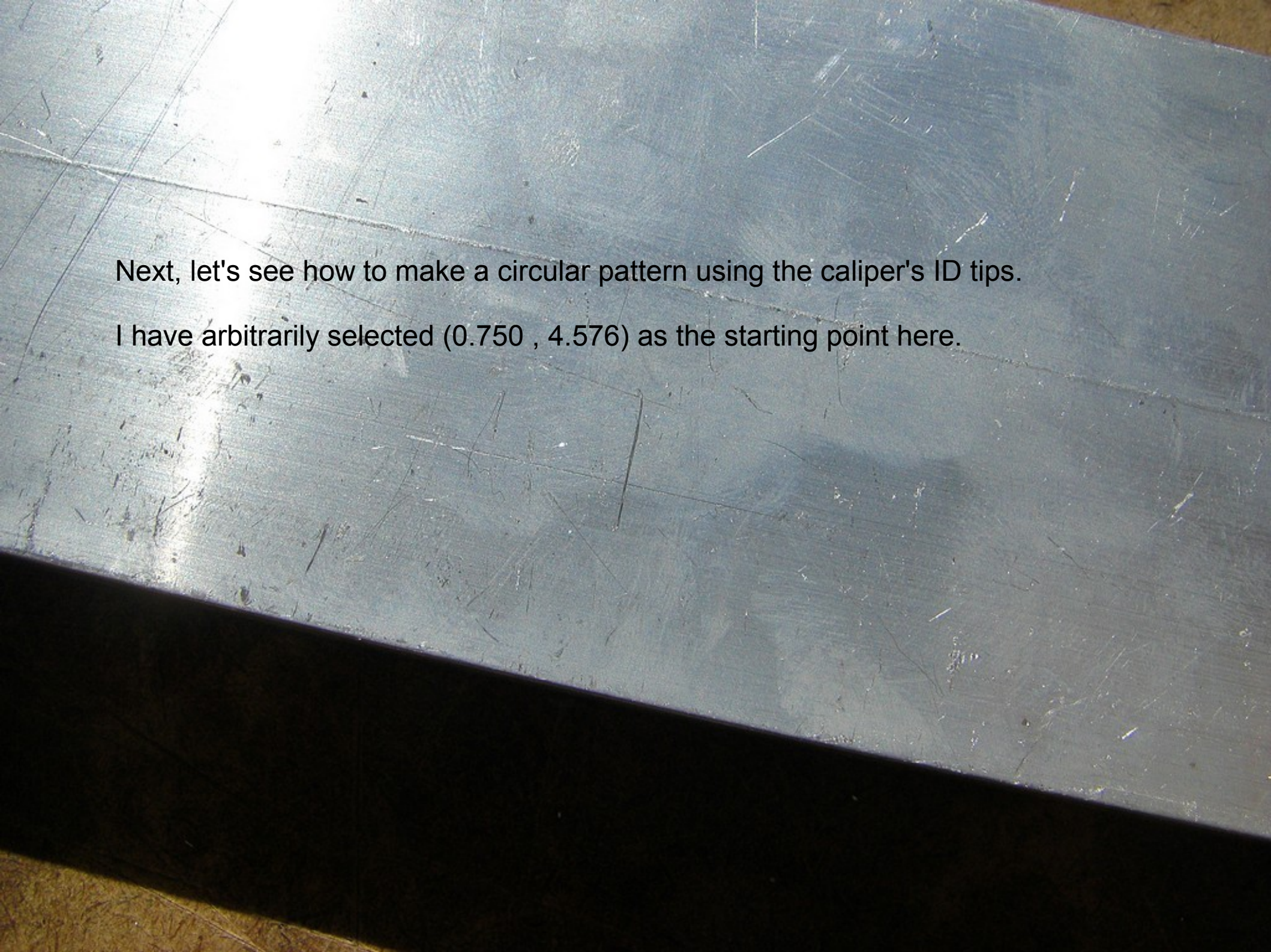
To mitigate this, if your dimensions stay under 6 inches, you can mark using absolute dimensions. In this case, you'd increment the caliper setting by 1” each time, but always swing off the same reference point.

This keeps your errors under control.



Center punch on the arc-line intersections. They are as good as line-line intersections. Remember geometry class?


If you did not punch too deep initially, you can *walk* a center punch dot over a few thousandths of an inch by tilting the point and punching again.
In this case, I am moving the faildot down and to the right in order to bring it towards the intersection.
At all other times, punch perpendicularly to the piece.



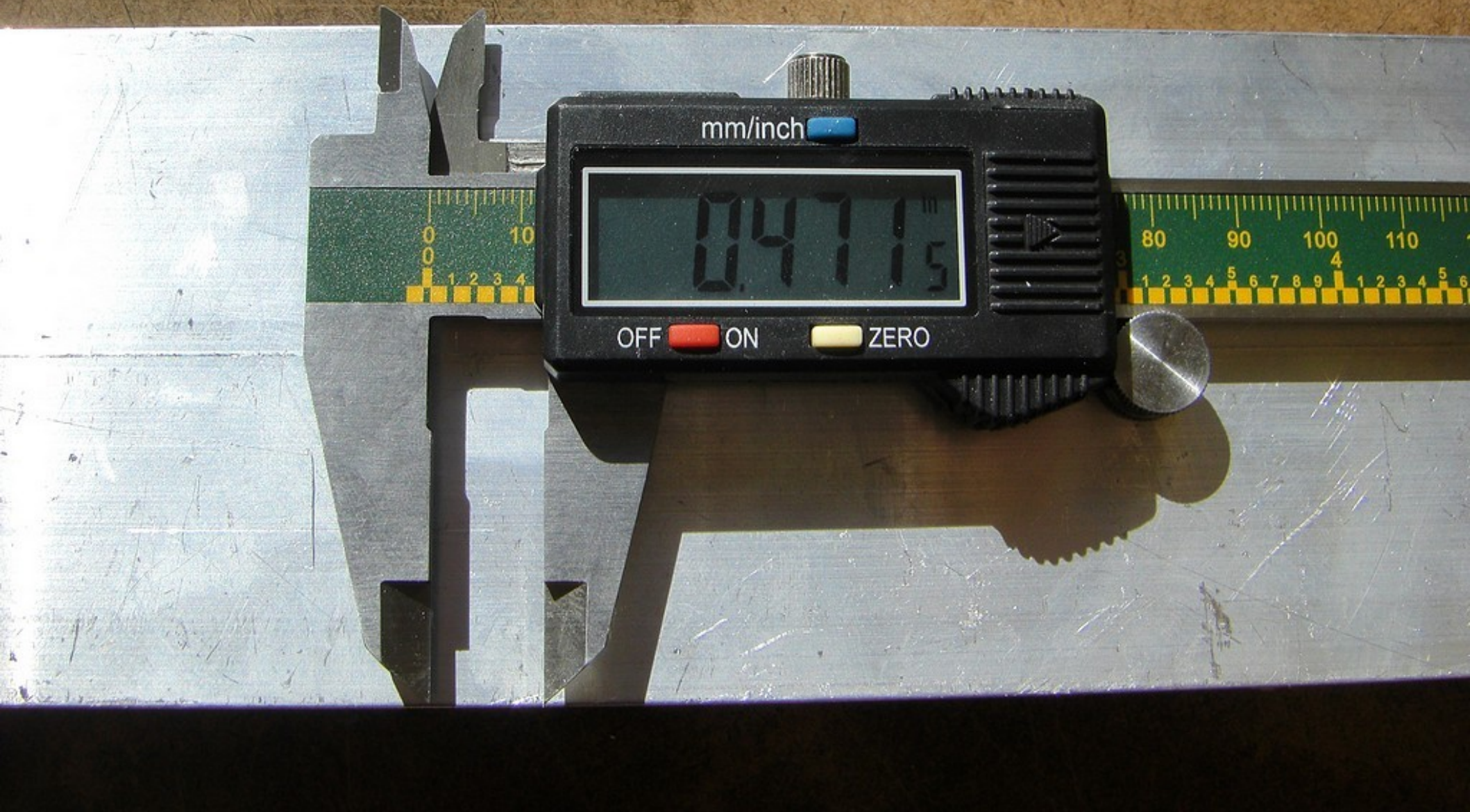
Next, let's see how to make a circular pattern using the caliper's ID tips.

I have arbitrarily selected (0.750 , 4.576) as the starting point here.

Let's say I wanted a 24 mm diameter bolt circle with 4 elements, centered on the previously determined point.

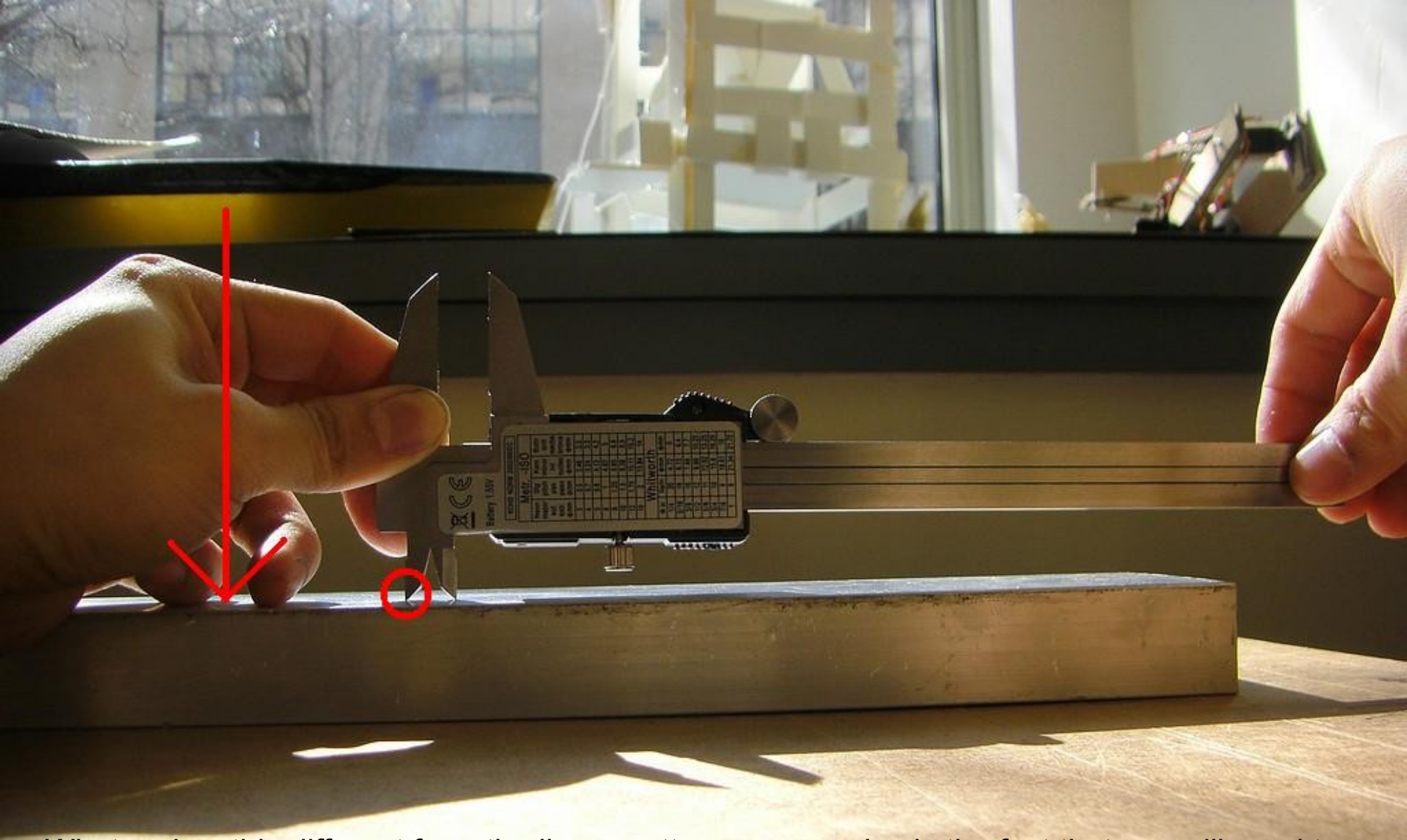
.

Set the caliper to the ***radius*** of the bolt circle. In thise case, half of 24 mm is 12 mm, or 0.4724”. You may OCD at will, but it is difficult to hold 0.001” (or even 0.003”) positioning manually, so don't try too hard.



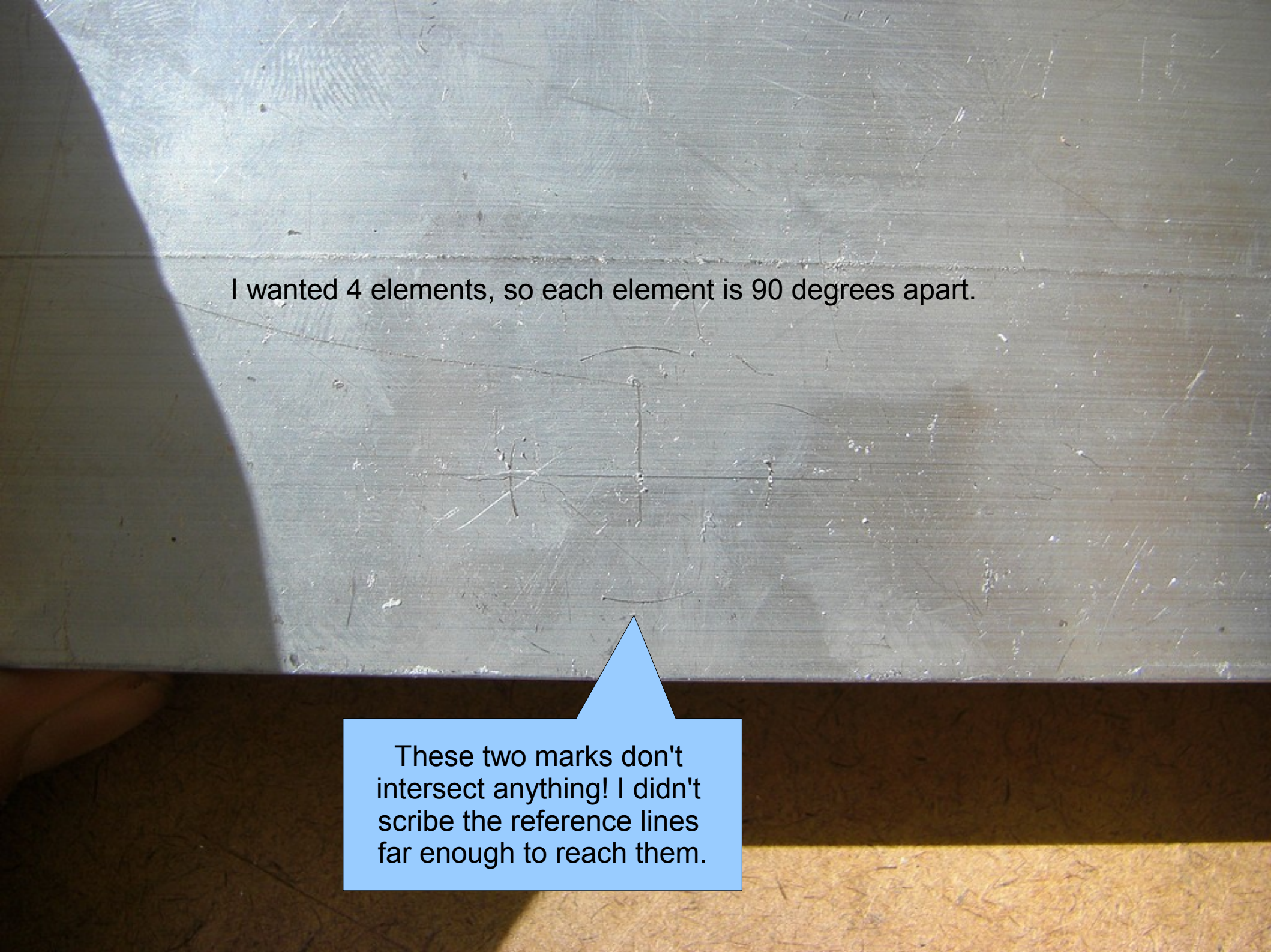
Again, the ID tips of the caliper will function as compass points.

Align the tip appropriately and give some gentle downforce to dig it in.



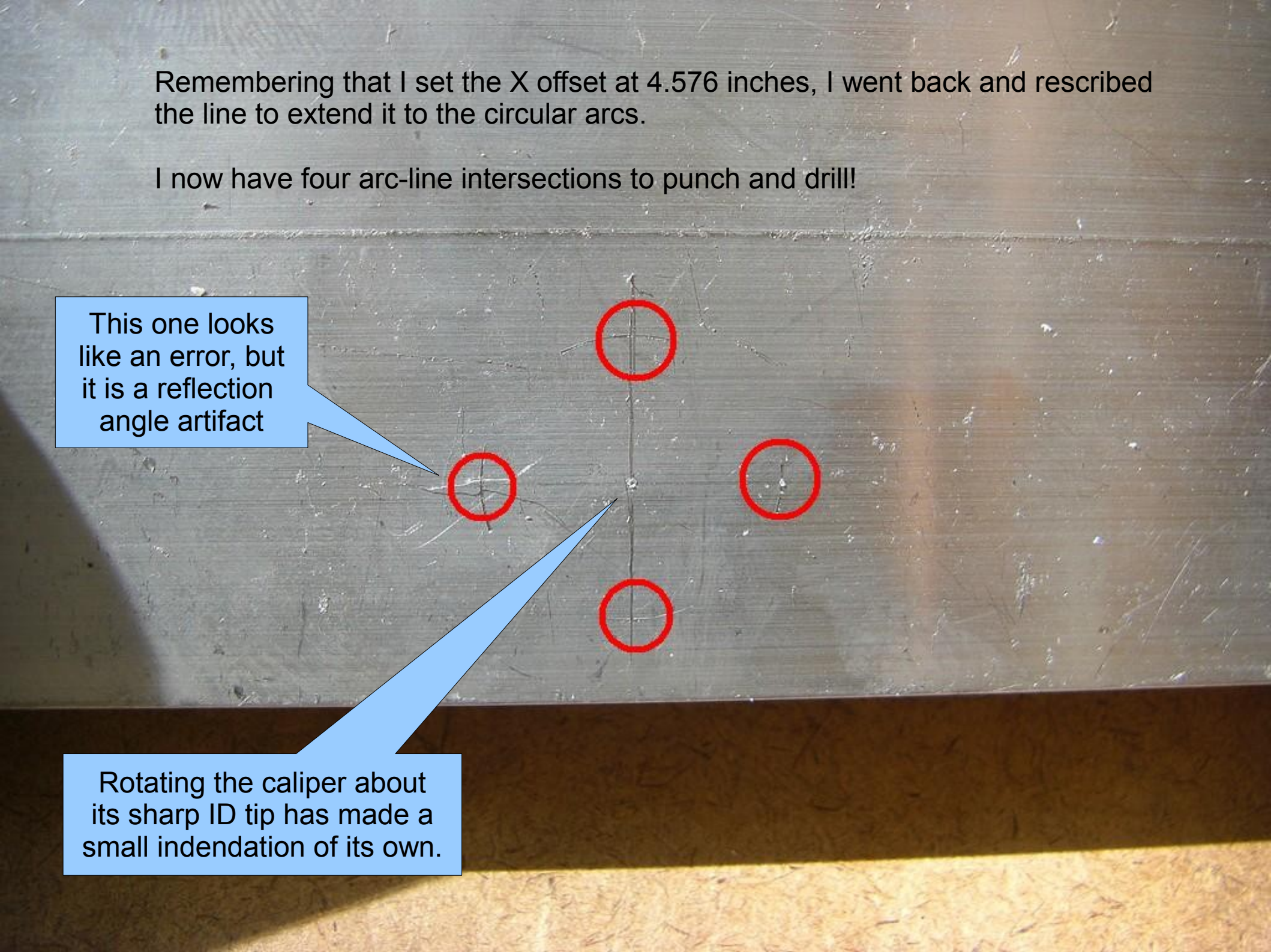
What makes this different from the linear pattern arc exercise is the fact that you will need to mark at different angular positions. For maximum control, keep one hand on the reference tip and make sure there is pressure on *it* at all times.

Use your other hand at the end of the caliper to control the scribing motion of the other tip. Lift up to skip portions of the circle.


I wanted 4 elements, so each element is 90 degrees apart.
These two marks don't intersect anything! I didn't scribe the reference lines far enough to reach them.

Remembering that I set the X offset at 4.576 inches, I went back and rescribed the line to extend it to the circular arcs.

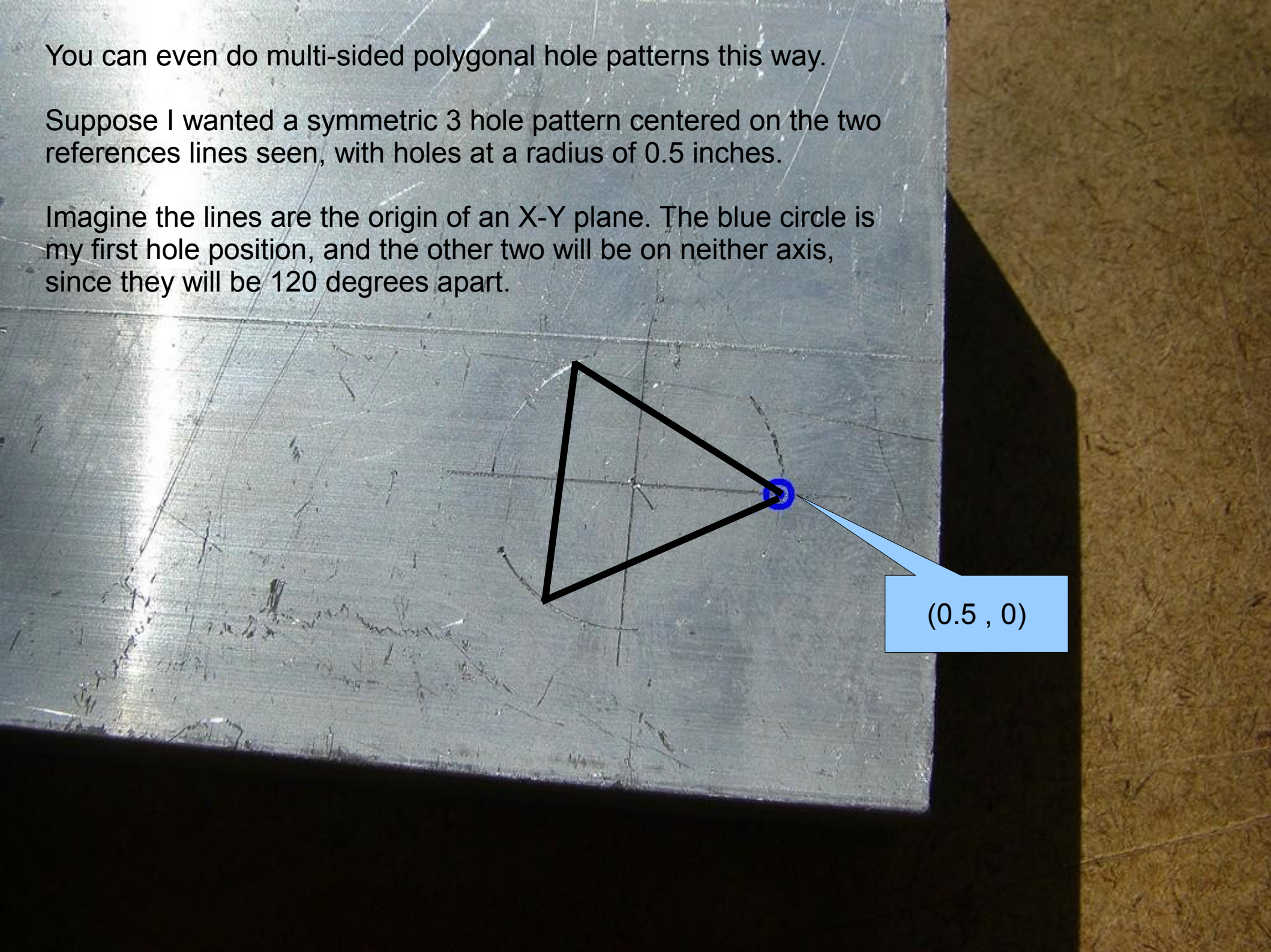
I now have four arc-line intersections to punch and drill!



You can even do multi-sided polygonal hole patterns this way.

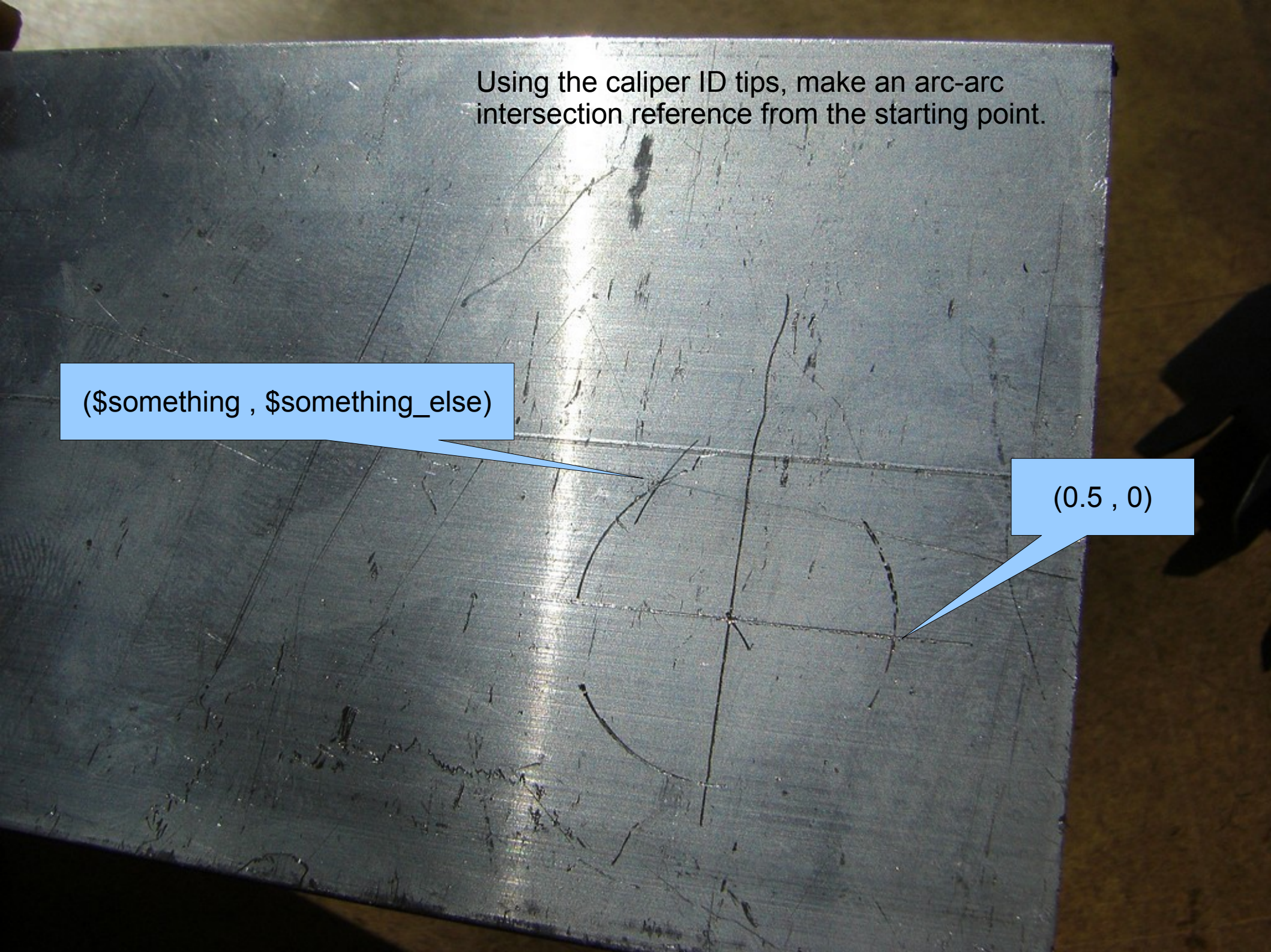
Suppose I wanted a symmetric 3 hole pattern centered on the two references lines seen, with holes at a radius of 0.5 inches.

Imagine the lines are the origin of an X-Y plane. The blue circle is my first hole position, and the other two will be on neither axis, since they will be 120 degrees apart.

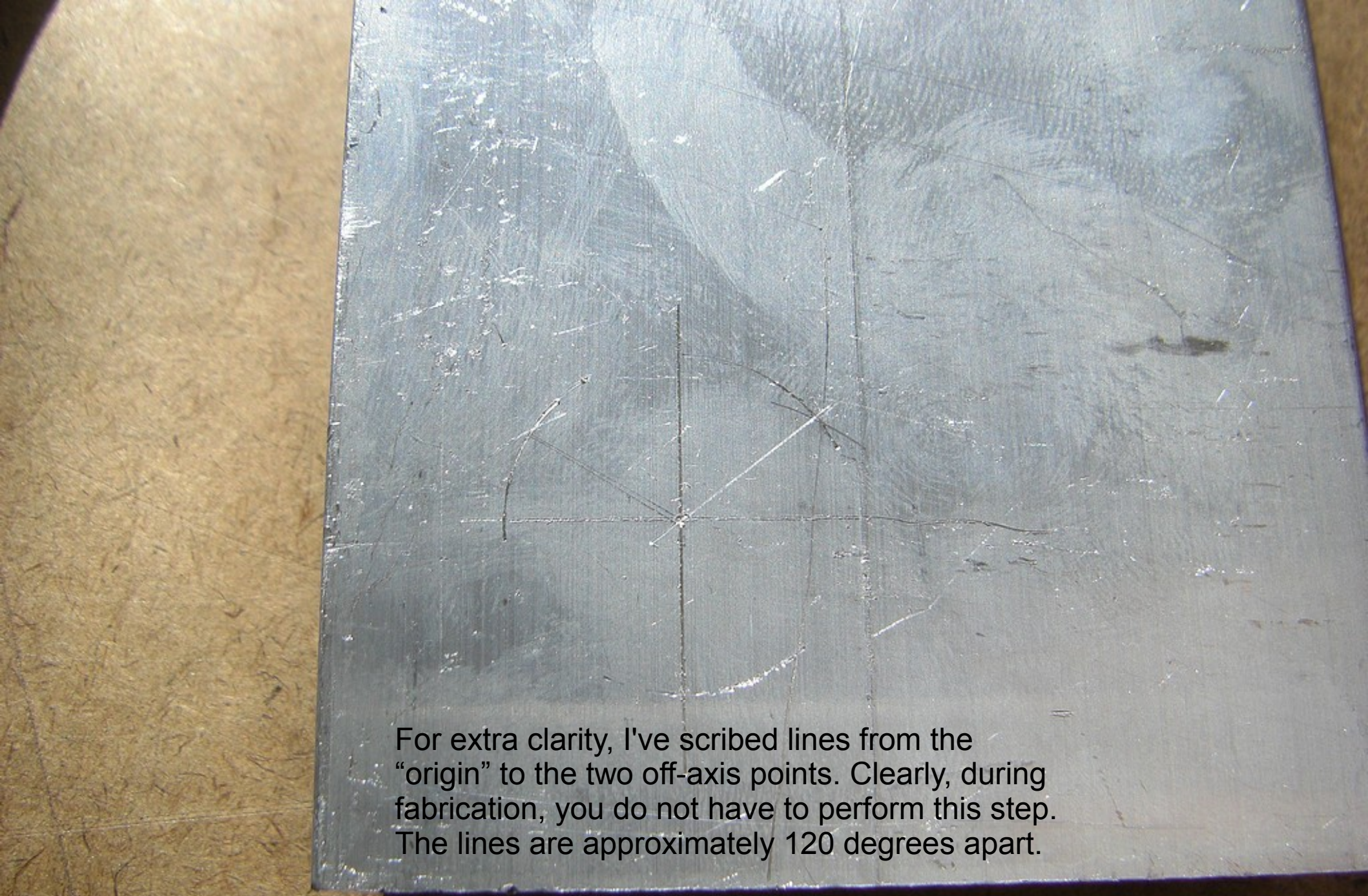


Aren't you glad you paid attention in Geometry class? An equilateral triangle *inscribed* in a circle has a side length of $R\sqrt{3}$, R the circle radius. We know one point already. So the calipers can be set to 0.5 * 1.732.

A list of common polygon formulae is here:
http://media.photobucket.com/image/polygon%20measure/oldtiffie/Black_book/Polygon_measure1.jpg


Using the caliper ID tips, make an arc-arc intersection reference from the starting point.
($something , $something_else)
(0.5 , 0)


Repeat for the rest of the polygon vertices. In this simple case, there was exactly one other vertex.



For extra clarity, I've scribed lines from the “origin” to the two off-axis points. Clearly, during fabrication, you do not have to perform this step. The lines are approximately 120 degrees apart.

Center punched for good measure.

You can also use your calipers to directly perform simple math, namely addition and subtraction.

This makes it easy to find differences in dimensions, offsets, etc.

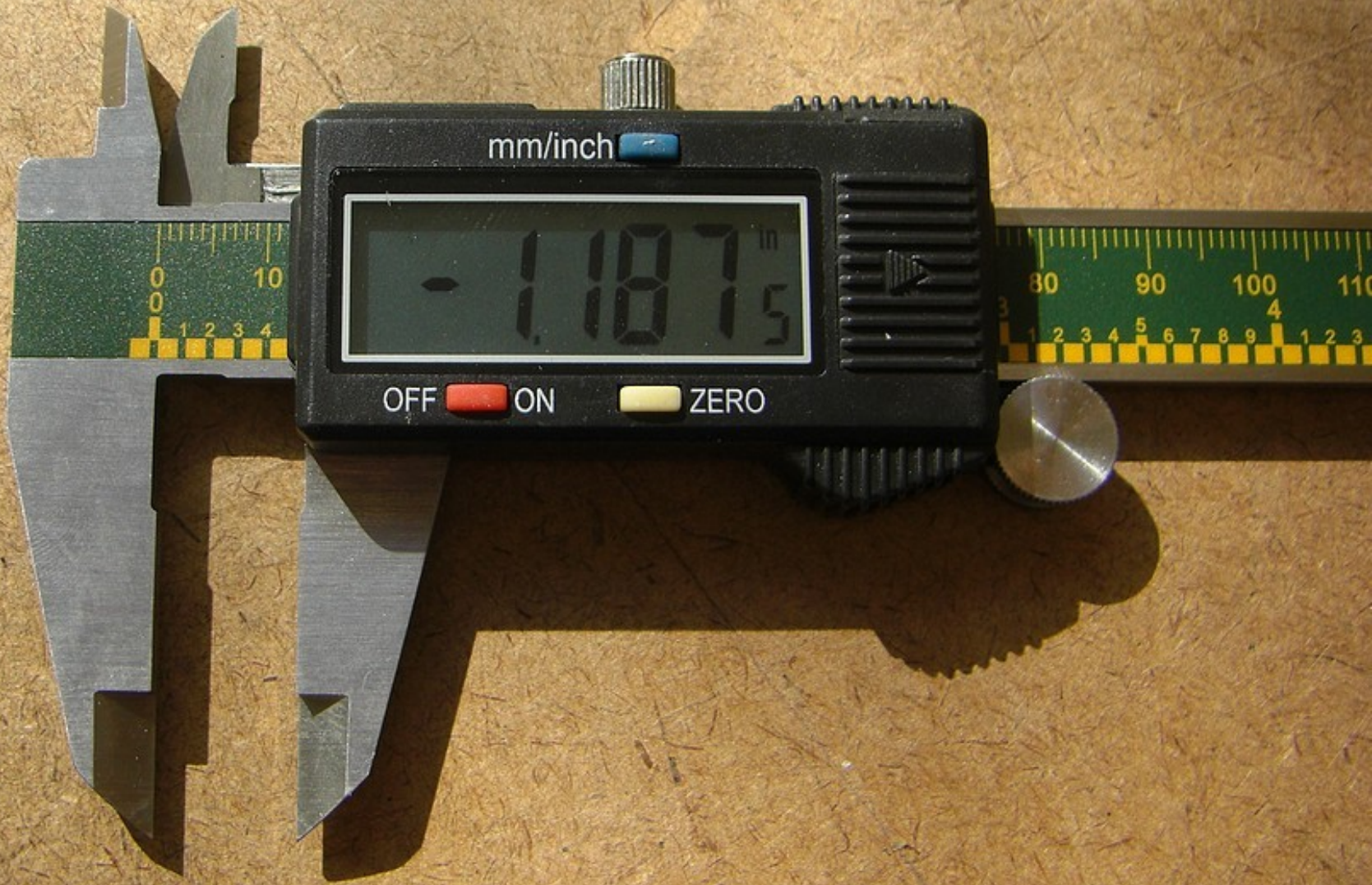
Always start with a zeroed caliper!

Let's say I had a 1.6875 (1 11/16”) wide piece...

After setting my first dimension, I zero the caliper to establish a reference for taking a difference.

Yikes! It turns out that my part needed to be 1.1875 (1 3/16”) wide instead. How much material do I need to remove?

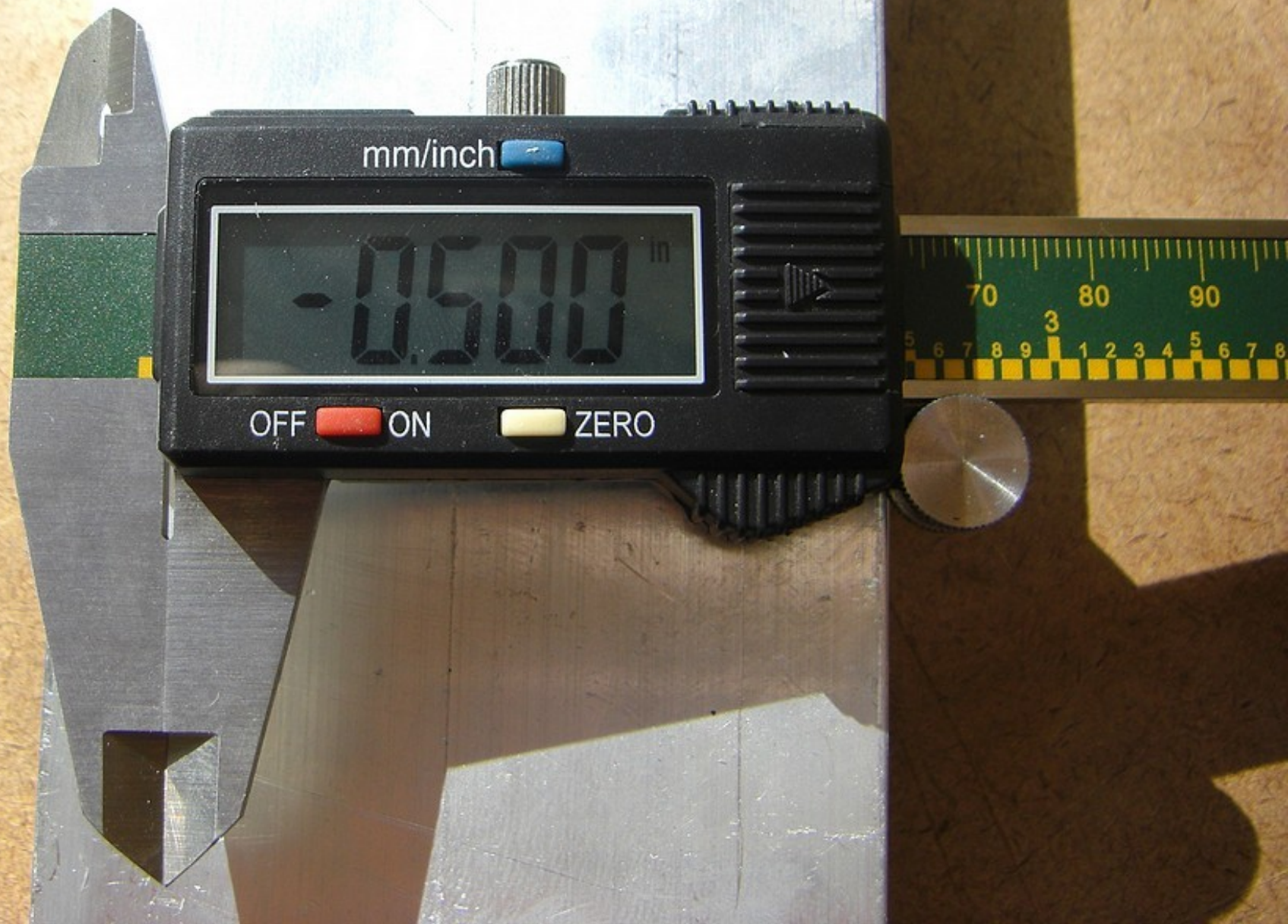
I could eyeball with a ruler, or sand-and-fit, or I can set *-1.1875* on my caliper from my zero at +1.6875.

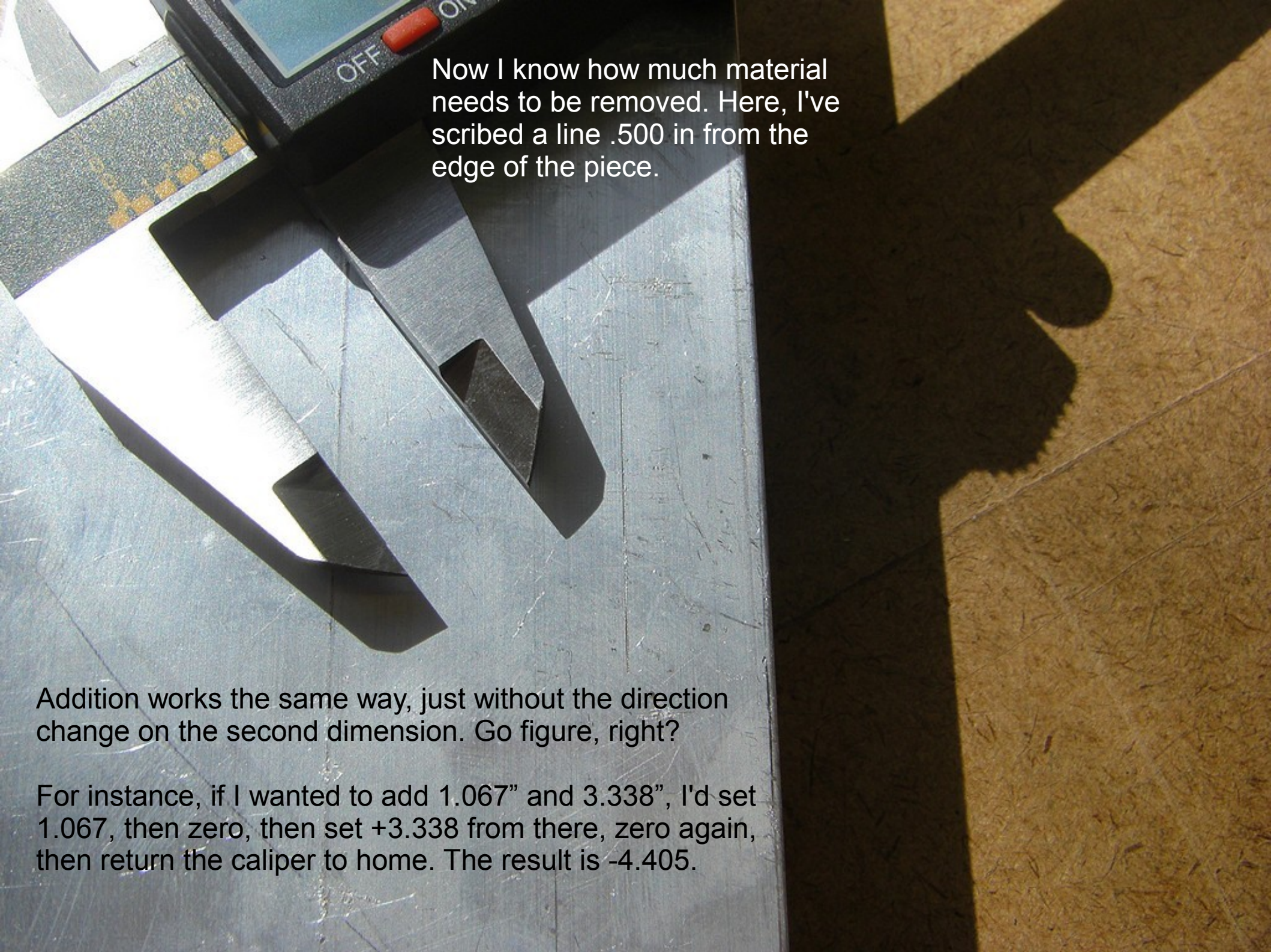


Zero the caliper again, then close the jaws completely.

That is, return to absolute zero.

Now you have the difference between your two dimensions! This will always be negative, so just abs()





Now I know how much material needs to be removed. Here, I've scribed a line .500 in from the edge of the piece.

Addition works the same way, just without the direction change on the second dimension. Go figure, right?

For instance, if I wanted to add 1.067” and 3.338”, I'd set 1.067, then zero, then set +3.338 from there, zero again, then return the caliper to home. The result is -4.405.

Helpful Advice

Because “tips” is too bad of a pun

- Again, do not **gouge** with your caliper tips. The lightest possible pressure that leaves a mark you can see is all that is required.
- For improved contrast on shiny surfaces such as aluminum, coat the area in black marker before marking.
  - The legitimate method of doing this is using Prussian Blue layout fluid, a natural dye dissolved in alcohol. This method has been used for more than a century.
  - Black Sharpies are easier to find and less messy. Additionally, you now only have to break the marker surface, which eases the suffering for your calipers.
- The less you tilt the caliper when marking, the closer your marked dimension will be to your desired dimension. The cost of more horizontal is less stability when marking.
  - Set your dimension 0.001 to 0.003 **over** to compensate for the angle!
- Practice approximates perfect to within 3 thousandths.
  - This was the only dimensionally consistent method of building robots for Yours Truly from 2003 to 2007.
- **Do not try this with anything except shady import calipers like the 2.007 kit units**

If you're crafty, these tools should be all you need to mark out **everything**