# The Intersection of Art and Precision (Using a Caliper), version 4

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## Introduction

It may come as a surprise and maybe even a disappointment to learn that making a precision measurement involves a lot of "art". The machinist must learn the proper "feel" in order to get a consistent and accurate reading. This article will present some exercises that will help you to cultivate this feel.

This article does not address ***how*** to use inside and outside calipers. The tests presented here are purely to assess you skill setting the instruments in a consistent way. Once the user can get repeatable results, they should focus on accuracy[2].

## Instruments (of torture?)

Here we have three measurement instruments that can drive you crazy. On the left is a 1" micrometer. In the middle is an inside caliper. On the right is an outside caliper. In the hands of a machinist with the proper feel, they can do

[1] You are free to copy and distribute this document but not to change it.
[2] For more on repeatability, resolution and accuracy, see http://www.aerotech.com/products/engref/resvsacc.html

amazing things. With practice, you too can get them to do amazing things.

## Practice Exercise 1: mic and Inside Caliper

Set your mic to read exactly 0.9000" according to the thimble. Then adjust the inside caliper until it easily slides into the mic with no side play. Be sure to have the caliper on the same plane as the body of the mic. Open the mic to 0.9010" and get a feel for this extra 0.001". Close the mic down to 0.8990" and again get used to how this feels. Repeat the exercise for 0.0005". Return the mic to 0.9000". I was barely able to fee this 0.001" change. For me, anything smaller would be tough to detect.

You should be able to start with the inside caliper just off of the mic. Then slide it in and feel a slight drag but no compression of the caliper[3].

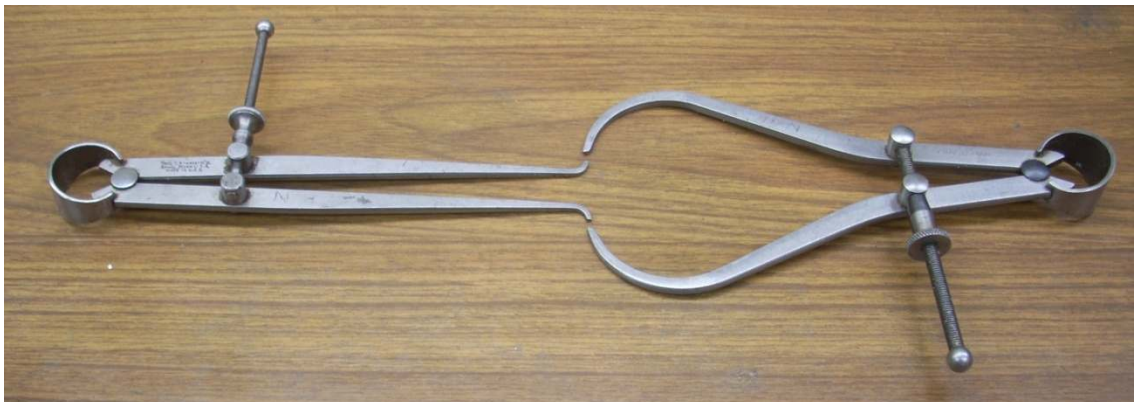
Next, open the mic up a few turns. Now comes the hard part. Use the mic to measure the inside caliper. Focus on proper alignment of the inside caliper in the mic and only look at the thimble when you are satisfied the feel is right. Record the

[3] Bob from the mill_drill yahoo group said "The only way that I was taught years ago was to do a cross approach with the calipers. That is where you first go in the x direction then when you find the high or low spot (depending on inside or outside measurements), then go in the y direction."

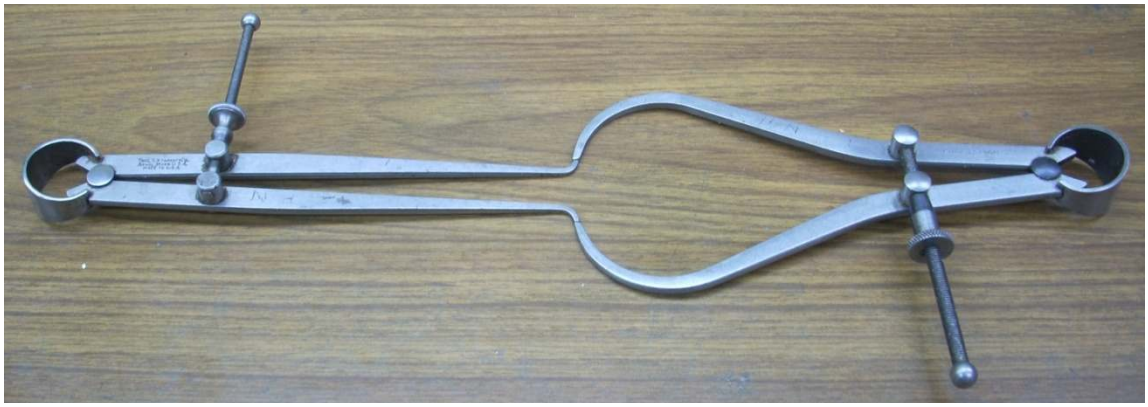
reading, open the mic up a few turns, and take another reading. At the very least, strive to get a consistent reading. Ideally, you want to get a reading of 0.9000" but don't be surprised if you can't hit that number every time. If you think you set the inside caliper a bit too tight, repeat the entire exercise.

## Practice Exercise 2: Mic, Inside Caliper, and Outside Caliper

We again start by setting our mic to 0.9000" and then adjust the inside caliper for a sliding fit with no deflection.



But this time we will use our outside caliper to measure the inside caliper.

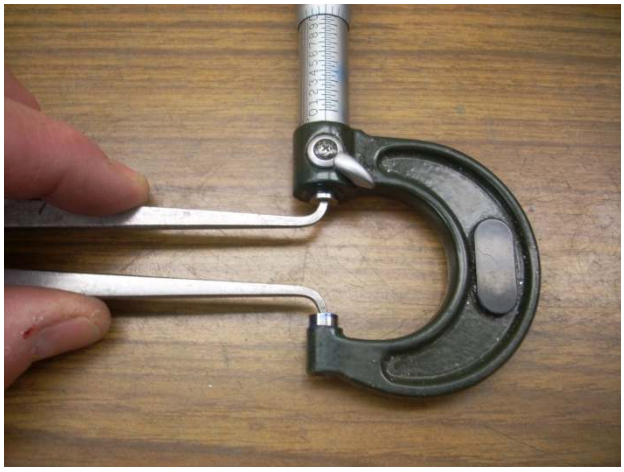


Adjust the outside caliper until it is a nice sliding fit on the inside caliper. If you get confused and adjust the inside caliper, return to the mic to set it again.

I show the calipers lying on my table but you should hold the outside caliper in your hand and may prop up the inside caliper such that you don't compress the jaws.

You have now transferred the measurement taken by the inside caliper to the outside caliper. This is hard to do accurately because the total contact surface is very small.

Crank in the inside caliper by about 1/16" and then widen it out again until it just contacts the outside caliper's tips. Move the two calipers around to verify the feel is right. Now open the mic up to around 1". Then move the inside caliper to the mic to measure the result.



The reading you get on the mic reflects the sum of a number of errors. There was error transferring the mic's opening to the inside caliper. Then we have the error transferring the inside caliper's opening to the outside caliper. This was followed by the error of using the inside caliper to read the outside caliper. And finally, we have the error associated with using the mic to read the inside caliper.

The problem with this test is that these errors can cancel. You might have lost a 0.001" going from mic to inside caliper and gained it back later.

Looking at the three instruments, I would say that it is likely that what is dialed in on the mic will not be effected by setting the inside caliper. Furthermore, the inside caliper error will always be reading large because it

easily compresses but can't expand beyond its set gap. It is squeezed into an opening but when removed, springs open to a larger value.

However, the outside caliper's jaws could deflect outward slightly even though the adjustment screw prevents it from opening. So it may read undersized.

So, let's see…

Inside caliper can read oversized.

Outside caliper can read undersized.

When using the outside caliper to measure the inside caliper, I don't know how the error will split.

When using the mic to measure the inside caliper, you again run the risk of compressing the caliper.

The bottom line here is that you could do this exercise and get an overall error close to zero yet have poor technique. Repeated passes should expose the truth.

## Put Up or Shut Up

Why would you believe what I have written if I don't show you ***my*** numbers? I set my mic to 1.000" because I know I have some range above this value. But otherwise, I have done what I said above. I wish I could convey the "feel" but that is something you will have to experience yourself.

### Mic to Inside Caliper Test

1. Set mic to 1.0000" and locked the spindle
2. Adjusted the inside caliper to fit the mic
3. Changed the mic to greater than 1"
4. Mic'd the inside caliper and got 1.0003"
5. Changed the mic to greater than 1"
6. Mic'd the inside caliper and got 1.0010"
7. Changed the mic to greater than 1"
8. Mic'd the inside caliper and got 1.0003"
9. Changed the mic to greater than 1"
10. Mic'd the inside caliper and got 1.0005"

11. Changed the mic to greater than 1”
12. Mic’d the inside caliper and got 1.0009”

Conclusion: The mic read 1.0006” +/- 0.0004”. It is possible that I set my inside caliper to 1.0006”. The important thing here is that I got +/- 0.0004” of variation trying to mic the inside caliper. With practice, I hope to reduce this error but think it unlikely.

### Mic to Inside Caliper to Outside Caliper to Inside Caliper to Mic Test

1. Set mic to 1.0000” and locked the spindle
2. Adjusted the inside caliper to fit the mic
3. Used the outside caliper to measure the inside caliper
4. Moved the inside caliper to be less than 1”
5. Used the inside caliper to measure the outside caliper
6. Used the mic to measure the inside caliper and read 1.0013”

Conclusion: Going the full circuit gave me a total error of 0.0013”. Clearly I need more practice!

## Advanced Studies

To gain more experience, you can take a smooth rod, measure it’s diameter with the outside caliper, transfer that dimension to the inside caliper and read it with your mic. Compare that value with the mic directly measuring the rod.

## Good Shop Practice

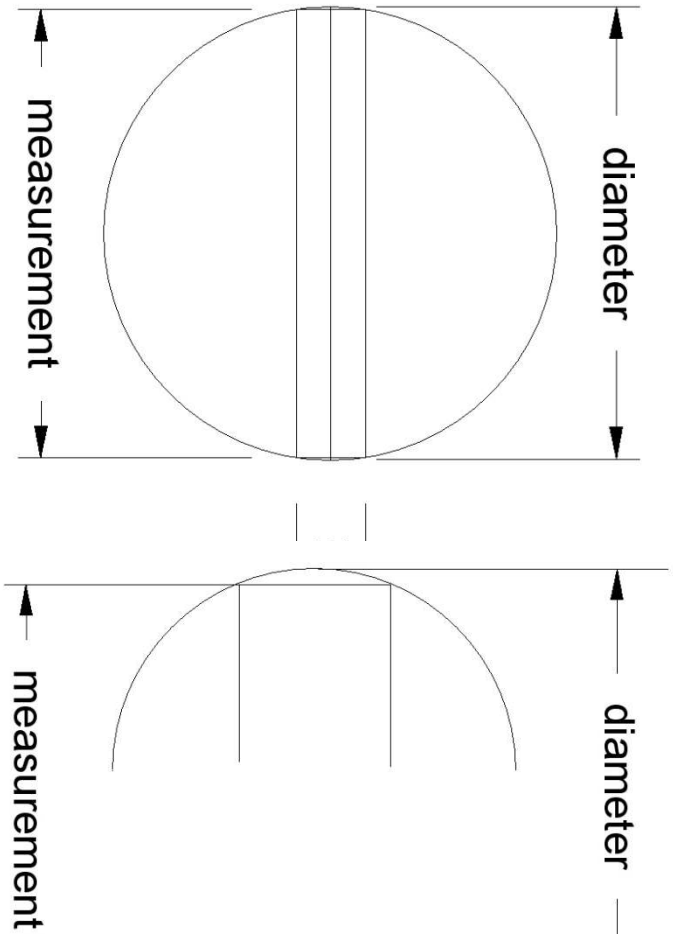
If a measurement matters to you and you plan to use a caliper, I suggest you spend a few minutes doing these exercises before counting on your skill. Professional welders spend a few minutes at the start of the day running a few beads just to re-capture their feel.

## Conclusion

I can’t tell you what precision to expect from a caliper. That depends entirely on your skill (except as noted on the next page). But with the above exercises, you should be able to both improve your skill and assess its limitations.

This article dealt with inside and outside calipers so I did not address errors associated with the mic. A mic has different error sources but most certainly requires a correct feel too. I'll leave this discussion to a later article.

## An Aside About Inside Caliper Error




I think I see an inherent error in using a square tip inside caliper to measure a hole. Our goal is to take a measurement and have it be the diameter. But let's take a closer look. You can see that the wider the caliper body, the larger the difference between actual diameter and the distance captured on the inside caliper.

If we converted the caliper measurement into a number, then we can calculate the diameter:

$$\text{diameter} = \sqrt{(measurement)^2 + w^2}$$

Of course the goal of using a caliper is to not have to convert it into a number so the user would incorrectly assume that the measurement is the diameter.

The error goes down as the measurement gets further away from the width, w. If we measured 1.000" and the caliper is 0.1" wide, then the diameter would actually be 1.005" which is a significant error. If we measured 5.000", then the error would

be only 0.001". One solution is to measure the bore with a telescoping bore gage and transfer this distance to an outside caliper.

## Acknowledgements

Thanks to EdwinB of the mill_drill Yahoo group for suggesting this topic. Thanks to Bob ("thunderclaw007") from this same group for explaining how he was taught to search out the high or low spot (see footnote on page 1). Thanks to Dave Patterson of gingery_machines Yahoo group for closely reading the article and seeing a misleading point (which has hopefully been corrected) plus the link to the article on repeatability, resolution and accuracy. Thanks to GlennN of mill_drill for the "advanced studies" entry.

## What's Next

Although this article was written for people new to our hobby, I do hope that experienced people read it too and can offer me suggestions on how to make it better. All of us are smarter than any one of us.

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