Accuracy and Repeatability of the Harbor Freight® Caliper

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June 1, 2007

Version 2

Executive Summary

The spec sheet for the Harbor Freight Caliper is discussed with respect to accuracy and repeatability.

Conclusion

It is *possible* that the accuracy of these calipers is better than a literal reading of the spec sheet indicates.

Key Reference

The following discussion refers to information found in the user manual supplied with each Harbor Freight caliper. You can view it on-line at http://www.harborfreight.com/manuals/47000-47999/47257.pdf

Repeatability

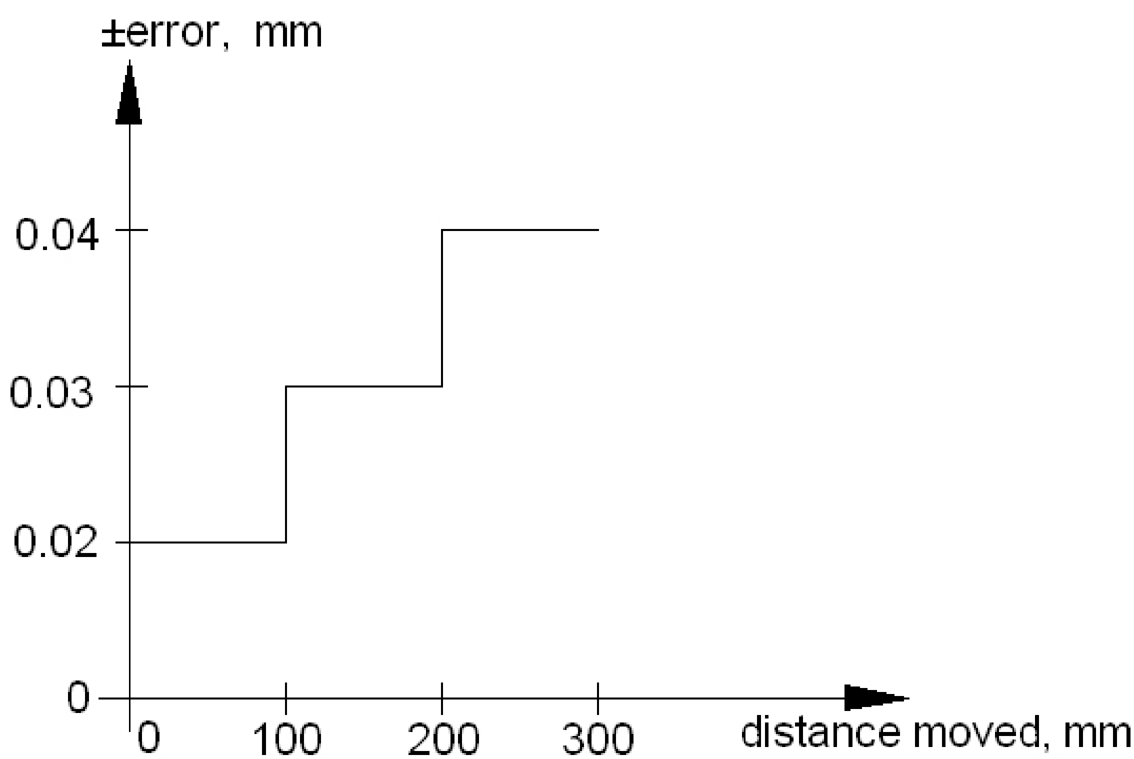
The spec essentially says that the caliper is repeatable to its smallest displacement indicator. In inches mode, that is to the nearest 0.0005". When in metric mode, it is 0.01 mm.

Accuracy

The spec sheet does a nice job of describing caliper accuracy. It uses metric to do it so I have chosen to stay with metric for most of this article.
The errors listed below are limits. The actual error can vary between ± these limits.

Error, mm	After moving a distance, mm
0.02	0 to 100
0.03	100 to 200
0.04	200 to 300

Graphing this information may provide more insight.

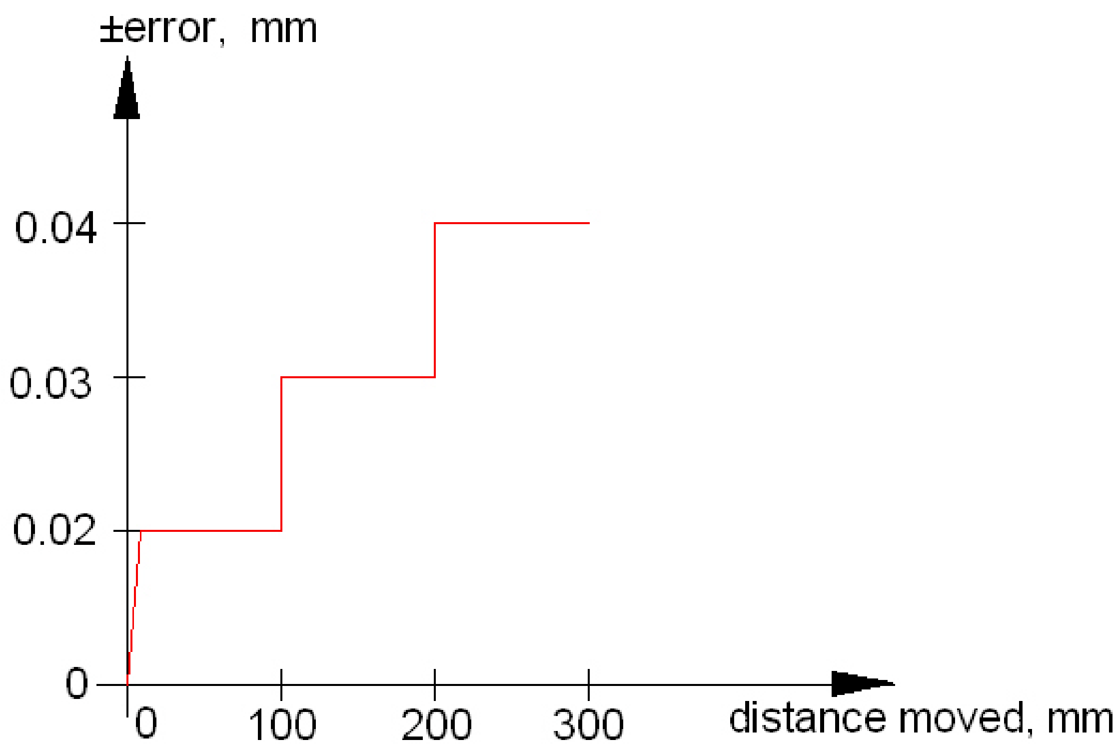


Between a distance moved of 0 and 100 mm, the actual error for a given caliper is bounded between ± 0.02 mm. When we move to between 100 and 200 mm, the actual error gets new boundaries of between ±0.03 mm.

The reasons behind these boundaries are beyond the scope of this article and beyond my present level of knowledge. However, there is clearly an error limit component that is a function of distance moved.

I do have a nagging, unresolved problem. Say I zero the caliper. This graph says that our caliper's display is showing a value that is within ± 0.02 mm of the exact position. That makes no sense to me since by pushing the button I have defined my present position with no error. How do we respect the manufacturer's spec yet square it with this observation? I will try to bracket the answer.

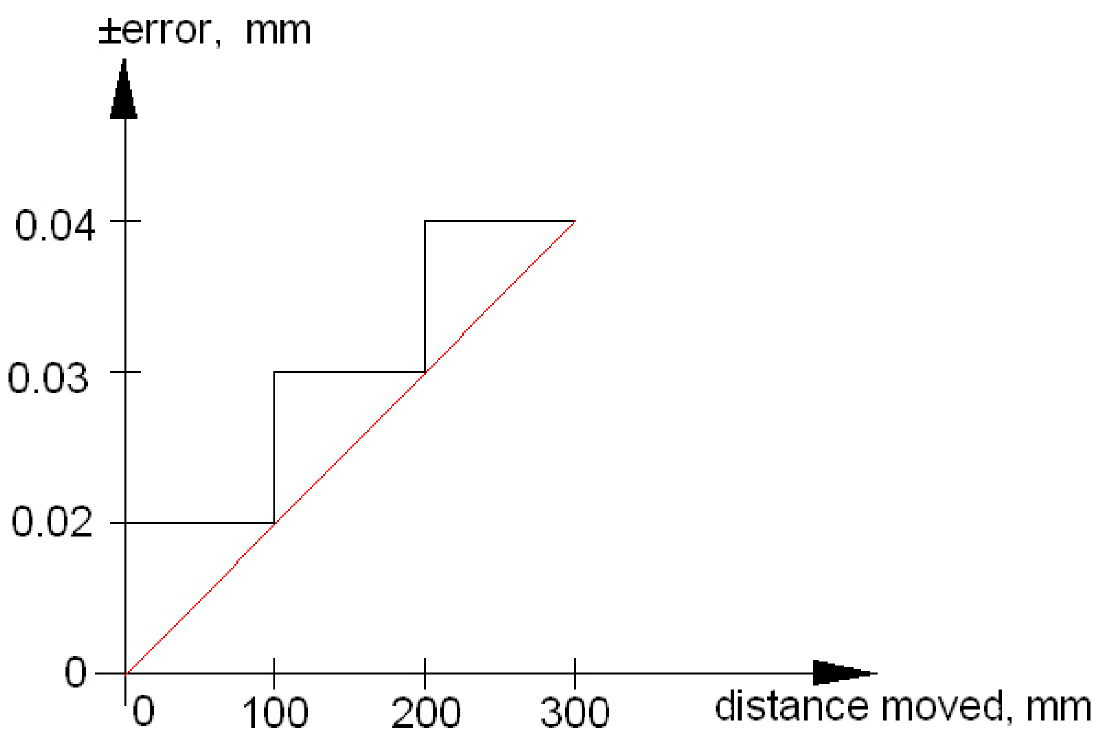
Consider the *pessimistic* interpretation of the spec first.



In this graph we begrudgingly accept that the error must be zero after a zero set. But once we get off that point, the error limit must rise quickly to the specified value. For argument sake, say as we move from 0 to 0.02 mm, the error limit rises from 0 to 0.02 mm. Further movement incurs no additional rise in the error limit. This fast rise to full error limit lets us be consistent with the spec as best we can given that we know there is no error after a zero set and no caliper motion.

I have a real problem with this interpretation when I go back to the original spec. Looking at only the error limit corresponding to movements of 100, 200, and 300 mm, the error limit increases linearly. The error limit is proportional to distance, *not* where we are on the scale. So if I happened to do a zero set at a point on the scale that had a change in error from 0 to 0.02 mm in a very short distance, what made me so unlucky?

Now on to an *optimistic* explanation of this situation: the error is really better than claimed in the spec.



The red line resolves my problem at zero set since it shows no error without movement. Although it does hit the spec at each point, it only does so at the bottom of the error limit band. For example, the spec says that between a movement of 100 and 200 mm, the error should be bounded by ±0.03 mm. Yet the red line shows us reaching ±0.03 mm only at the end of this range. Since we are in the optimistic section of the article, that is OK. After all, we do know that the error limit increase with distance so why would it start off rising quickly and then level off?

The red line shown above can be represented by the simple equation:

$$\pm\text{Error} = (\text{distance moved})/(5000)$$

Funny thing here, the equation is correct for both metric and inches. In hindsight, that does make sense because the slope of the line is a pure number. The units for "distance moved" must be the same as for Error.

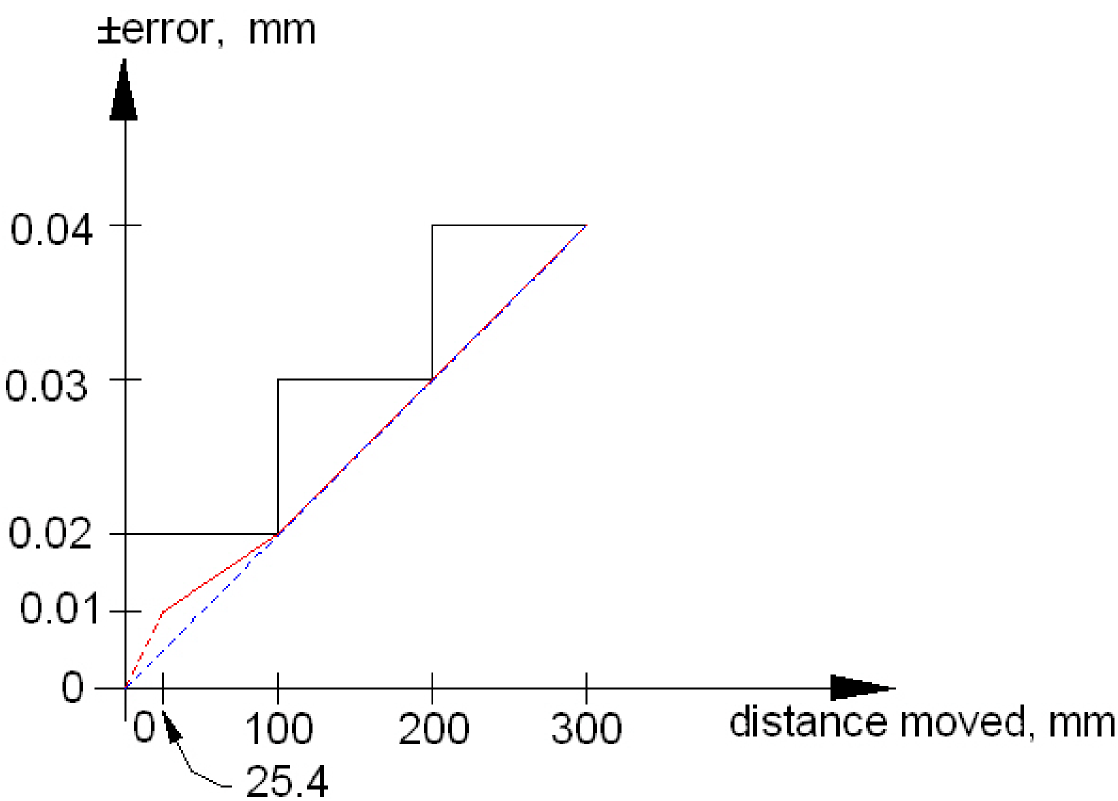
What does this equation tell us?

- If we set zero and move 0.005", the error will be too small to see. Sounds a bit fishy to me.
- If we set zero and move 0.500", the error will be ± 0.0001". Could that be true?

Sounds like trouble to me. My gut tells me that the error can't be this small as we are in the neighborhood of 0. Fortunately, I have some real data to breathe a bit of reality into this rosy picture. This data came from my "Jitter Bug" article.

- If we set zero and move 1.000", the error limit will be ±0.0002" according to the equation. I measured an error of 0.0005" after avoiding the software bug. So my measured error was 3 tenths *outside* of the limit.
- If we set zero and move 2.000", the error limit will be ±0.0004"" according to the equation. I measured an error of 0.0004". That puts me right on the hairy edge of the limit which is not good.
- If we set zero and move 3.000", the error limit will be ±0.0006" according to the equation. I measured an error of 0. Luck? Most likely.

Based on the above real data, consider this possible model of reality for our error equation.



The dashed blue line shows the original optimistic curve. The red line follows the optimistic line down from 300 mm but takes a new heading below 100 mm. Our existence proof says we saw an error of 0.01 mm at 25.4 mm of movement so the line bends to hit that point. This is still optimistic since it says I just happen to hit the error limit boundary. The truth is that the error limit at 25.4 mm is between 0.01 mm and 0.02 mm.

We can then say that-

When zero is set:

> There is no error.

For distances moved greater than 0 but less than 25.4 mm (1"):

> Don't know yet but you can say ±0.02 mm and be safe.

For distances moved greater than 25.4 mm (1") but less than 100 mm (4"):

> Play it safe and say ±0.02 mm or follow the red line:
>
> ±Error = {(distance moved)/(7460)} + 0.007 mm

±Error = {(distance moved)/(7460)} + 0.0003 inches

For distances moved greater than 100 mm (4"):

±Error = (distance moved)/(5000)   mm or inches

Our one data point at 25.4 mm (1") proves the error does *not* follow the dashed blue line. Our spec says the error could be as bad as 0.02 mm and still be acceptable. So the truth should be between these points. It is equally possible that the data at 50.8 mm (2") and 76.2 mm (3") could have shown more error. The fact that they agree with my speculation does not prove anything.

Temperature effects

A test was run to see how temperature effects these calipers.

The caliper was put in the fridge overnight and sat at 40°F. The pair of 1-2-3 blocks were bolted end to end and sat at a room temperature of 80°F. The cold caliper was used to measure the warm blocks and I saw 6.0005".

Next the blocks sat in the fridge for 4 hours. The caliper was at room temperature and was again used to measure the blocks. The warm caliper on the cold block read 5.9995".

In the first test, the caliper was cold so would contract. This would produce a measurement on the high side and we got that. In the second test, the block was cold so it would contract. This would produce a measurement on the low side and we got that too.

The fact that the first test produced an error equal in magnitude to the second test implies that there is no temperature compensation in these calipers. If cooling the blocks caused an error much greater than when the caliper was cooled, it would imply that there was temperature compensation.

This demonstrates that a 40°F change in the shop acting on a 6" block can cause a 0.0005" error. At least in my shop the change is around ± 2°F so is not an issue.

What Next?

This article will only improve if member of the hobbyist community send in their questions, comments, and most importantly, challenges. I welcome these inputs. All of us are smarter than any one of us.

Thanks go out to Paul Alciatore of the Home Shop Machinist BBS, and Chris of the Shumatech Yahoo group for their contributions to this effort.

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