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Effects of Temperature on Dimensional Gages

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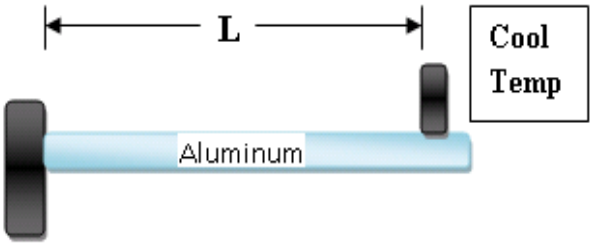

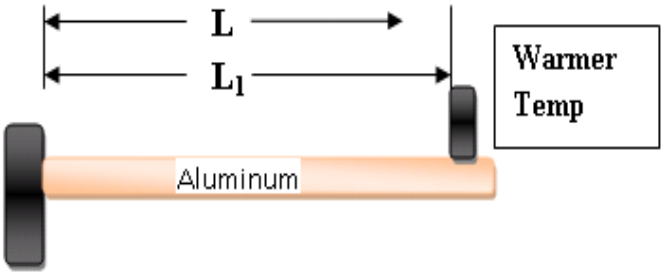

Thermal Expansion of Steel

"Soaking" Dimensional Gages

The 'While you Wait" expedite policy at Tangent Labs allows us to immediately provide calibrations when someone drops by the lab and waits on their gages to be calibrated. While many customers enjoy this quick and urgent service, there are some gages that cannot be calibrated immediately. These gages are typically dimensional in nature--Calipers, micrometers, pin sets, end measuring rods, gage blocks, plugs, and ring gages are just a few dimensional items that need time to "soak" in a temperature controlled lab before they are accurately calibrated. Soaking a gage means letting it acclimate to the temperature of a room or a lab. While this may not make sense at first, a little knowledge of what happens to materials at different temperatures will help make this issue become clearer.

Problem Statement

All dimensional gage materials have a specific attribute to them called a Thermal Expansion Coefficient. That's an impressive technical term that simply means materials expand or grow a certain length when heated, and contract or shrink when cooled. The two pictures of aluminum on the left illustrate this point. Assuming it's measured with an accurate enough piece of equipment, aluminum that is acclimated in a cold environment will measure shorter than that same piece of aluminum acclimated to a hotter environment.

To the naked eye this difference is negligible. Even when performing certain measurements the difference is negligible. If you're building a deck in winter or building it in summer and you use a standard tape measure to make the measurements, the deck will look the same and there won't be any dissimilarity. That's because those are considered non temperature-critical measurements.

Laboratory Acclimation

In the case of pin sets, micrometers, or calipers, the soak time is much less than it is for gage blocks, plugs, or rings. That is because of the difference in accuracy and amount of steel. A typical digital caliper can have an accuracy of ±0.001" and a typical digital micrometer can have an accuracy of ±0.0001". The measuring surfaces on those two types of instruments are more often than not steel. When talking about those kinds of accuracies, the expansion or contraction of steel is still a vital contributor to the accuracy of the measurement, but the effects become negligible after 2-4 hours of laboratory acclimation. That is partially due to the smaller amount of steel that is on the measuring surfaces, and partially due to their accuracies.

When talking about gage blocks, plug gages, ring gages, and other more accurate and thicker dimensional gages, the acclimation time becomes much higher and much more critical. The standard soak time for these types of gages is 24 hours. Ceramic gages take about twice as long to acclimate, so those gages can be left to acclimate up to 48 hours. Depending on the grade, a typical 1" steel gage block can have a tolerance from ±0.000003" to ±0.000024". Those types of accuracies require a tightly controlled temperature environment.

Standard dimensional laboratory calibration temperature is 20 °C (68 °F). This is the temperature that gage blocks and other more accurate gages are calibrated at when they are manufactured. In a dimensional lab environment all possible sources of heat must be neutralized. Human body heat, human breathing, human hand heat, heat from electronics, and heat from room lighting all have to be considered and eliminated from the measurement.

Thermal Expansion Example

So just how much does a gage block expand per degree? Let's look at a 1" and a 2" gage block example. The official equation for change in length per 1°F is:

$$\Delta L = (\text{block length}) \times (\text{thermal expansion coefficient } t)$$

The thermal expansion of a steel gage block is 6.4 ppm/°F. The thermal expansion of a ceramic gage block is 5.5 ppm/°F.

That means that for every 1°F of temperature increase those blocks experience, a 1" steel gage block will grow 6.4 µin, and a 1" ceramic gage block will grow 5.5 µin. For a 2" block, a 1°F temperature increase will make a steel block grow 12.8 µin and a ceramic block will grow 11 µin!!!

As was stated before, the naked eye will never visibly see this increase. But when applying µin tolerances, one degree can be the difference in a block passing or failing.

Summary

With Tangent Labs' valuable "While You Wait" policy it's important to understand why some gages have to be acclimated to a lab temperature and why others can be done immediately. And with the ability to calibrate most anything on-site at any time, often times Tangent Labs is asked to calibrate very temperature-critical gages onsite. A short explanation of the thermal expansion of materials helps customers better understand the reason why Tangent Labs requires that these gages be calibrated in the lab.