Hot Topic – Electrical Calibration

There are generally two kinds of calibration: electrical and chemical. The electrical brings your instrument into agreement with the NIST values for millivoltage conversions which changes the analog thermal couple signal into digital form. The Chemical calibration brings the chemistry/microstructure equations into agreement with the findings of the Lab. This month's eLetter will take on the first issue – electrical calibration. The other issue will be addressed next month.

Why

The electrical circuits that measure voltage are complex but basically, a capacitor is charged at a constant rate, which causes the voltage to rise on the capacitor in a linear mode over time. The unknown voltage is compared with this voltage on the capacitor until they are equal. Then, the convertor works the math to figure out the unknown voltage. For example, if the capacitor charges at the rate of 0.001 volts per time cycle, and the voltages match at 534 cycles, then the unknown voltage is 0.534 volts.

There are lots of issues with this kind of circuit. Capacitors are only linear over a short range of less than half their normal rating, i.e. a 10 volt capacitor is linear only up to about 5 volts. The time cycle has to be very fast to measure to 4 decimal points in 1/10 of a second, and resistors are used to adjust the unknown voltage into a range acceptable to the circuit. The MeltLab converter has ranges of +/- 15 mV, +/- 50 mV, +/- 100 mV, +/- 500 mV, +/- 1 Volt, +/- 5 Volt. We use the 50 millivolts range, which can range up to 55 millivolts with lesser accuracy.

So what makes calibration necessary? First your thermal couple wiring has some resistance, so there is a slight voltage drop from the thermal couple to the converter box. Multiple junctions in the wire also add to the resistance of the circuit. So, to get the most accurate reading, we need to offset our voltage calculation to compensate for the wiring. Second, there may also be variation in the conversion circuit due to aging of the electrical components. The transistors that do these circuits are made by doping the metal with certain elements. These elements will continue to diffuse through the transister over time. Although this is a very slow process, there is a distinct change in amplification over the period of years. Your Spectrometer has the same problem, and should be not only standardized every day, but also recalibrated every few years to compensate for amplifier aging.

How

You will take an instrument called a calibrator and apply the output signal to the rails on your thermal couple stand while the MeltLab is in thermal couple calibration mode. The program will continuously read the signal, and calculate a standard deviation on the last 100, readings which is about 11 seconds worth of data. If the average temperature is within +/- 20˚C of the set temperature, and the standard deviation is within the required value[1], the system will lock on the value. You will then have the option to either redo the calibration, or to accept and save the values.

Secrets

There are a lot of little secrets to getting a great calibration.

- Calibrators are not all equal. The good ones can cost over $1,000. This might be a reason to employ an outside firm to do your calibrations. The components of good calibrators are expensive, highly accurate resistors and amplifiers.
- Certifications on the calibrators also need to be renewed every year. These calibrations can also be poorly done. The National Institute of Standards Testing (NIST) allows a calibrator to be certified if it is within 2 degrees F or 1 degree C. Modern technology allows a much more accurate adjustment to calibrators, and a deviation of 0.1 degrees is possible with a good calibrator. We encourage you to ask for the exact value the calibrating technician got at the temperatures you use. For example: if you calibrate at 2150˚F. the technician should check your instrument and report what your instrument actually outputs at 2150, such as 2150.87. You can then tell the MeltLab program that you will be calibrating at 2150.87 degrees F and remove another source of error.
- Batteries are not all the same. First, you should always have a good strong battery in your calibrator. And, you should always use the same brand and type of battery. You have seen all the commercials pushing the different kinds of batteries. There are slight differences and those differences result in a different output voltage. We have found 5 volt batteries ranging from 4.95 to 5.15 volts in the “new” condition but varying by manufacturer. The variation within one type of battery from the same manufacturer is much smaller providing they have not been in storage a long time. We use Duracell, but choose your preferred supplier and stick with it. Rechargeable batteries are not a good idea for calibrators because their output voltage goes down over their lifetime.
- Your calibrator needs to be the same temperature as your cup stand. Let your calibrator sit out in the foundry for at least 30 minutes to come to temperature. I check this by calibrating a stand, waiting for a few minutes and then recalibrating the stand. When the calibrated correction value found keeps moving in one direction, then you either have a weak battery or your calibrator has not stabilized its temperature yet. When the calibrated correction starts bouncing back and forth, you are done. When the movement is less than 0.05 degrees in several minutes, you have a good calibration.
- A great system will have a correction of less than 3 degrees C or 5 degrees F. This is due to your wiring and the connections minimizing resistance, and the wiring shielding not picking up radiated energy.

Frequency

Demming stressed that at times less is better. Constant recalibration adds noise to the system and increases variability, because frequency decreases the care and time we take with the calibration. You should recalibrate your MeltLab electrical calibration once or twice a year, based on experience. If the calibration doesn’t change much every 6 months, you can go to a lower frequency of calibration. ISO generally requires a minimum of yearly calibrations. You should also recalibrate for any “assignable causes”. An assignable cause is a change to the system that could be reasonably expected to change the calibration. Rewiring your thermal couple wiring runs, a fire, or replacing a module would fall under assignable causes. Changing a stand head is a very minor change, and I don’t recommend a calibration for that cause.

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Other sources of problems

I alluded to the problem of electromagnetic radiation being picked up by unshielded wiring. Foundries have lots of spare electricity running around. I once saw a melter lay his temperature pole against the furnace railing and generate a significant spark – it happens: furnace magnetism induces electricity in all the metal around the inductor. The only way to prevent that energy from affecting the MeltLab instrument is to shield it. Other manufacturer's instruments may not be so affected, but, in order for MeltLab to attain the highest accuracy we could, the circuitry has 10 million ohms resistance, which means it is working off of less than 1 millionth of an amp of power. Shielding is the price you pay for high precision.

Thermal couple wiring is made from ingots made in foundries, and that means some variation in chemistry. All good cup manufacturers use two levels of quality control: special limits wire, and a system called wire matching. In the first, they pay a premium to buy only wire that is within 1 degree C or 2 degrees F of nominal as generally tested at 1000˚ C. In the second, they match a positive coil of wire with a negative coil of wire so that the differences from nominal are minimized, i.e. they take a coil of wire that is say +0.018 millivolts from nominal, and match it with a coil that is – 0.022 millivolts from nominal. Summing the errors we get -0.004 from nominal: a great improvement. Not every match is that good, and the improvement is not completely linear over the temperature range. Variations between batches of cups do cause problems with silicon values jumping suddenly. We have added a Wire Bias value in MeltLab to correct for the difference from nominal, and in our experiments, it seems to reduce variation from batch to batch of cups by 90%. Minco and Matrix report their bias numbers on their boxes. ElectroNite has in the past reported their bias numbers to some customers but does not include it on their boxes to my knowledge (please change this[2]).

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[1] Calibration settings in terms of standard deviation
Very Tight implies < 0.005˚ C standard deviation – suitable for lab research
Normal implies < 0.015˚ C standard deviation – suitable for a premium installation
Medium implies < 0.030˚ C standard deviation – suitable for a normal installation
Relaxed implies < 0.050˚ C standard deviation – for an installation having troubles
Loose implies < 0.150˚ C standard deviation – for a temporary situation that needs fixing

[2] We know our competitors receive our eLetters and read everything they can that comes from us. They are constantly the highest click rate readers. They will probably have an internal meeting on this eLetter lol.