How Do I Compute Total Uncertainty When Using a Dry-Well Calibrator?

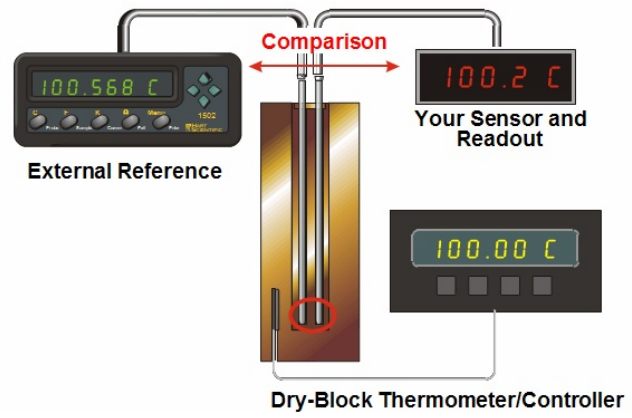
By Chris Juchau, Vice President

The calibration of a temperature sensor involves placing the sensor into a stable temperature environment, measuring the temperature of that environment with a reference thermometer, and comparing the reading
from the reference thermometer to the reading of the sensor under test. Due to imperfect measurements of the reference thermometer and temperature gradients between the reference thermometer and the sensor under test, the actual temperature at the location of the test sensor can be estimated only within a stated uncertainty. The lower this uncertainty, the better the quality of the calibration.

How we estimate our uncertainty depends on how the heat source is used. For dry-well calibrators, two methods are common—using an external reference thermometer or relying on the dry-well's internal control sensor. Each system offers a different set of uncertainty sources to consider, though many sources are common to both methods. What follows is a list of the key sources of uncertainty for each system.

Using an External Reference Thermometer and Its Readout

No matter how good a reference thermometer we use or the device that reads it, no system yields
perfect measurements. Thermometers drift, uncertainty exists in their own calibrations, readouts rely on unstable electronic components, and the references used by readout devices (such as standard resistors) change with time. Uncertainties should be estimated for the reference thermometer, its readout, and any references used by the readout.



Temperature Gradients between Thermometers

Having accounted for the uncertainty in the reference thermometer, the fact remains that the
reference thermometer and the test sensor are not in the exact same place at the same time. Likely they are in two different wells, with a slight temperature difference between the wells. Further, unless both sensors have identical construction and are inserted to exactly the same depth, vertical gradients must be accounted for.

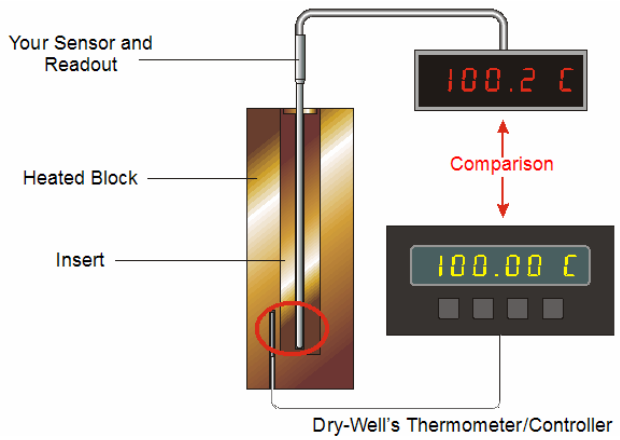
Even the heat-sinking effect that results from the construction of certain test sensors or from loading a dry-well with many test sensors simultaneously can alter the temperature within portions of the block. The magnitude of these types of uncertainties can be estimated by the manufacturer, but is best ascertained within a user's own lab under conditions typical for that user.

Dry-Well Stability

The quantification of a heat source's stability is simple and does not even require a calibrated thermometer. Two things should be mentioned here, however. First, temperature blocks often require more time to reach optimum stability than their built-in displays indicate. And second, the length of time that should be considered in a stability test varies with the length of time required by a particular user to complete a measurement cycle and with the time constant of the dry-well.

Using an Internal Reference Dry-Well Display Accuracy

In concept, an internal reference is the same as an external reference. Both a thermometer and readout device are still involved. The difference exists in how they're calibrated and in the fact that internal systems are not as accurate as good external systems. Most dry-wells come factory calibrated (and can be recalibrated periodically using an external thermometer to calibrate the internal thermometer) with a quantified uncertainty value, which should take into account the resolution of the dry-well's display.



Temperature Gradients between Thermometers

The display accuracy of the dry-well includes the temperature difference between the location of the control sensor and the location of the external thermometer that was used to calibrate the dry-well. But unless the construction of the sensor you're testing is identical to that of the thermometer used to calibrate the dry-well and unless it's placed in the same well at the same depth as the calibrating thermometer, the same types of gradient issues are involved as with an external reference.

Dry-Well Stability

Short-term stability issues (typically 30 minutes or less) are the same as with external references. However, long-term drift issues that can occur to the control sensor between calibrations must now be considered. This is most easily quantified by recalibrating the dry-well periodically and charting its drift patterns under typical usage conditions.

Dry-Well Hysteresis

Without a reference thermometer, the hysteresis of the dry-well must be considered, though in many cases it will already be factored into the calibration uncertainty of the dry-well's display.

Conclusion

The largest errors in calibrations using dry-wells often come from misuse. Poor fit of test thermometers in wells, insufficient thermometer immersion, inadequate stabilization time, and a host of other blunders can render an uncertainty analysis of a dry-well calibration virtually meaningless. It's important to use a dry-well as specified by its manufacturer.

It's also important to recognize the limitations of dry-wells and to use fluid baths or other heat sources when they are more appropriate and yield much better results. Recently the EA (European Co-operation for Accreditation) published their reference EA-10/13, "EA Guidelines on the Calibration of Temperature Block Calibrators," which discusses the testing and calibration of dry-well calibrators and the major sources of uncertainty that should be considered when so doing. EA-10/13 also serves as an excellent reference document for users of dry well calibrators to ensure that all sources of errors are understood allowing the user to define robust procedures to minimize error and maximize quality of calibration work undertaken.

Further, a new class of dry heat sources, called Metrology Wells, are now available which incorporate new design philosophies such as dual zone heater control. Fully published specifications defining performance against key EA-10/13 considerations enable the user to quickly evaluate the suitability of the product against the required system uncertainty.

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