Selecting an industrial temperature calibrator

Dozens of dry-well manufacturers around the world are producing hundreds of different models of dry-wells. How do you know which will perform best and which is best suited for your work? Here are ten important things to keep in mind.

Understand your needs

The remaining nine items will be pretty worthless to you without this one. Dry-wells have many characteristics. For you to know which ones will be most important to you, you need to understand how you intend to use your dry-well.

Will it be in a lab environment or in the field? What temperatures will you need? What kind of throughput do you need? Do you want to maximize throughput through speed or through capacity? How accurate are the thermometers you'll be testing in your dry-well—i.e. how accurate does your dry-well need to be? Will you rely on the dry-well's display for a reference or will you use an external thermometer? How long are the thermometers you'll be placing inside the dry-well? Will you be calibrating short or odd-shaped sensors that are better served in a liquid bath? Will you wish to automate your dry-well calibrations? Et cetera.

Temperature range

Ideally, your dry-wells cover all temperatures at which your thermometers need to be calibrated—with a little room to spare. If you have too much room to spare, you're probably over-spending. Be careful when evaluating low-limit specifications. "–40 °C" is not the same as "–40 °C below ambient."

Reliability

The more frequently you run your dry-well from one extreme end of its temperature range to the other, the shorter the life of your dry-well will be. This is especially true for "cold" dry-wells, which rely on thermo-electric cooling. The life of those devices is shortened by extreme cycling and by excessive use at the high end of the dry-well's range. If your application would require either of these usage patterns, consider an additional unit for high temperatures—or buy the extended warranty option.

Watch for blocks and inserts made from degradable material. Copper, for example, has great thermal properties—except that copper inserts oxidize rapidly and flake apart as a result of thermal history at extreme temperatures.

A large variety of dry-well calibrators from which to choose may make finding the right one for your applications and use a little overwhelming. Read this article and find out what you should be considering for your next calibrator purchase.

Accuracy

Four things to know here. First, the internal control sensor in your dry-well (which feeds your dry-well's display) is fairly inexpensive and does not have the robust performance characteristics of a good reference thermistor or PRT (or noble-metal thermocouple, as the case may be). If it's an RTD (most are), it's subject to shift from mechanical shock and may exhibit poor hysteresis. On the other hand, it may be perfectly adequate for your application.

Second, the control sensor and display system were probably calibrated against a high-quality PRT. However, that PRT was inserted into a particular well at a particular depth and contains a particular sensor construction. The specific thermal and mechanical characteristics of that PRT (sensor length, sensor location, lead-wire conductivity, etc.) were essentially "calibrated into" your dry-well. So, unless you're calibrating an identically-constructed sensor inserted in the same place as the one that calibrated your dry-well, the accuracy of your display may not be quite what you think it is.

Third, external references are generally more accurate than internal references. External probes share with probes under test a more common "point of view" of a block's temperature than does the internal control sensor. But beware of built-in electronics for external reference sensors and how they are specified. Many have poor resolution and do not accept calibration constants for specific reference thermometers. Be sure also to consider both the reference probe and the electronics that read it. A dry-well that has built-in electronics is probably only specifying the accuracy of reading the probe—not of the probe itself.

Fourth, there's a lot more to accuracy than the calibrated internal sensor or a calibrated external reference. You also need to consider—depending on your particular use of the dry-well—the next five items below (stability, axial gradients, radial gradients, loading effects, and hysteresis).

Stability

The European Association of National Metrology Institutes, in their document EURAMET/Cg-13/V.01, defines "stability" as temperature variation "over a 30-minute period." Be careful not to over-rely on your dry-well's display to indicate stability. The resolution of the display and the filtering techniques it uses may limit its ability to show instability. And the stability of the control sensor has limited

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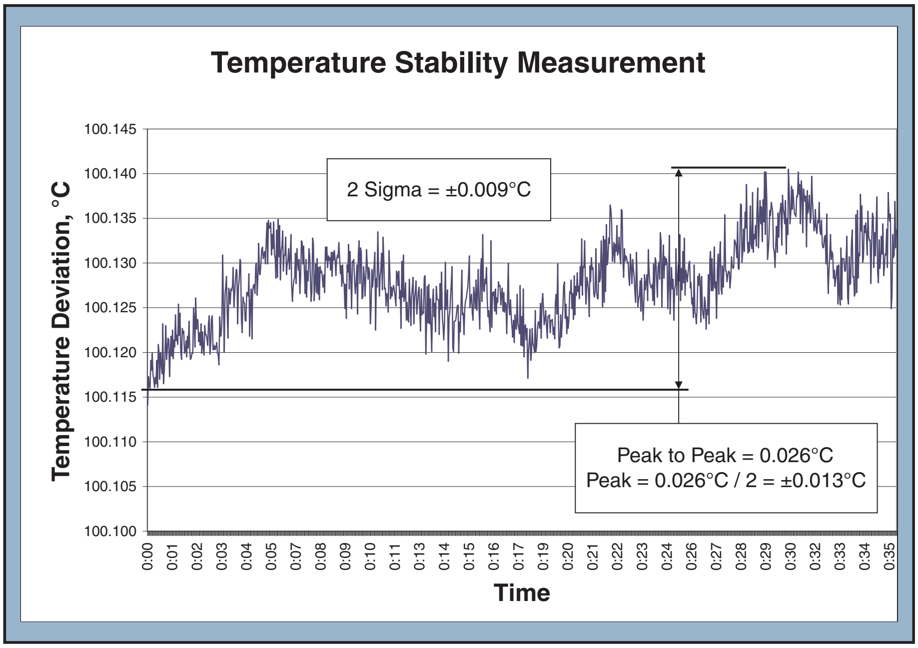


Don't be afraid to ask for stability information and documentation to help in your decision making.

relevance to the stability at the bottom of whatever well you're using.

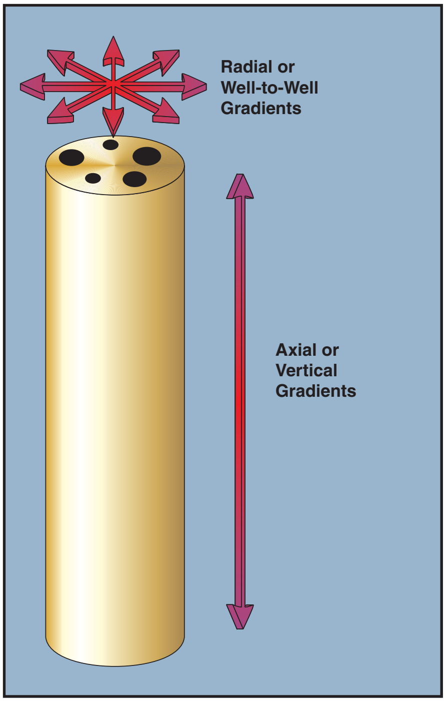
Also, remember that long-term stability or "drift," in the control sensor requires the dry-well's display to be periodically re-calibrated. How long should you wait between re-calibrations? That depends on the dry-well and how it is used. The best advice is to start with short calibration intervals (3-6 months) and then to lengthen the intervals as the dry-well demonstrates ability to "hold" its calibration.

Axial (or "vertical") gradients (sweet spots)

Because the top end of a dry-well is directly (or most closely) exposed to the ambient environment, the temperature at that end of the dry-well is closer to ambient temperature and less stable than is the bottom end of the well. It's just physics.

According to EA guidelines, dry-wells should have a "zone of sufficient temperature homogeneity of at least 40 mm (1.5 in) in length." Axial gradients create significant problems when comparing two probes inserted to different depths (should be avoided!), when comparing two probes at the same depth but with different sensor constructions, and when comparing to the displayed temperature a probe which is at a different depth or of a different construction than the probe used to calibrate the display.

Axial gradients can be minimized through design techniques such as block mass and depth, insulation, multiple-zone controlling, and use of profiled or imbalanced heating. It can also be



Axial and radial gradients are important considerations in your calibration process.

measured, though it is difficult to separate a measurement of vertical gradients from the stem effects inherent in the probe making the measurements.

Radial (or "well-to-well") gradients

Radial gradients limit the usefulness of comparing a probe in one well to a probe in another well. While the control sensor of the dry-well is measuring temperature at one fixed location, temperatures may vary within different measuring wells due to variations in the distances between wells and heaters and in variations in hole patterns and how heat flows into and around those holes. In some cases, the temperature in a specific well may even differ depending on how the insert is rotated within the block. (To make sure we all understand terms the same way, "block" refers to the fixed mass of metal, usually containing or surrounded by heating elements; "insert" refers to a metal mass that is removable from the fixed block; and "well" or "hole" refers to the boring in either the insert or the well into which thermometers are introduced.)

To further complicate things, it is difficult to compare a probe of one diameter in one well against a probe of another diameter in another well. Probes with more thermal conductivity draw more influence from the ambient environment into the block. For that reason alone, large-diameter probes (10 mm [3/8 in] in diameter) are often ill-suited for calibration in dry-wells.

Loading effects

Speaking of heat draw (or "heat suck" as we call it in Utah), the more probes that are inserted into a dry-well, the more heat that will be drawn away from or into the dry-well, depending on its temperature relative to ambient. The displays of dry-wells are typically calibrated when loaded with the one probe that is calibrating it. Adding more probes may cause a larger difference between the control sensor and any one of the probes inside the block. Such effects are easily measured by adding probes and noting the change in reading to the first probe. Design characteristics of dry-wells (block mass, well depth, insulation, and multiple-zone temperature control) can minimize loading effects, as can the use of small-diameter probes. The deeper a probe is inserted into a dry-well, the better also.

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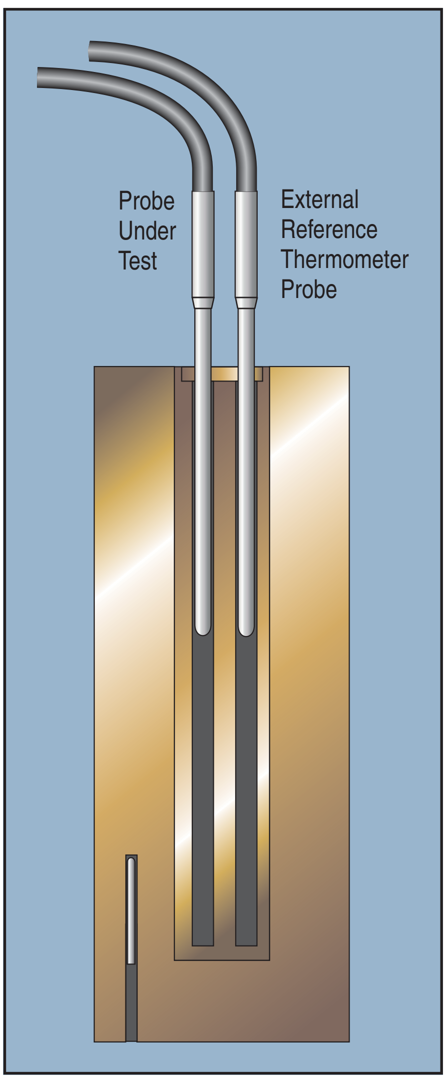
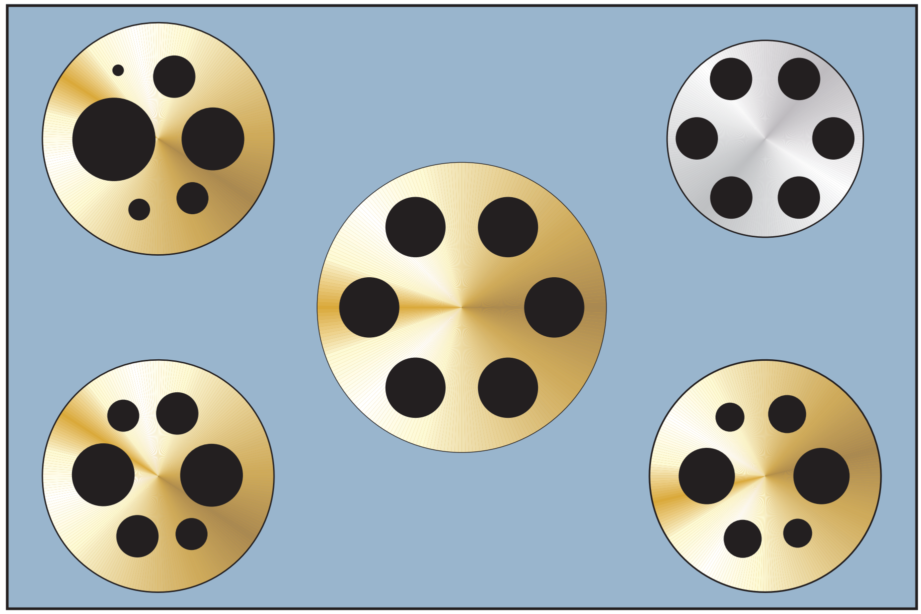
Hysteresis

Hysteresis is the difference in a dry-well's actual temperature resulting from the direction from which that temperature was approached. It is greatest at the mid-point of a dry-well's range. For example, a dry-well with a range of 35 °C to 600 °C will have a different temperature at 300 °C when 300 °C was approached from a colder temperature than when 300 °C was approached from a higher temperature. It is a characteristic of the internal control sensor used in the dry-well. The impact of this is eliminated when comparing a test probe to a reference probe, but should be understood when comparing against the unit's calibrated display.



Maximum accuracy for short probes can be obtained by comparing to a similar probe at the same well depth.



The availability of a variety of blocks or inserts can enhance the flexibility of your calibrator and allow for multiple calibrations at one time.

Immersion depth

Probe immersion errors (or "stem conduction" errors) can be huge. They vary not only with the dry-well, but with the probe being placed in the dry-well. Different probes utilize different designs and construction techniques, including the size and location of the sensor within the probe assembly and the type and size of the lead wires used in the probe. Therefore different probes have different immersion characteristics. These characteristics can be tested by noting the change in readings from a probe at various depths within the same temperature.

Generally speaking, deeper wells do a better job of eliminating the "stem effects" in probes due to inadequate immersion. Separate "top zone" temperature control of a dry-well also helps minimize stem effect. If you use probes that are too short to adequately reach the homogeneous measurement zone (usually at the bottom) of the dry-well, consider using a bath instead. At a minimum, be sure to compare it to another probe inserted to the same depth in another well. (See illustration at left)

Flexibility

Speed issues aside at the moment, the most "flexible" dry-wells provide for a removable, multi-hole insert. Multi-hole inserts can accommodate larger numbers of probes of varying sizes. Be sure when considering the number of wells in a block and the spacing between them, to consider the size of the hubs or handles of the probes that will be used inside the well. While it may appear that two probes can fit snugly near each other in a block or insert, their handles may actually get in the way of each other.

Functionality

Size, weight, speed, and capacity all involve important tradeoffs—against each other—and against many of the performance characteristics just described. For example, a large, deep thermal mass may provide the most capacity, least gradients, and best stability, but it probably won't be very small, light, or fast. Generally speaking, the fastest, lightest dry-wells provide the poorest performance. High speed and high stability are also difficult to get in the same block design.

This is why it's important to understand how your dry-well will be used and the characteristics of the probes you'll be calibrating in it. In the end, it's those probes you'll be calibrating which should make the decision for you as to whether to use a bath, a metrology well, or a field dry-well.