

Selecting an industrial temperature calibrator

Application Note

Dozens of dry-well manufacturers around the world are producing hundreds of different dry-well models. 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

Dry-well calibrators have many characteristics that can be challenging to understand. For you to know which characteristics 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 as a reference temperature 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.



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.

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, for example; “-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 span of your dry-well will be. This is especially true for “cold” dry-wells, which rely on thermoelectric cooling. The life span of these devices is shortened by extreme cycling and excessive

use at the maximum temperature of the dry-well's range. If your application requires either of these usage modes, consider an additional unit for high temperatures.

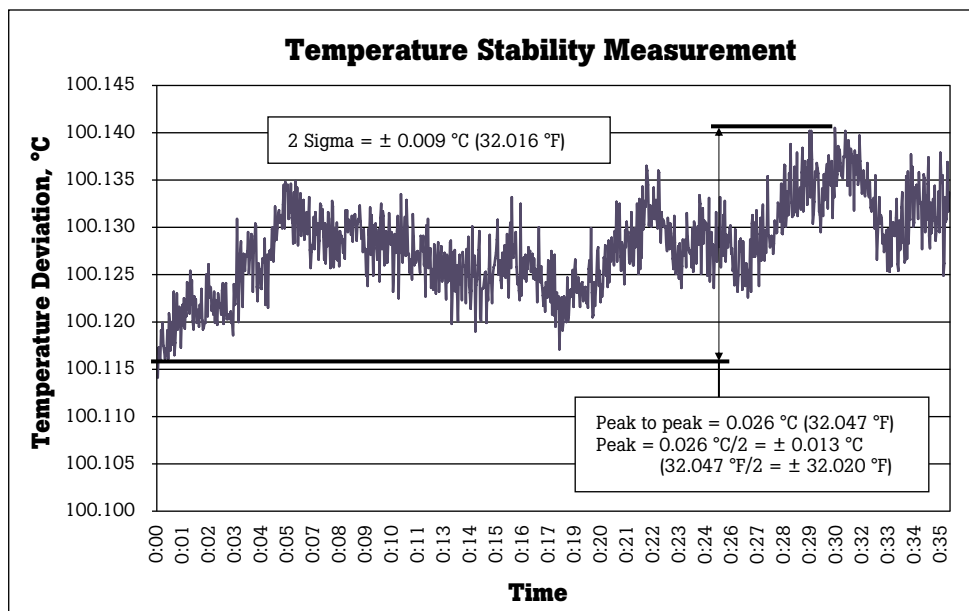
Watch for blocks and inserts made from degradable material. Copper, for example, has great thermal properties, but can oxidize rapidly and flake apart as a result of thermal history at extreme temperatures.

Accuracy

There are four things you should understand about dry-well accuracy. 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 reference PRT. However, the reference PRT was inserted into a particular well, at a particular depth, and has a particular sensor construction. The specific thermal and mechanical characteristics of the reference 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, positioned in the same location as the reference PRT used to calibrate your dry-well, the accuracy of your display may not actually be what it is claimed to be.

Third, external reference thermometers are generally more accurate than internal control sensors. External probes share with probes under test, a more common "point of view" of the



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

block's temperature than does the internal control sensor. Be mindful, however, that simply using an external reference thermometer does not necessarily mean that your measurement is more accurate. You still need to understand how your reference readout is specified. Many have poor resolution and do not accept calibration constants for specific thermometer types. Be sure also to consider both the reference probe and the electronics that read it. A dry-well with a built-in reference readout likely only specifies the accuracy of the readout—not the combined accuracy of readout and probe.

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

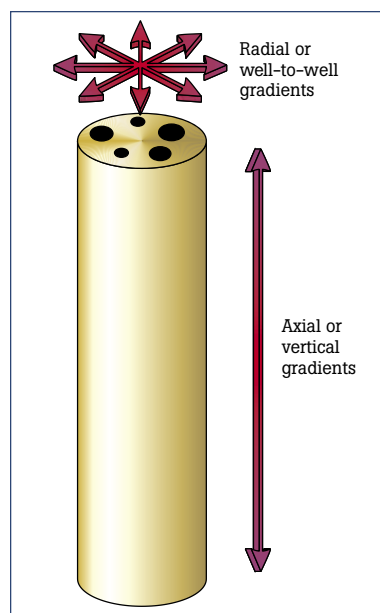
Also, remember that long-term stability or "drift," in the control sensor requires that the dry-well's display be periodically calibrated. How long should you wait between calibrations? That depends on the dry-well and how it is used. The best advice is to start with short calibration intervals (3-6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

A dry-well’s axial temperature gradient can create significant measurement errors when comparing two probes against each other when inserted at different depths (should be avoided!). Or when comparing two probes at the same depth, but with significantly different sensor construction (e.g. different sensor lengths).

Measurement errors due to a dry-well’s axial temperature gradient can also be significant if the probe under test is inserted to a different depth, or is significantly different in construction, than the reference probe that was used to calibrate the dry-well—especially if it is the dry-well’s display that is being used as the reference temperature.



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

Axial gradients can be minimized through design techniques such as increasing block mass and depth, insulation, multiple-zone controlling, and use of profiled or imbalanced heating. Axial gradients can also be measured, though it is difficult to separate a measurement of axial gradients from the stem effects inherent in the probe making the measurements.

Radial (or “well-to-well”) gradients

To make sure we 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.

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.

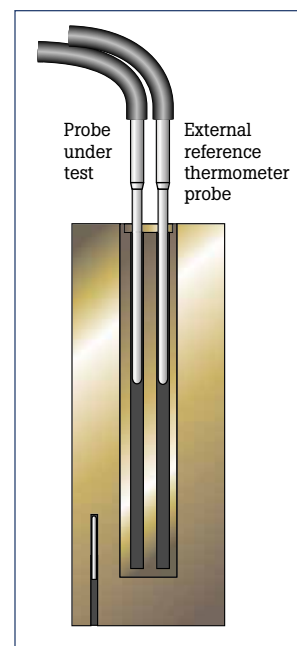
To further complicate things, it is difficult to compare a probe of one diameter in one well against a probe of another diameter in another well. Probes with more thermal conductivity draw more influence from the ambient environment into the block. For that reason alone, large-diameter probes (10 mm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

Loading effects

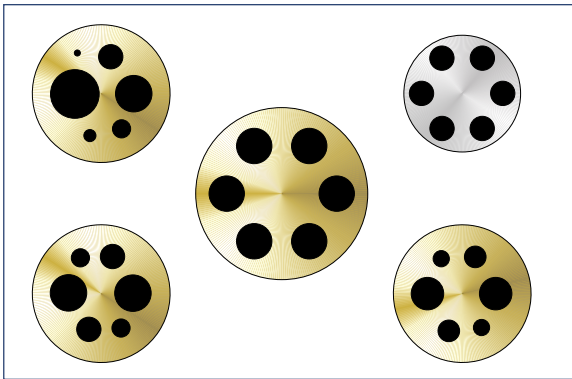
Speaking of heat draw, the more probes that are inserted into a dry-well, the more heat will be drawn away from or into the dry-well, depending on its temperature relative to ambient. A dry-well’s display is typically calibrated when loaded with a single reference probe. Adding more probes may create a temperature 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 temperature change from the reading of 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.

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, the approximate mid-point of a dry-well that ranges in temperature from 35 °C to 600 °C is about 300 °C. The actual temperature at the mid-point, relative to a reference thermometer, will vary by some amount when approached from a higher temperature than when approached from a lower temperature. This temperature deviation, or hysteresis, is dependant on



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.

characteristics of the control sensor. The impact of hysteresis is significantly reduced when comparing a test probe to an external reference probe. The effects of hysteresis should be understood when comparing against the dry-well's calibrated display.

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 at the same temperature. Generally speaking, deeper wells do a better job of eliminating “stem effect” due to inadequate immersion. Implementation of top heater “zone-control” in a dry-well also helps minimize stem effect. If you use probes that are too

short to adequately reach the dry-well's homogeneous measurement zone (typically at the bottom of the well), consider using a bath instead. At minimum, be sure to compare it to another probe inserted to the same depth in another well. (See illustration on previous page)

Flexibility

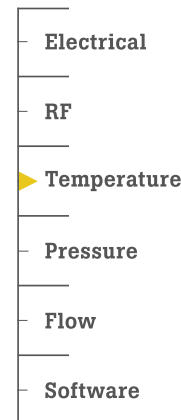
The most flexible dry-wells accommodate removable, multi-hole inserts. Multi-hole inserts can accommodate larger multiple probes of varying sizes. When considering the number of probes to be used in a single insert, remember to account for the diameter of the probe hub (sometimes referred to as the probe “handle”). The insert holes should be adequately spaced apart from one another to prevent the probe hubs from interfering with one another.

Conclusion

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 less 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.

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