# How to Avoid Common Pitfalls when Operating Dry Blocks

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*Performing temperature calibrations by comparing sensors to accurate reference sensors may seem rather simple at first. But upon closer inspection, there are lots of things that can go wrong. This could lead to false results that compromise your calibration efforts, or even worse, your production.*

*This paper provides you with the required insight to avoid the most basic problems and overcome most of the challenges associated with using dry blocks for temperature calibration. With the current technology, dry blocks are now so advanced and can outperform most other alternatives, provided that they are operated according to best practices.*

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## What is a Dry Block?

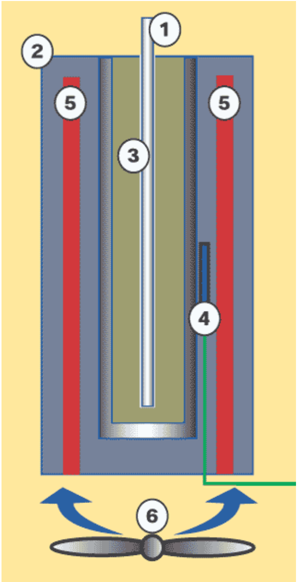
A Dry Block is an electronic equipment that provides a constant and stable temperature over a longer period. The design incorporates an electronic controller, a heated/cooled well that works as the calibration zone and a removable insert that has suitable holes/borings for inserting sensors-under-test. Dry blocks come with an internal measurement circuit that, when calibrated, can be used as a reference unit. Alternatively, an external reference temperature sensor can be inserted into one of the holes, turning the dry block into a heat sink. As the tolerances must be very strict (+/- 0.1 mm on the sensor/ insert diameter measurements) to ensure a low thermal resistance and proper contact between the sensors and insert, several different inserts are required. These inserts should be manufactured with holes of the appropriate sizes to fit the sensors and reference instrument perfectly. Due to stem conduction, sensors may be slow- or fail to reach the required temperature if the diameter of these holes do not match.

The main benefits of using dry blocks are:

- Easy to carry and transport
- No fluid that can spill
- No contamination of the temperature sensors that are being calibrated
- Quick to change temperature – fast operation
- Ideally designed for long/straight sensors

The drawbacks of using dry blocks are:

- Lower accuracy/stability when compared to liquid bath
- Difficult to calibrate short and odd shaped sensors




*The figure shows the basic design of a dry block | 1. Sensor-under-test | 2. Solid metal block (dry block) | 3. Interchangeable inserts for the sensor-under-test | 4. Internal RTD reference sensor | 5. Heating elements | 6. Cooling fan*

## Reliable Temperature Source

Good temperature homogeneity and stability are essential for dry blocks, as sensors-under-test may have varying measuring zones. This important factor needs to remain true, even when dealing with large thermal loads, like multiple- or “heavy” sensors.

To solve the aforementioned thermal problems, a dual-zone designed heating block would be the best step towards eliminating the need for insulating the sensors being tested, thereby making it possible to calibrate almost any type of straight sensor.

The design consist of two separate zones, each with active-control of the temperature:

- The lower part of the block that will experience homogeneity levels close to that of laboratory baths and control the calibration temperature.
- The upper part of the block that ensures good homogeneity and is independent of the load by compensating for the loss of heat between the top of the block and the sensors-under-test.

## Calibrating Short Sensors

Several different sensors geared for the needs of individual companies are fairly common in processing plants. Especially in the life science and food/beverage industries. These sensors, however, can be short and manufactured in odd shapes that can make calibration hard. As a general rule of thumb, a sensor must be fully immersed in calibration equipment at least 15 times the sensor diameter in order to be considered accurate. Due to this, a sensor's active part needs to be in a temperature-homogenous zone. Using liquid baths is one way around this issue, as sensors are fully immersed by liquid that is pumped around axially, thereby ensuring the homogeneity of the temperature.

However, for "pure" calibrations that do not contaminate sensors with oil residue, dry blocks with dual zone technology is the answer. Special inserts can even be used in some cases to reduce or eliminate temperature dissipation.

The thermal gradient that occurs as a result of the thermal load in dry blocks, is compensated for through the dual zone technology. Which means that the calibrator is able to sense and control the heat dissipation, allowing short sensors to be calibrated by simply elevating the reference probe to match the horizontal level.

## Using Inserts

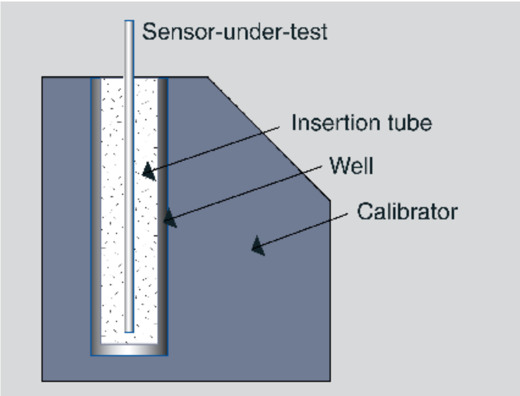
A common reason for issues when working with dry blocks, is not being able to meet the temperature specifications. This is most often caused by operators not using the correct insertion tube, which unfortunately results in lot of time wasted. Therefore, it is essential to follow the guidelines set out in user manuals and other documentation.

The **do's** when using inserts:

- Always use the insert removal tool to remove inserts
- Ensure the inserts are removed upon calibration completion, as they may be difficult to remove if left in the well
- Take adequate precautions and use appropriate protective equipment to remove hot or cold inserts
- Ensure that inserts and sensors are clean and free from dirt and particles prior to insertion. Not doing so may result in inserts getting jammed, as they are designed to fit perfectly in order to maximize thermal conductivity
- Dirt and dust build-ups should regularly be cleaned from wells and inserts using a piece of cloth or detergent

### Always use the Correct Inserts

It is always recommended to use the inserts provided by the dry block manufacturer, as they have the required specifications that will lead to the optimal performance. Several issues and situations that result in wasted time can be avoided as a result of this.



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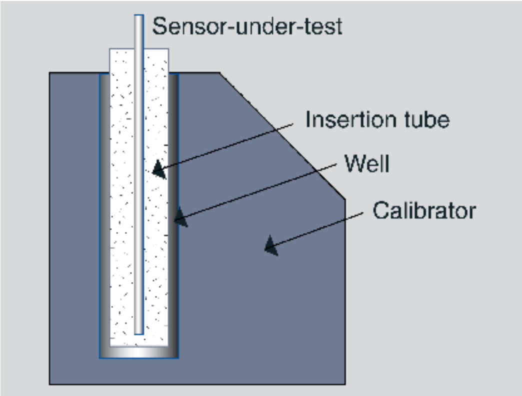
The **don'ts** when using inserts:

- Never force inserts or other equipment into the well
- Never allow foreign objects or materials into the well
- Never attempt to optimize performance by using other liquids, as this may lead to leakage and ruined components
- Never use inserts constructed from metals that are not similar to the block, unless the manufacturer specifies otherwise, as the degree of expansion and contraction may vary.

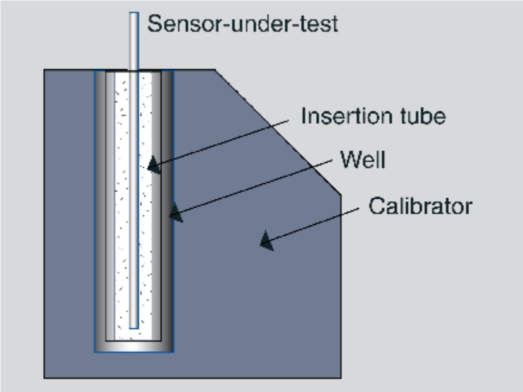
### Using Inserts Designed for Other Dry Blocks

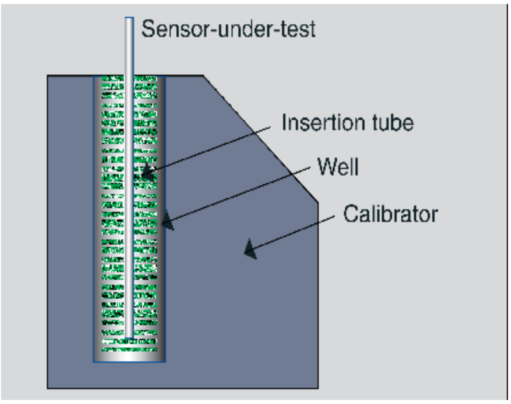
Even though some inserts taken from other dry blocks might have the correct diameter, they might not have the correct length. The example shown here illustrates a tube that is too tall, which would drastically change the temperature uniformity as heat would escape through the top of the well.




### Using Inserts that are too Small

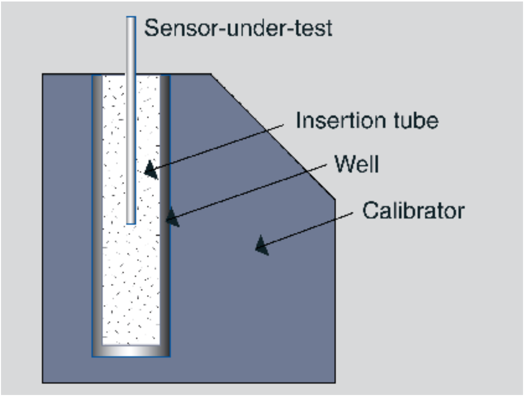
Insert tubes with too narrow a diameter result in insufficient heat transfer between the well and tube, as the air surrounding the tube will have an insulating effect. This causes the temperature to be unstable and unable to reach the desired value.





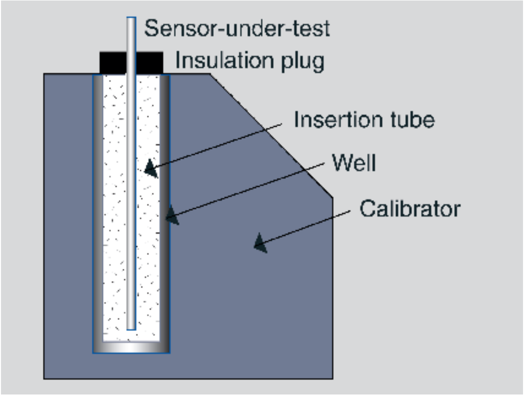

## Using Inserts made of the Wrong Material

Even if foreign inserts have the right length and size, the materials that they consist of may have critical effects on the process. For instance, if it is specified that an aluminum insert is required, using inserts made of brass or other materials may cause problems or inaccurate results due to the difference in conductivity.




## Using Inserts with too Short Sensor Holes

A common mistake when making custom inserts is making the holes too short. When using inserts like these, the temperature gradient may be influenced, as dry blocks can have been calibrated at the bottom of the well.




## Using Inserts Without the Insulation Plug

Dry blocks designed with active cooling facilities will be equipped with an insulation plug that should be used to seal the well. Dry blocks that come with insulation plugs require them to function properly, as they, by default, have been calibrated while using these plugs. If the plugs are not used, it will result in a large flow of heat escaping the well, thereby making reaching the desired temperature a challenge.

## Sources of Uncertainty when Using a Dry Block for Temperature Calibrations

Performing temperature calibrations is a relatively simple task when using dry blocks. However, to meet the required accuracy, there are quite a few sources of uncertainty and error to be considered. These uncertainties are often found in the procedure rather than from the performance of the dry block components.

## Dry Block Designs

In principle, there are two methods to correctly measure dry block temperature:

- A built-in controller sensor used as an internal reference sensor that turns the dry block into its own reference instrument
- An external reference sensor (e.g. the ETS) that is mounted through the insert, thereby turning the dry block into a heat sink

The two methods each represent various effects of uncertainty:

### Calibrating Using an Internal Reference Sensor

An internal reference sensor is by default placed within the dry block. The measuring device will usually be positioned near the bottom of the well, surrounding the insert. Due to its positioning, the internal reference sensor does not measure the temperature inside the insert where the sensors-under-test are located, but instead the area surrounding it. The temperature measurements are not that accurate due to the thermal resistance between the insert and the dry block. Which is only worsened by the change in temperature, as insert temperatures typically change slower than the temperatures found in the rest of the dry block. This can result in a detrimental error if the calibration is performed too quickly and without waiting for the appropriate stabilization time to have occurred. In addition to this, recalibrating internal reference sensors is a troublesome issue, as only the dry block manufacturer is able to perform this sort of calibration.

### Calibrating Using an External Reference Sensor

Unlike the internal reference sensor, the external reference sensor is placed directly into the insert along with the sensors-under-test. Due to this fact, temperature measurements are more precise. In order to have the same thermal characteristics as the sensors being calibrated, the reference sensor should ideally have the same size and thermal conductance in order to accurately follow the changes in temperature. This is, however, rarely the case, and extended holding times (dwell times) must therefore be considered. One of the best elements to using external reference sensors like the ETS, is the more accurate and less uncertain results when compared to an internal reference sensor. On top of the increased accuracy, the external option also provides reliability and independence should errors occur – as the external reference sensor can be examined without having to examine the entire dry block unit.

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## Loading Dry Blocks

As long as the environmental temperature differs from that of the dry block, it is near impossible to avoid heat being conducted through the sensors, which is a phenomenon known as stem conductance. The more sensors that are placed within the same insert, the more the temperature will "leak" – this also applies thicker sensors. In addition to this, the more of a temperature difference there is between the environment and the insert, the more it will leak. In practice, this would mean that the higher temperature a dry block is running, the more it will leak. Resulting in the insert cooling down near the top, more so than it would at the bottom, subsequently creating a temperature gradient. To avoid this, the loading effect can be reduced or almost eliminated by using two or more heating/cooling zones as described earlier in this paper. For internal reference sensors, the loading effect is usually more severe, as the reference sensor is placed near the bottom, measuring the temperature surrounding the block instead of inside the insert, which results in the loading effect not being recognized and therefore not compensated. For that reason, the error caused by the loading effect is far smaller when using an external reference sensor, and the uncertainty is therefore much better

## Achieving Temperature Homogeneity

The difference in temperature across the vertical (length) of the insert is referred to as axial homogeneity or, in some cases, axial uniformity. It is fairly common that the temperature at the bottom of the dry block will differ from at the top. This is mainly due to the temperature at the top "leaking" to the surroundings.

The actual measuring elements in sensors, that being Pt100 or 1000 elements of RTD's or the welding points of thermocouples, may be positioned at various lengths, as some elements are placed closer to the tip than others. This makes it extremely important to ensure that the different sensors are exposed to the same temperature. In order to achieve this, the homogenic zone at the bottom of the well must be deep enough. Sensors should therefore be kept within this zone, whose depth is usually specified somewhere between 40 and 60 mm to eliminate or reduce uncertainty – or at the very least, be inserted and aligned at the same depth.

## Temperature Distribution

There can always occur a difference in temperature between wells, regardless of inserts having good thermal conductivity. This can typically be caused by the following:

- One insert touching the block more than the other
- Unequal loading in inserts, e.g. one insert may have thicker or additional sensors when compared to the other
- The tolerances of the heaters and coolers on either side may be affected

Fortunately, the difference in temperature between wells are typically rather miniscule. They should, however, still be considered and identified through heat distribution studies.

## Temperature Stability

It is mandatory that temperature must be stable during periods of operation, as different sensors often have varying thermal characteristics and therefore take various times to stabilize. If there is a constant change in temperature, different sensors might read differently. This could be the case when e.g. placing calibration equipment in "uncontrolled" areas, where working with external reference sensors would provide more accurate results, even under challenging conditions such as this. The long-term stability specification is usually part of the documentation from the manufacturer.

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*Conclusion:*

## Slow and Steady Wins the Race – Make Your Calibration Fully Automatic

*It is a well-known fact that temperature usually changes rather slowly and due to the passive nature of the system it will take a decent amount of time before every part of the system has been able to stabilize at the same temperature – thereby reaching its equilibrium. Calibrating takes time and should not be rushed, as rushing dry block temperature calibrations introduces the largest source of uncertainty. It is therefore important to learn about your system, e.g. through tests of how long the various steps in a calibration routine take. This is especially important for internal reference sensors, as these sensors reach the required temperature a lot faster than the sensors being tested. Accepting the results too early in the process will therefore lead to a major error. This is not as severe for external temperature sensors, as they remain far more accurate, even when rushed to a result prior to equilibrium.*

## What Ellab has to Offer

Ellab's ValSuite® software is the perfect tool calibrating, as it is not only a validation software, but also a calibration software. This means that all sensors can be user calibrated at defined intervals and store offset values. Using the Ellab Temperature Standard (ETS) and one of the many dry block reference instruments connected to the PC, a fully automatic calibration can be executed without requiring operator interference – a very safe and time saving feature. A report is automatically generated that shows the overall calibration results. When using the calibration setup, users can choose manual, semi-automatic or full-automatic calibration. At the same time, various templates can be stored and uploaded whenever required. The found offset values are linked directly to the ID number of sensors and will be considered whenever the sensor is used in future measurements.