Common Problems in Achieving Maximum Performance From Dry-Well Thermometer Calibrators

Uncertainty in Measurement

"An estimate characterizing the range of values within which the true value of a measurand lies."

Nicholas & White; Traceable Temperatures

Dry-well Thermal Uncertainties

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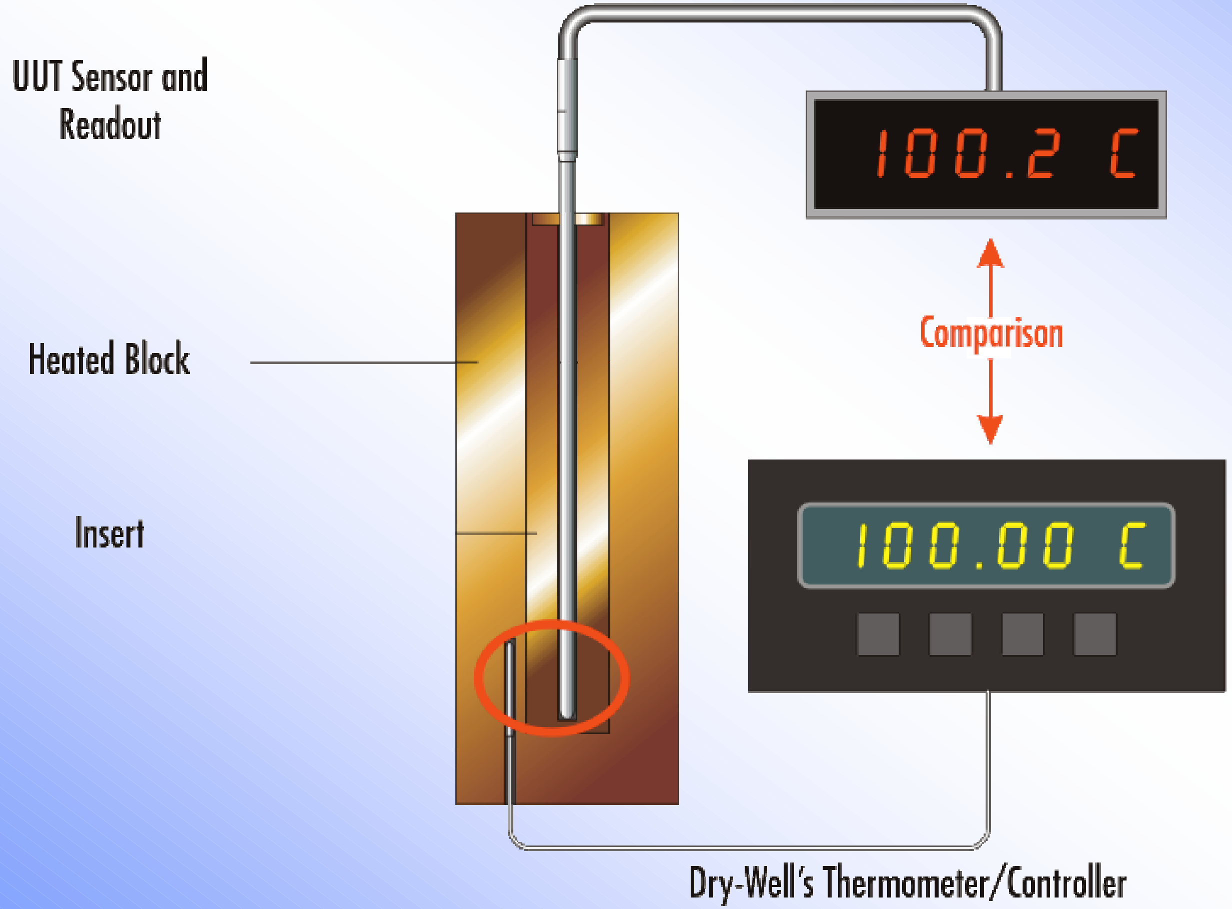
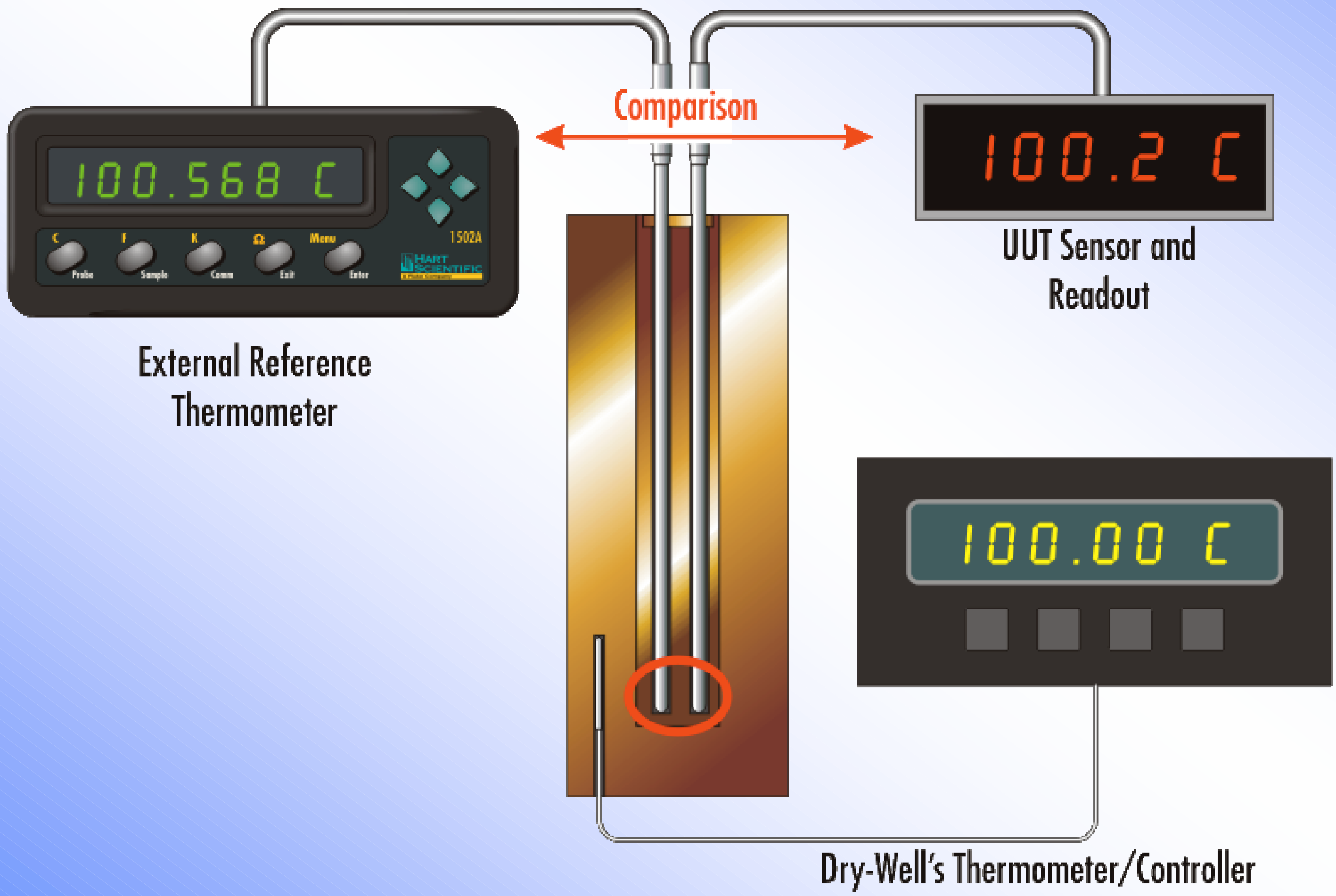
- Temperature Stability
- Temperature Uniformity
  - Axial
  - Radial
- Block Loading
- Hysteresis of the Control Sensor
- Immersion Effects (Stem Conduction)

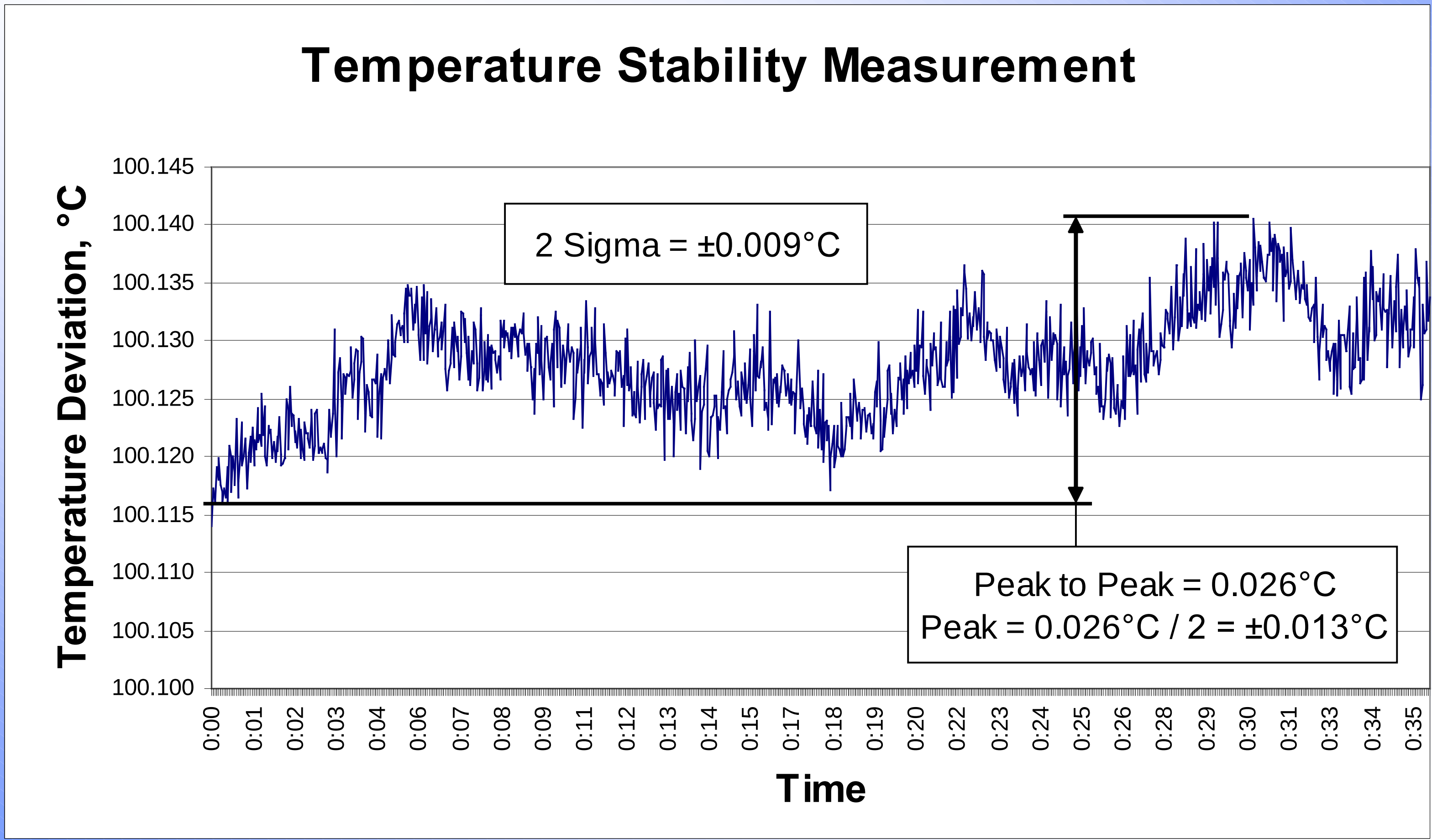
Temperature Reference Standard- *Direct Mode*



Temperature Reference Standard- *Indirect Mode*



Temperature Stability



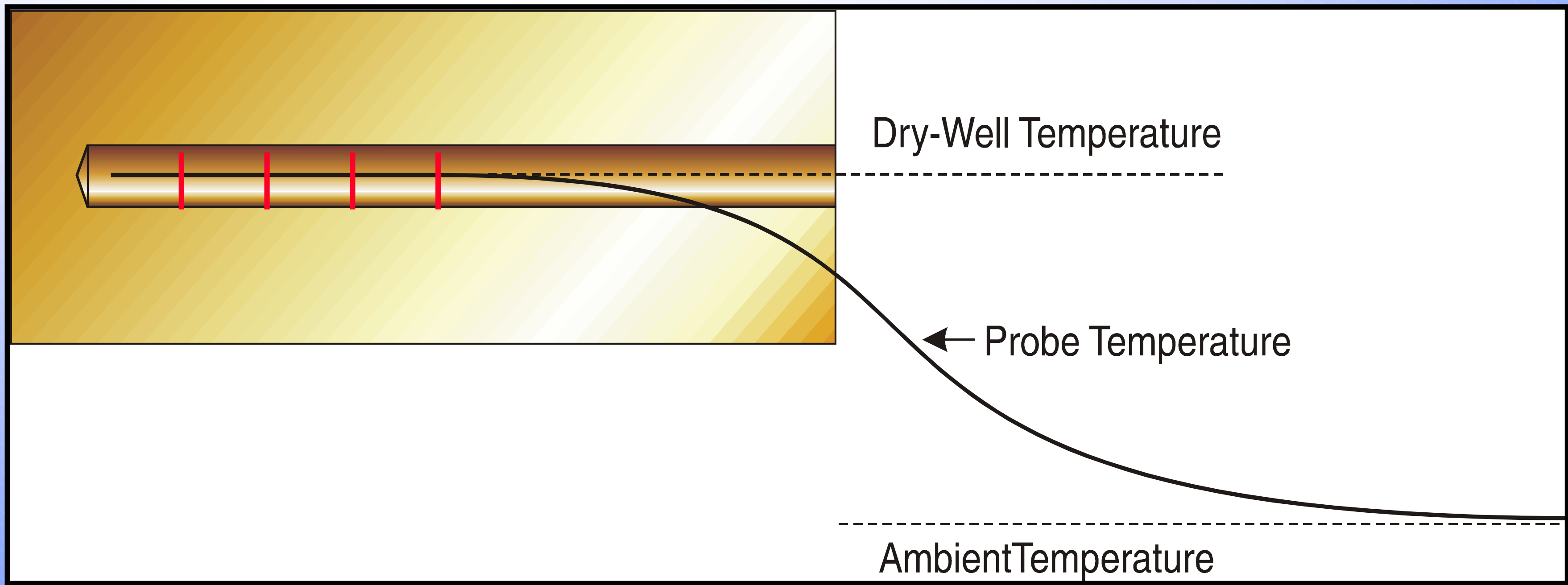
Temperature Uniformity:

- ***Axial Uniformity*** – Variation in the temperature along the axial length of the insert (block) within the measurement zone.

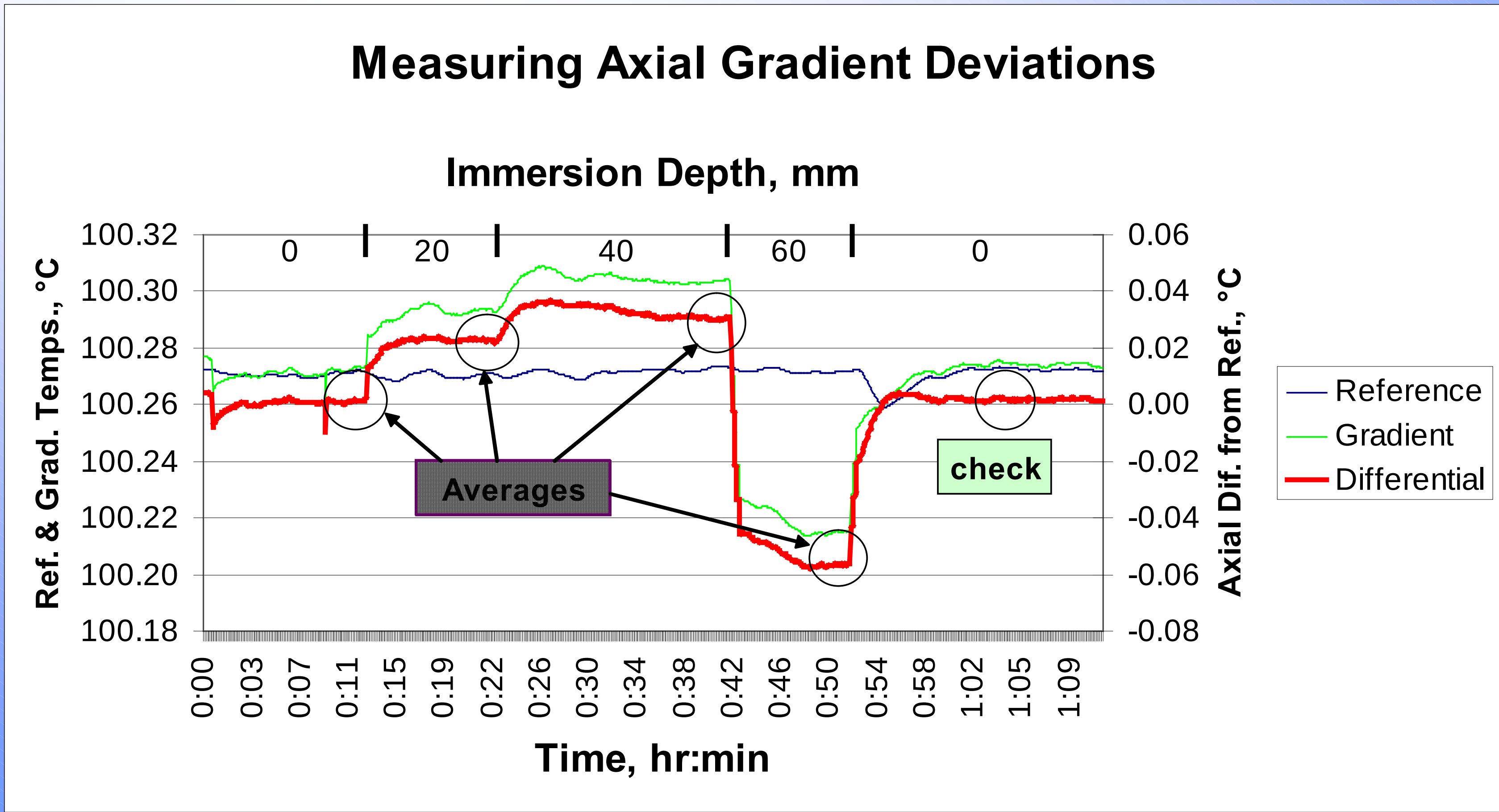
- ***Radial Uniformity*** – Variation in the temperature between different wells of the insert (block) within the measurement zone.

- ***Measurement Zone*** – Space occupied by the sensitive elements of the UUTs measured, both axially and radially. Allow for the range of sensor length.

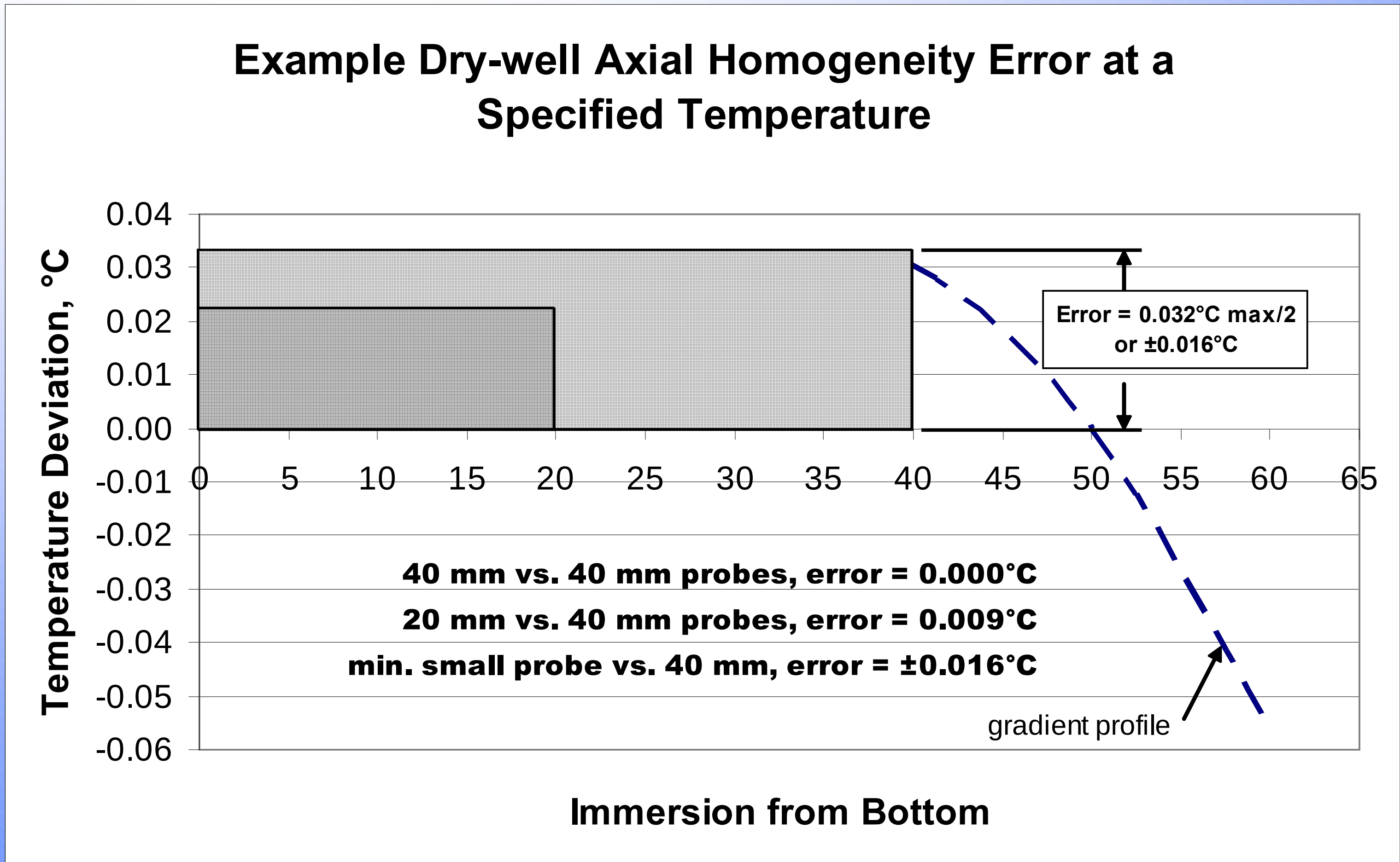
Axial Temperature Uniformity



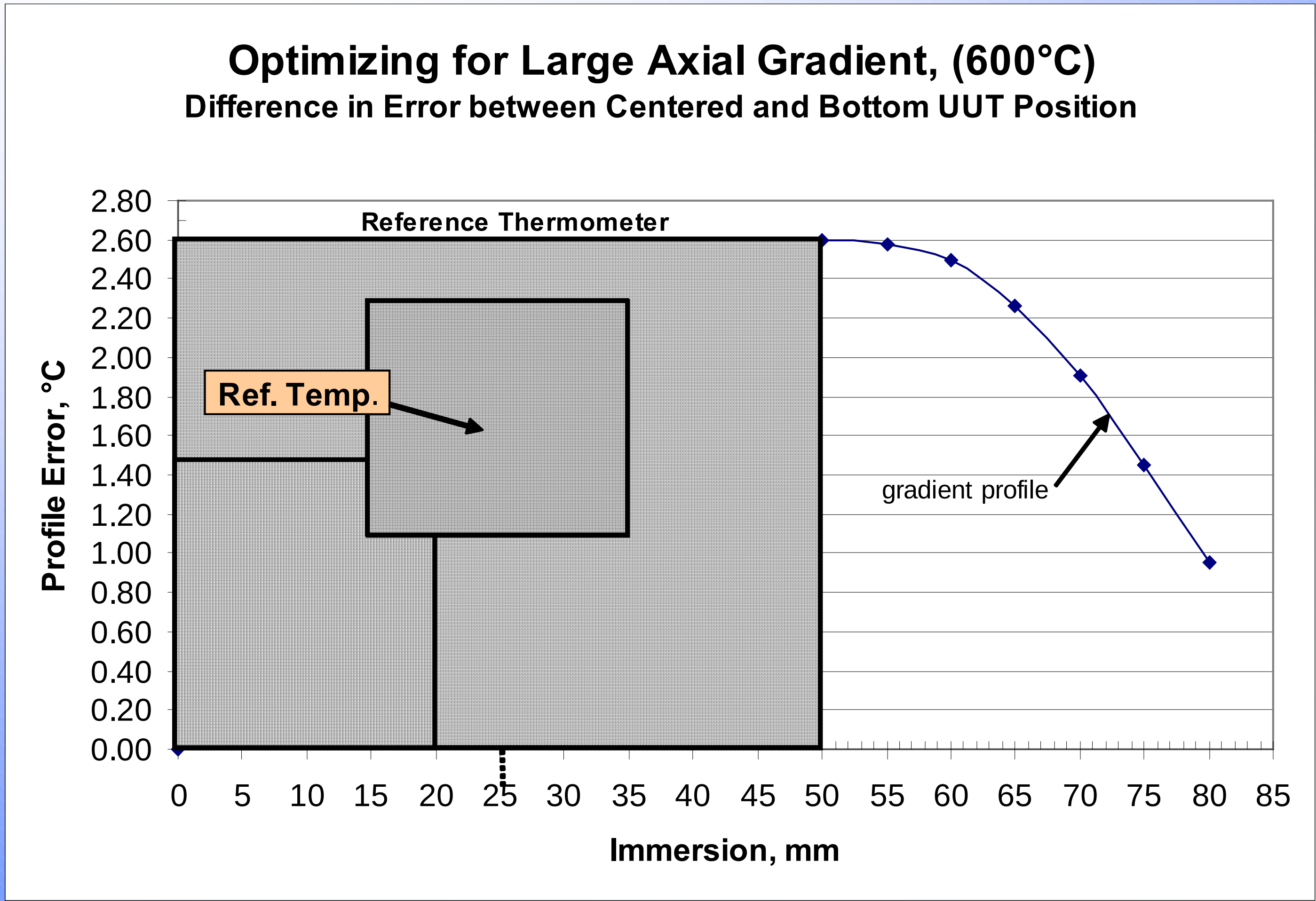
Axial Temperature Uniformity: *Gradient Measurement*



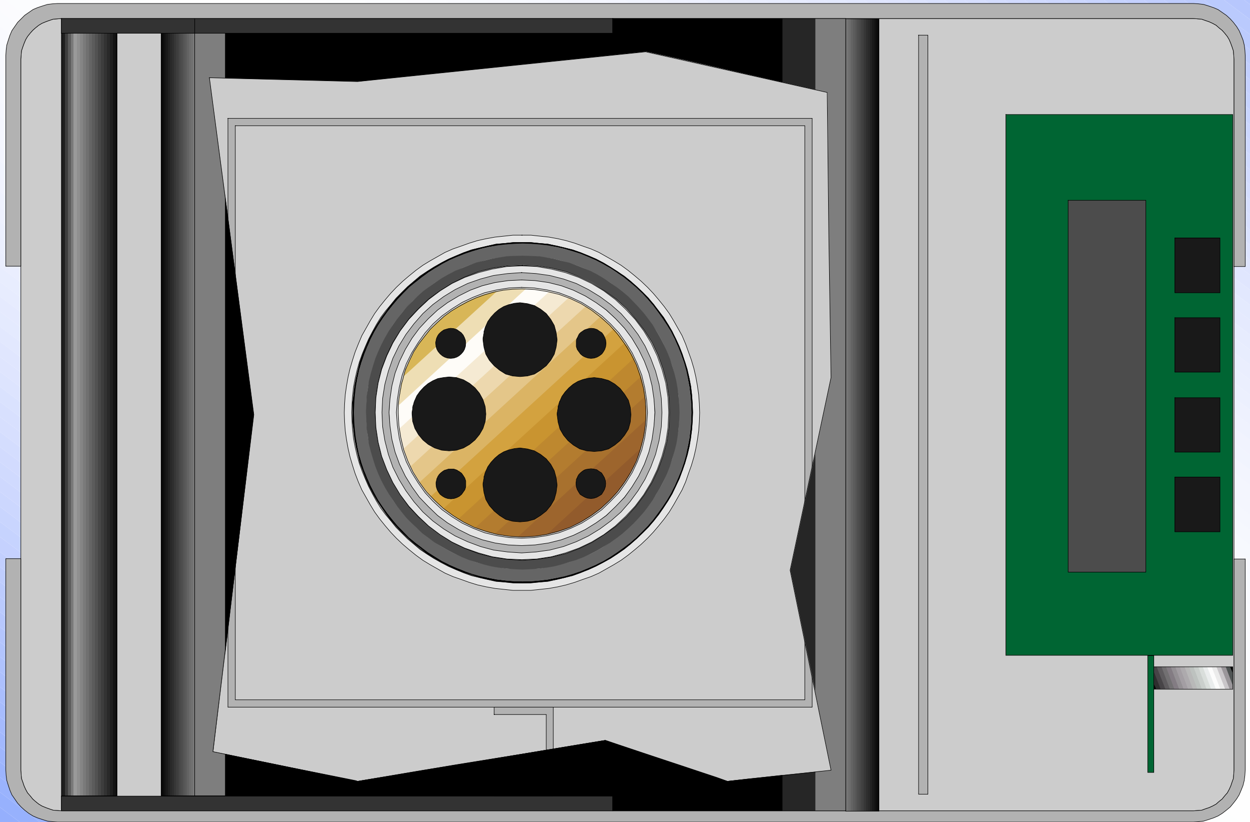
Axial Uniformity:
Gradient Profile



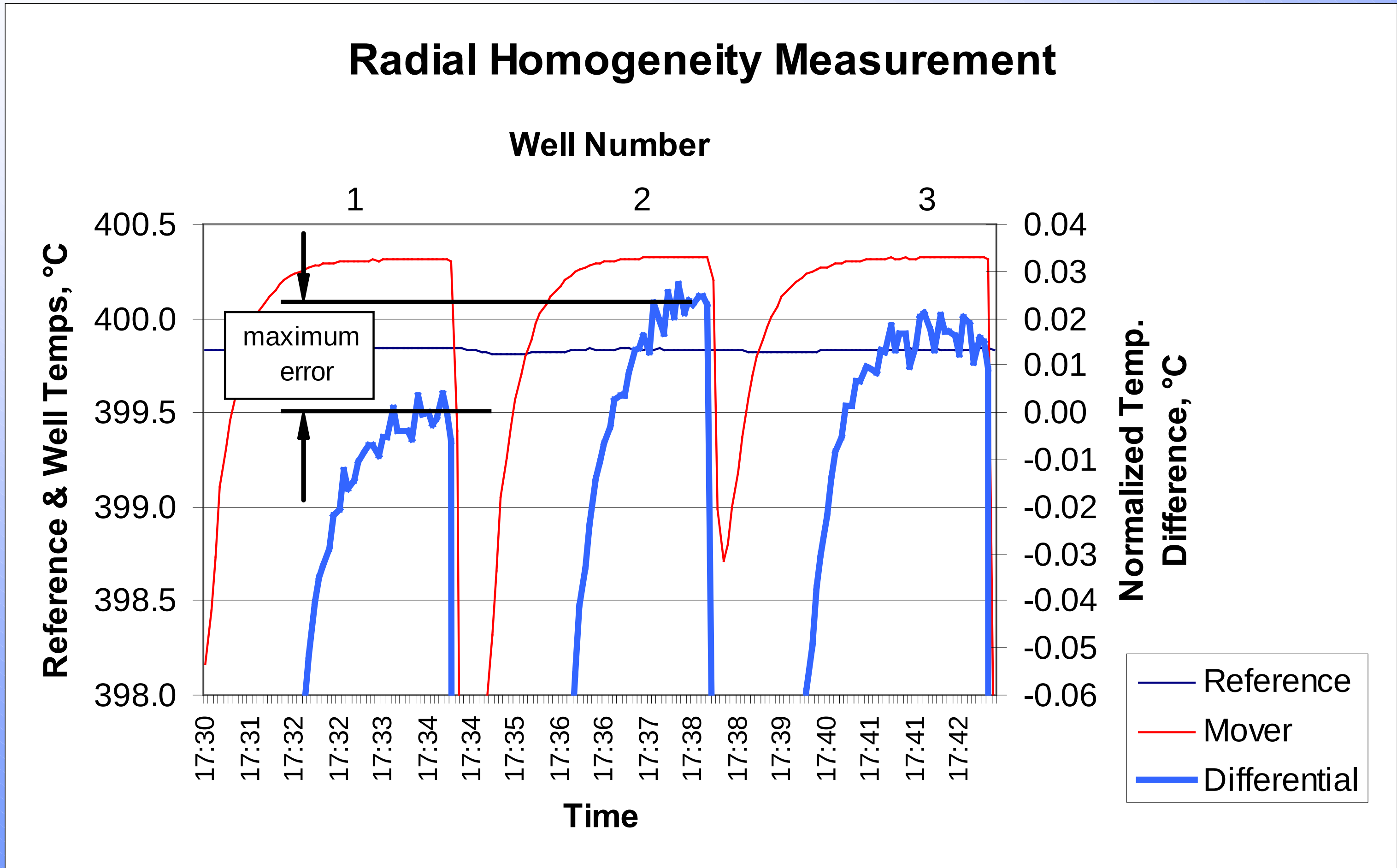
Axial Gradient:
Calibration Optimization



Radial Temperature Uniformity



Radial Temperature Uniformity: *Measurement*



Radial Temperature Uniformity: *Cyclic Exchange*

$$TD = |((P_1W_1 - P_1W_2) + (P_2W_1 - P_2W_2)) / 2|$$

TD = *Temperature Difference Between Wells*

P_1, P_2 = *Probes 1 and 2*

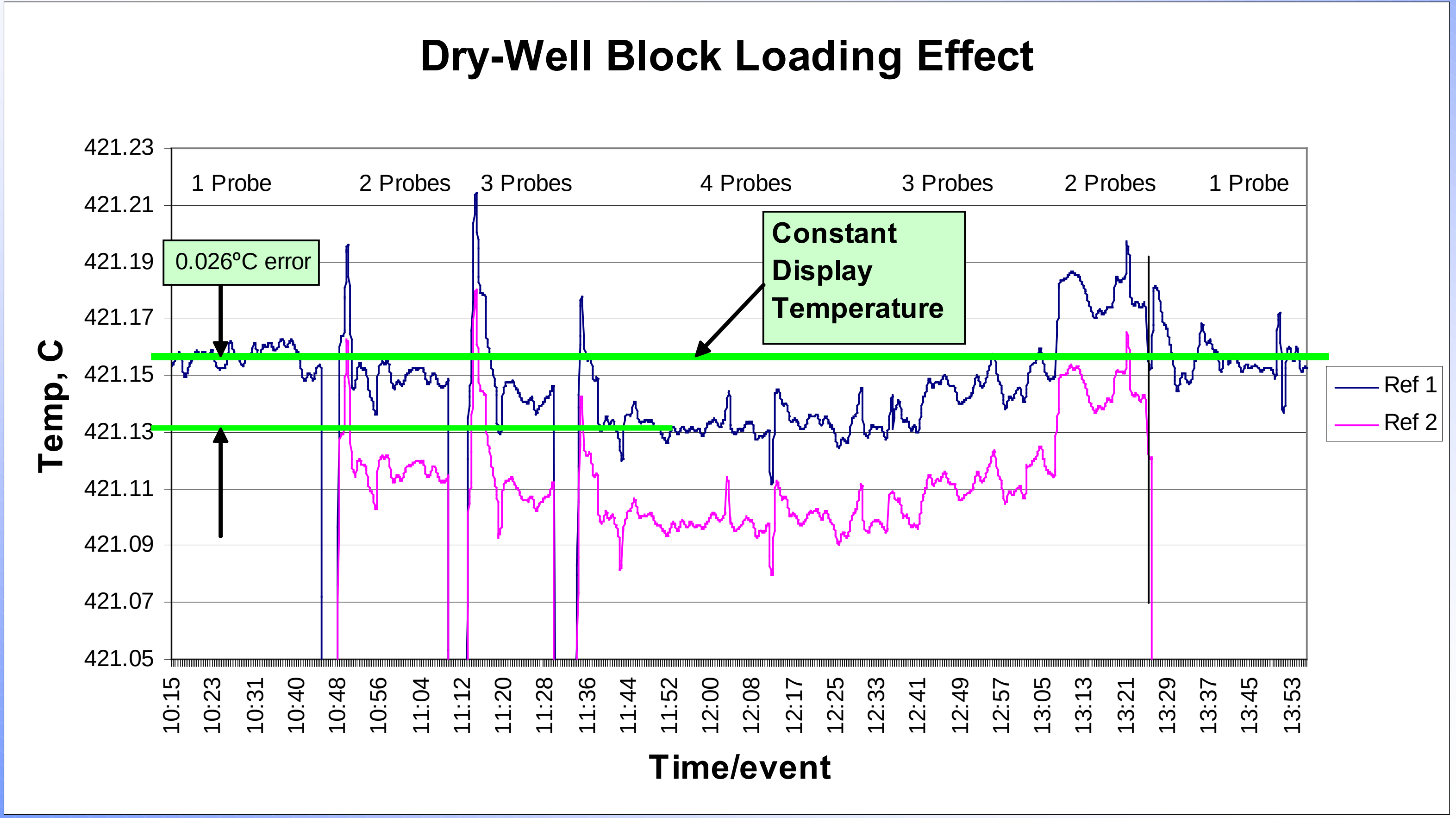
W_1, W_2 = *Wells 1 and 2*

P_1W_1 *is probe 1 in well 1, etc.*

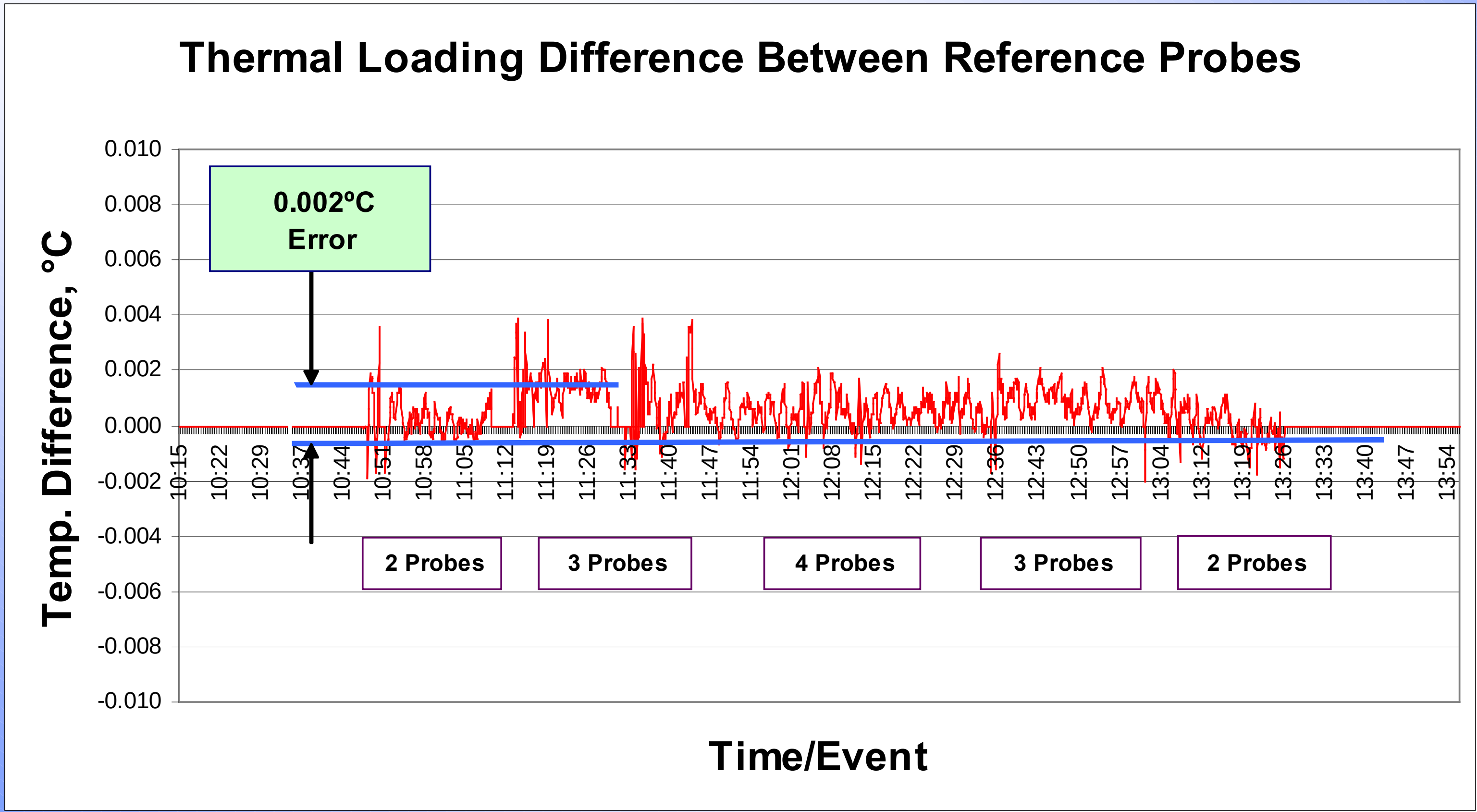
Block Thermal Loading

- Added *Heat Loss* due to increased numbers or size of thermometers, creates a shift in the temperature gradient in the insert (block) of the dry-well.
- The Temperature Controller cannot completely compensate for this shift.
- The result can be a temperature error that is particularly apparent in the Direct Mode.

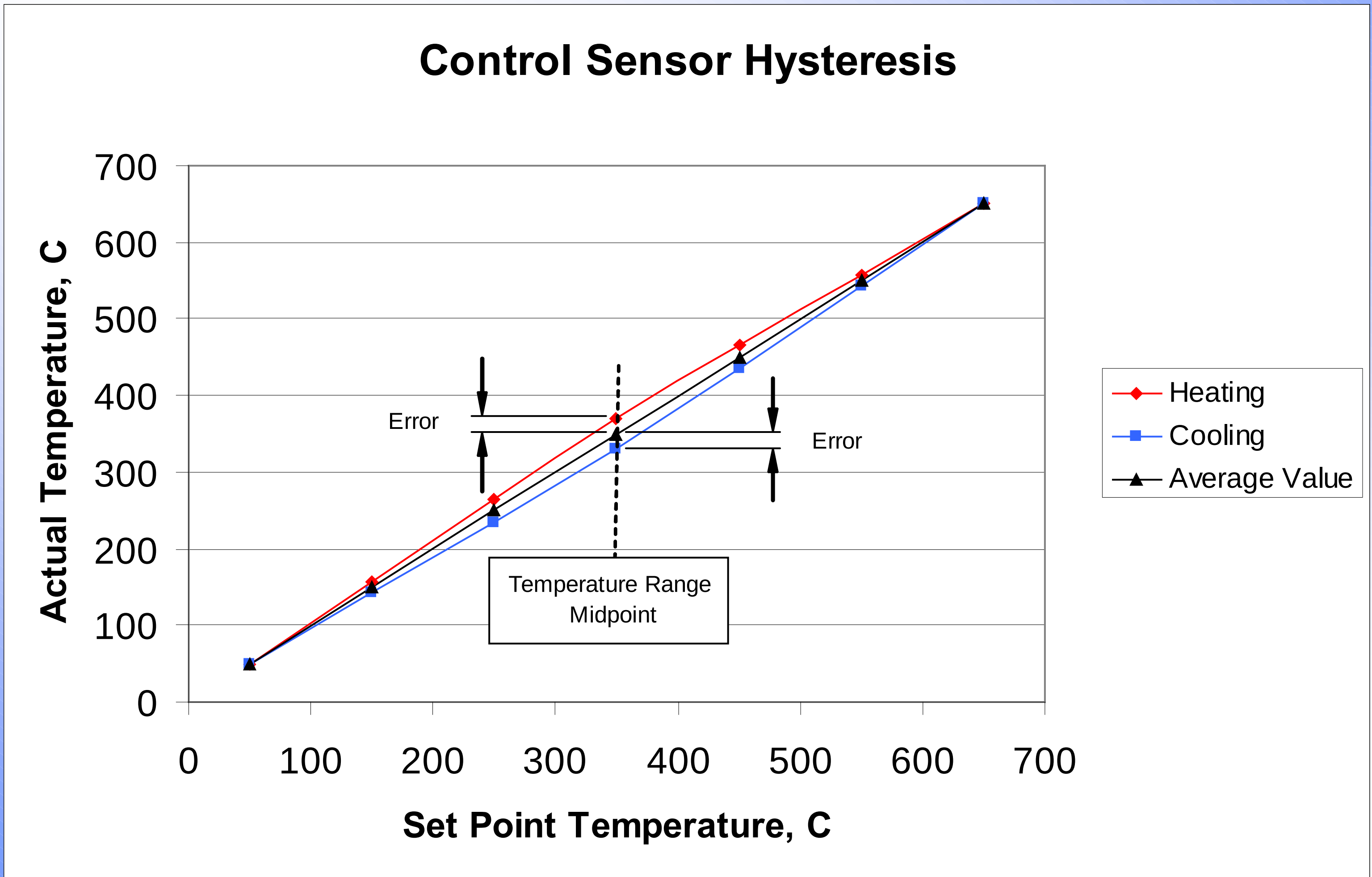
Block Thermal Loading:
Measurement-Direct Mode



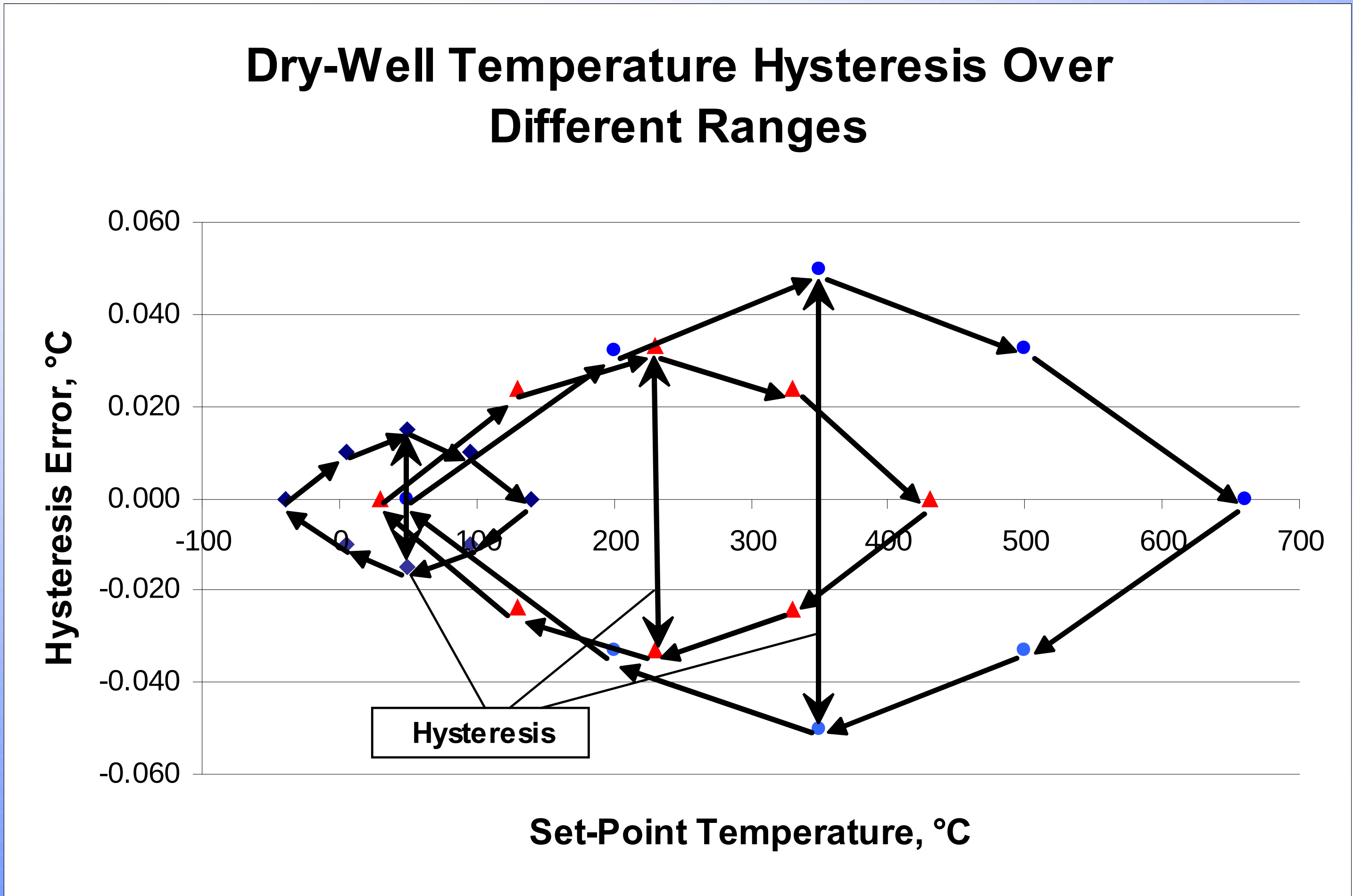
Block Thermal Loading: Measurement-Indirect Mode



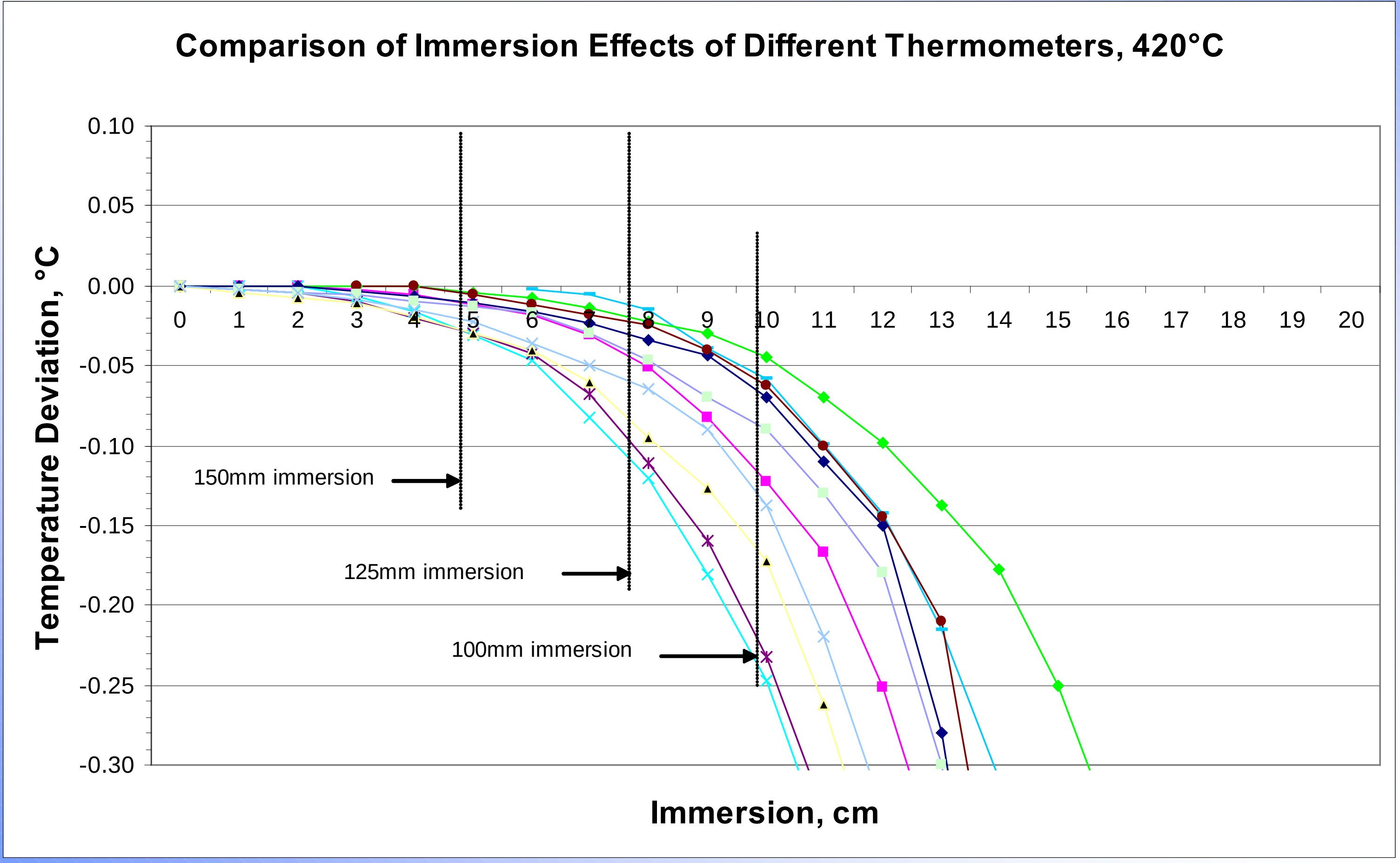
Control Sensor Hysteresis



Control Sensor Hysteresis: Temperature Range Effect



Immersion Effects and Thermometer Stem Conduction



Uncertainty Budget: Direct Mode

Uncertainty Source	Probability Distribution	Uncertainty, ±°C	Divisor	Contribution, ±°C
Electronic Measurement	Normal	0.012	2	NA
Ref. Thermometer (SPRT)	Normal	0.010	2	NA
SPRT, long term drift	Normal	0.010	2	NA
Dry-well Accuracy	Rectangular	0.300	v3	0.173
Dry-well, long term drift	Normal	0.100	2	0.050
Homogeneity, Axial	Rectangular	0.150	v3	0.087
Homogeneity, Radial	Rectangular	0.070	v3	0.040
Resolution of indicator	Rectangular	0.005	v3	0.003
Temperature Stability	Normal	0.030	2	0.015
Thermal Loading (direct)	Rectangular	0.100	v3	0.058
Hysteresis	Rectangular	0.025	v3	0.014
Stem Conduction	Bias	0.050	1	0.050

Combined Standard Uncertainty, ±°C (k=1) **0.219**

Combined Expanded Uncertainty, ±°C (k=2) **0.438**

Uncertainty Budget-Indirect Mode

Uncertainty Source	Probability Distribution	Uncertainty, ±°C	Divisor	Contribution, ±°C
Electronic Measurement	Normal	0.012	2	0.006
Ref. Thermometer (SPRT)	Normal	0.010	2	0.005
SPRT, long term drift	Normal	0.010	2	0.005
Dry-well Accuracy	Rectangular	0.300	v3	NA
Dry-well, long term drift	Normal	0.100	2	NA
Homogeneity, Axial	Rectangular	0.150	v3	0.087
Homogeneity, Axial (SPRT*)	Rectangular	0.070	v3	0.040
Homogeneity, Radial	Rectangular	0.070	v3	0.040
Homogeneity, Radial (SPRT*)	Rectangular	0.070	v3	0.040
Resolution of indicator	Rectangular	0.005	v3	NA
Temperature Stability	Normal	0.030	2	0.015
Thermal Loading (indirect)	Rectangular	0.002	v3	0.001
Hysteresis	Rectangular	0.025	v3	NA
Stem Conduction	Bias	0.050	1	0.050
Combined Standard Uncertainty, ±°C (k=1)				**0.123**
Combined Expanded Uncertainty, ±°C (k=2)				**0.247**

Conclusions:

- Thermal properties inherent in dry-wells contribute to uncertainty of calibration.
- An estimate of the uncertainty can be made through measurement and analysis.
- Different modes of use of the dry-well influence the overall uncertainty.
- Careful testing and analysis can be used to improve accuracy of the calibration for specific cases.

Questions

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