Evaluating the performance of Metrology Wells

It's a Metrology Well, not a Dry-Well!

How do you determine dry-well accuracy?

Need to know

- How the dry well will be used
- Important sources of error
- How dry well manufacturers write specifications

How you use a dry-well greatly affects performance!

- Temperature range

  in general errors increase further from ambient

- Will dry-well temperature be measured using external reference or internal control sensor and display

  each method is valid, but an external reference will generally provide better uncertainties

How you use a dry-well greatly affects performance!

- Metrology wells and dry wells are used for comparison calibration
- Comparison calibrations require thermal equilibrium and consistency
  - without thermal equilibrium cannot make measurements
    - equilibrium requires stability
  - consistency allows comparisons to have meaning over time and between different tests
    - good consistency requires similar loading, low drift, good handling practices and verification

Errors depend upon mode of use

External Reference

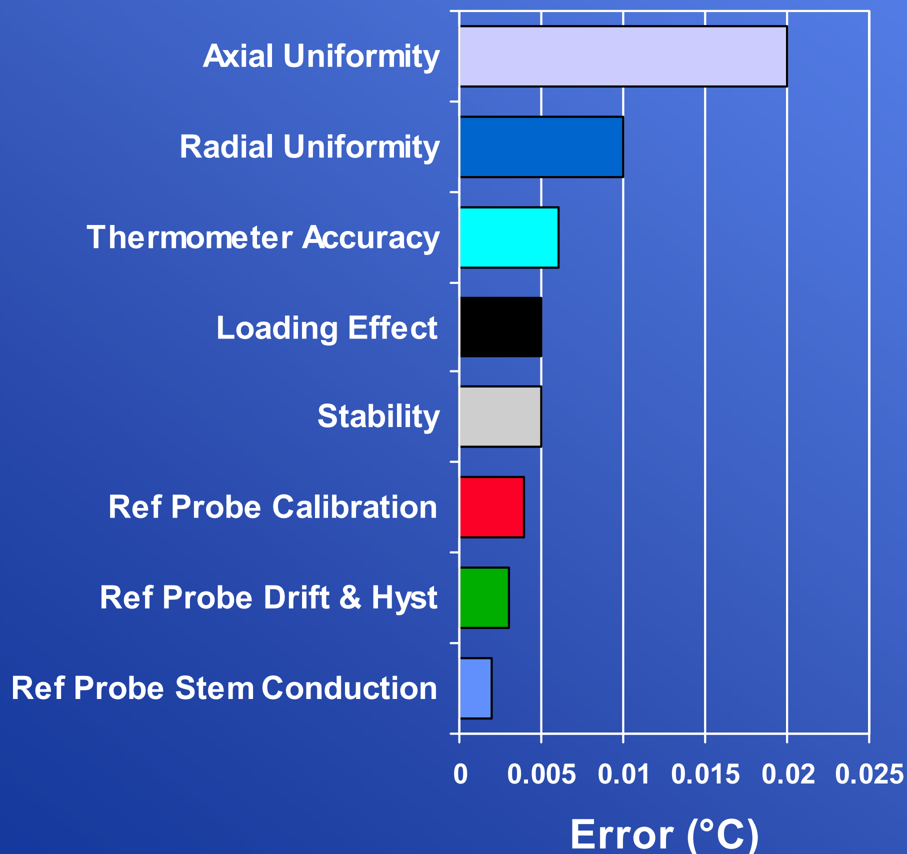
1. Axial Uniformity
2. Radial Uniformity
3. Stem conduction
4. Loading Effect
5. Stability
6. Reference temperature measurement
   - *reference probe*
   - *reference readout*
   - *hysteresis*

Internal control sensor and calibrated display

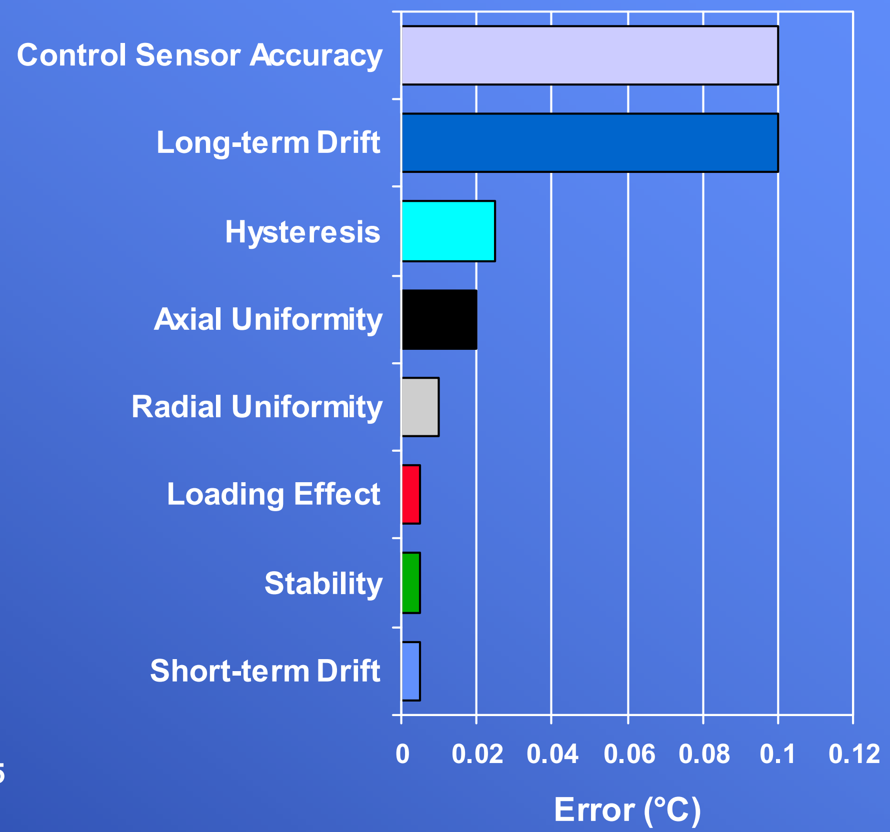
1. Axial Uniformity
2. Radial Uniformity
3. Stem conduction
4. Loading effect
5. Stability
6. Reference temperature measurement
   - *sensor and display drift*
   - *hysteresis*
   - *sensor calibration*

Estimate of significance

Errors with External Reference



Errors with Internal Reference

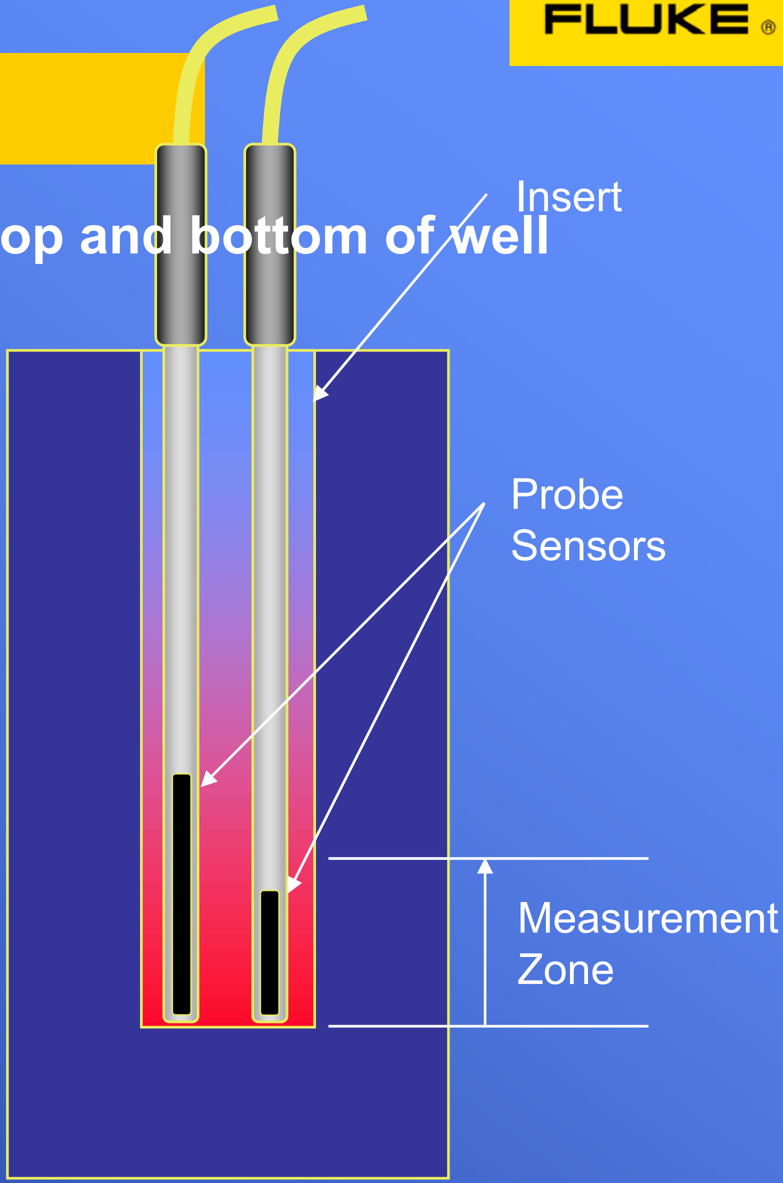


Note different scaling

Axial uniformity

Temperature difference between top and bottom of well

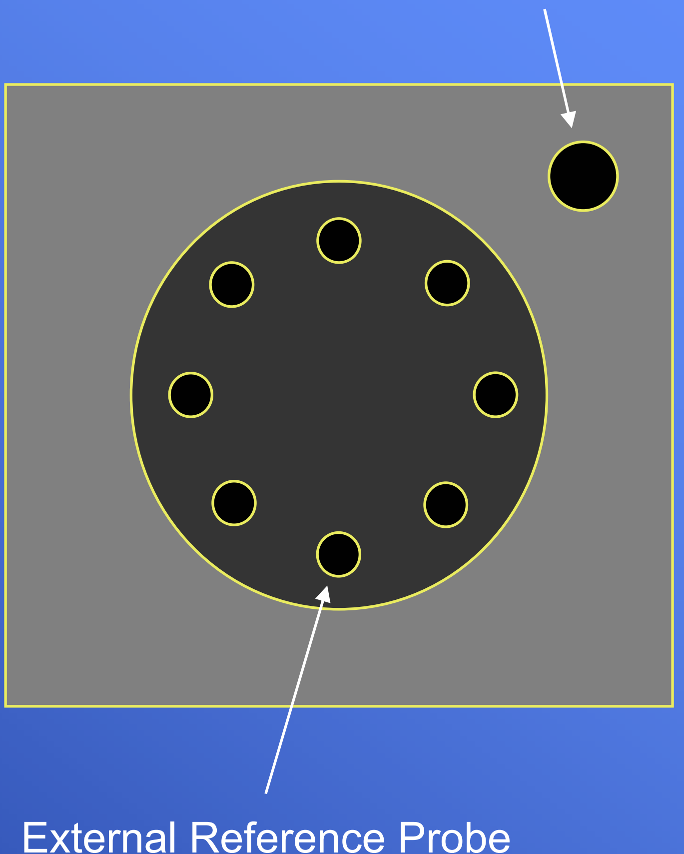
- Measurement zone is where axial uniformity is smallest
  - *EA10/13 requires 40mm*
  - *Hart recommends 60mm*
- Axial uniformity in measurement zone needs to be known to determine uncertainty
  - *Hart has special probe to measure this error*
- Errors can be minimised by
  - *Dual zone control*
  - *Ensuring sensor sits in measurement zone*
  - *Aligning centres of reference and UUT*



Radial uniformity

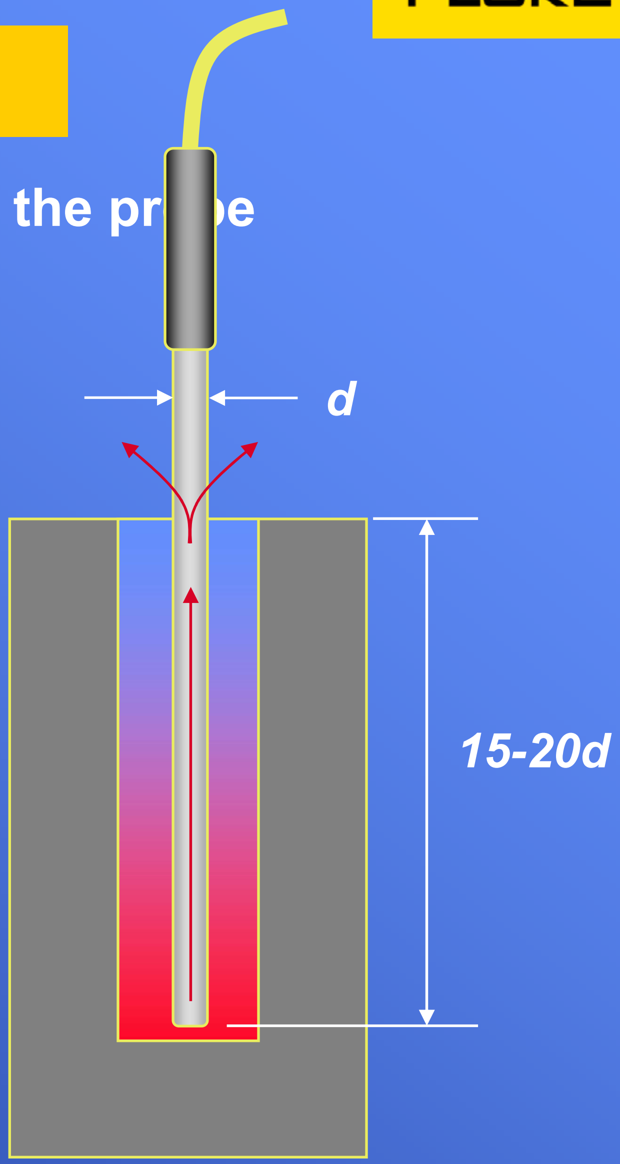
Temperature difference between holes and reference at same depth

- Primarily a function of distance and material type
- External references can be closer to UUT
- Radial uniformity needs to be known to determine uncertainty
- Minimised by placing reference close to UUT



Stem effect

Heat conducted up the sheath of the probe



- Causes non equilibrium between sensor and source
- Function of size and type of material

  large diameter probes conduct more heat

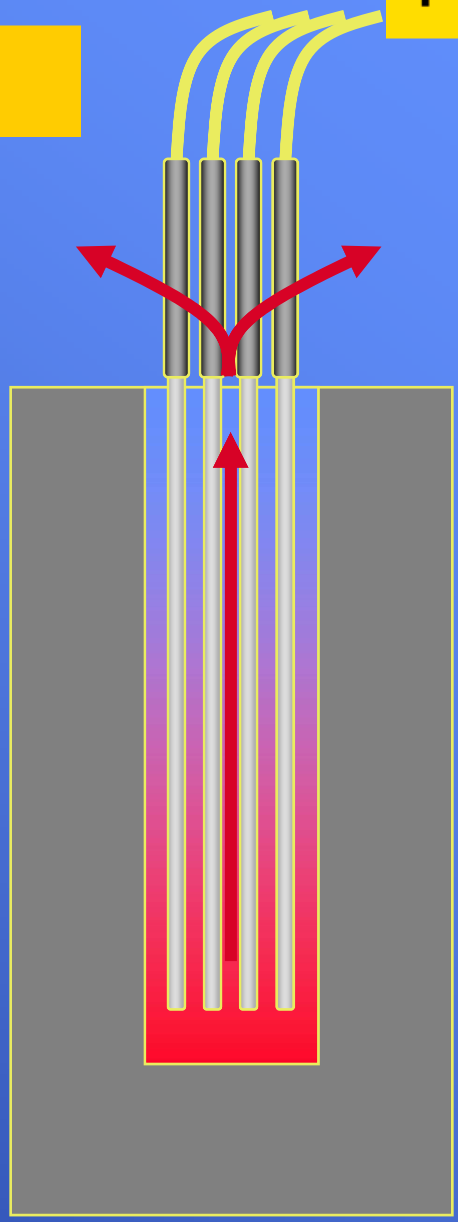
  Al conducts more than Inconel
- Error minimised by deeper immersion

  Hart suggests 15-20 times probe diameter

    8mm probe should have 120mm to 160mm depth

    Metrology wells have extra depth to minimise this error

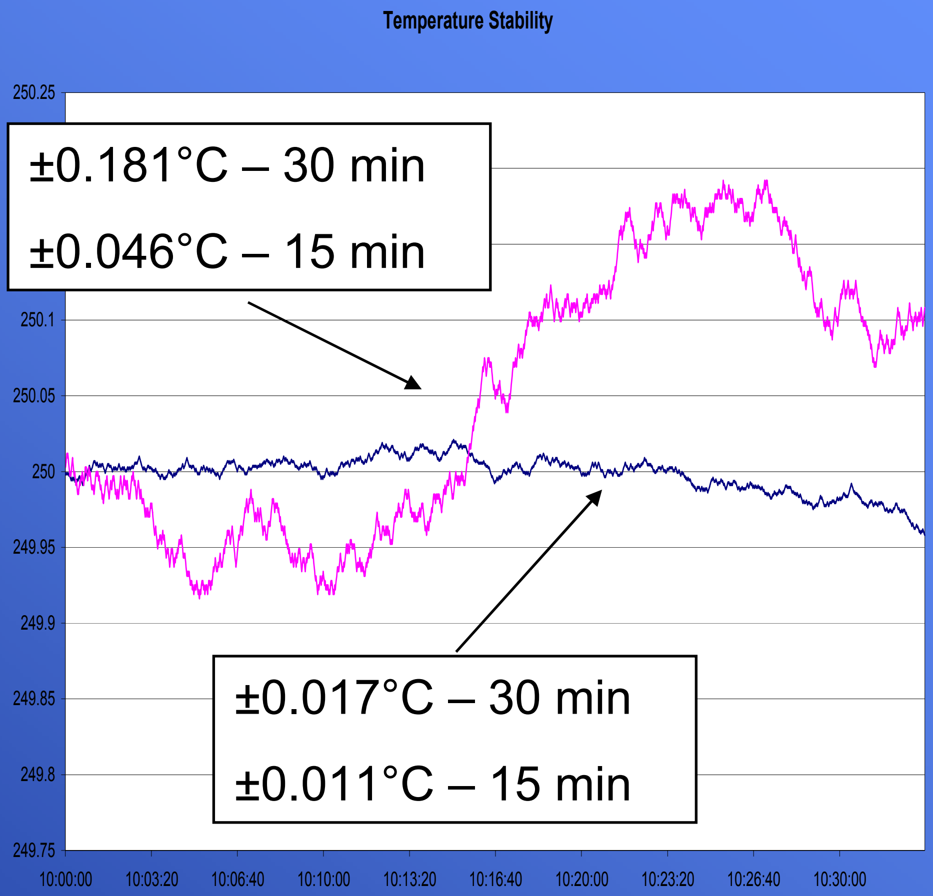
Loading effect



- Number of probes will impact heat drawn from or into well
- Loading effect minimised by
  - *deeper immersion*
  - *dual zone control*

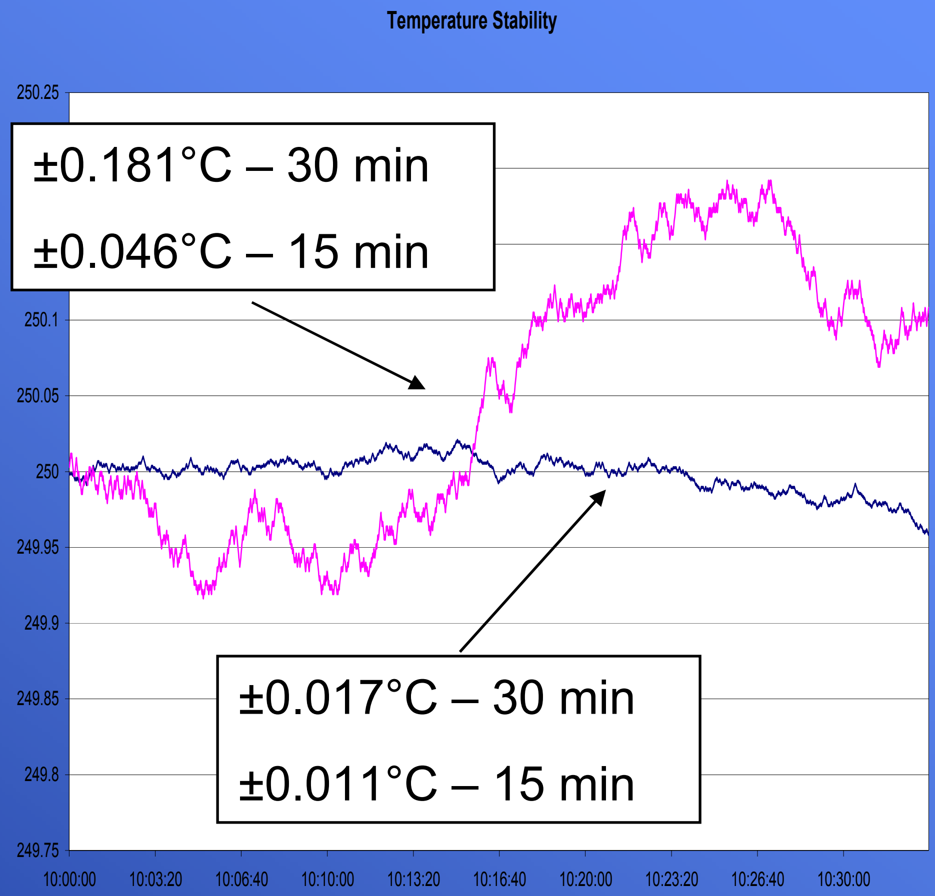
Temperature stability

- Stability is temperature variation with time
- Time should be specified
  - *EA10/13 recommends 30 minutes*
  - *Should be stated with high confidence*
- Use of TYPICAL to be avoided



Temperature stability

- Stability required to reach thermal equilibrium
  - *Probes need time to reach equilibrium with their surroundings*
  - *Multiple measurements rarely instantaneous*
- Stability error minimised by design
  - *Accurate control with good resolution*



Reference temperature measurement

Sources of error to consider

- External Reference

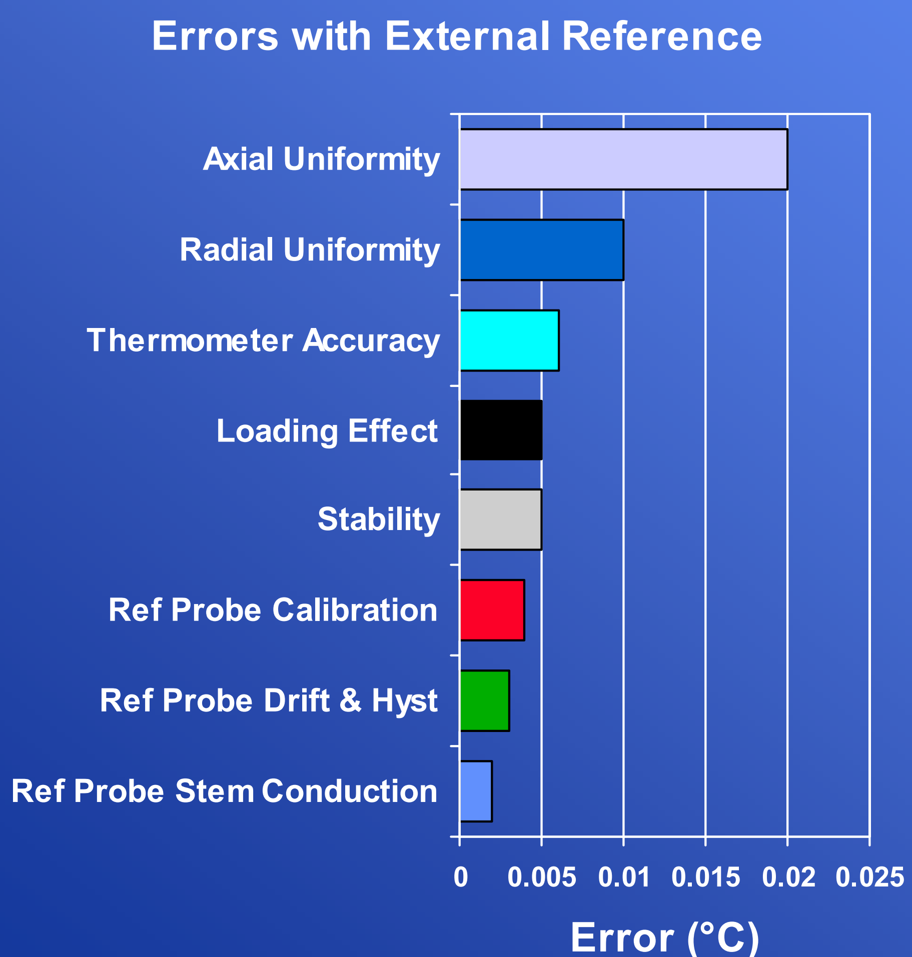
  Probe calibration uncertainty
  Probe handling
  Probe characteristics
  Readout calibration uncertainty
  Readout resolution
  Measurement technique

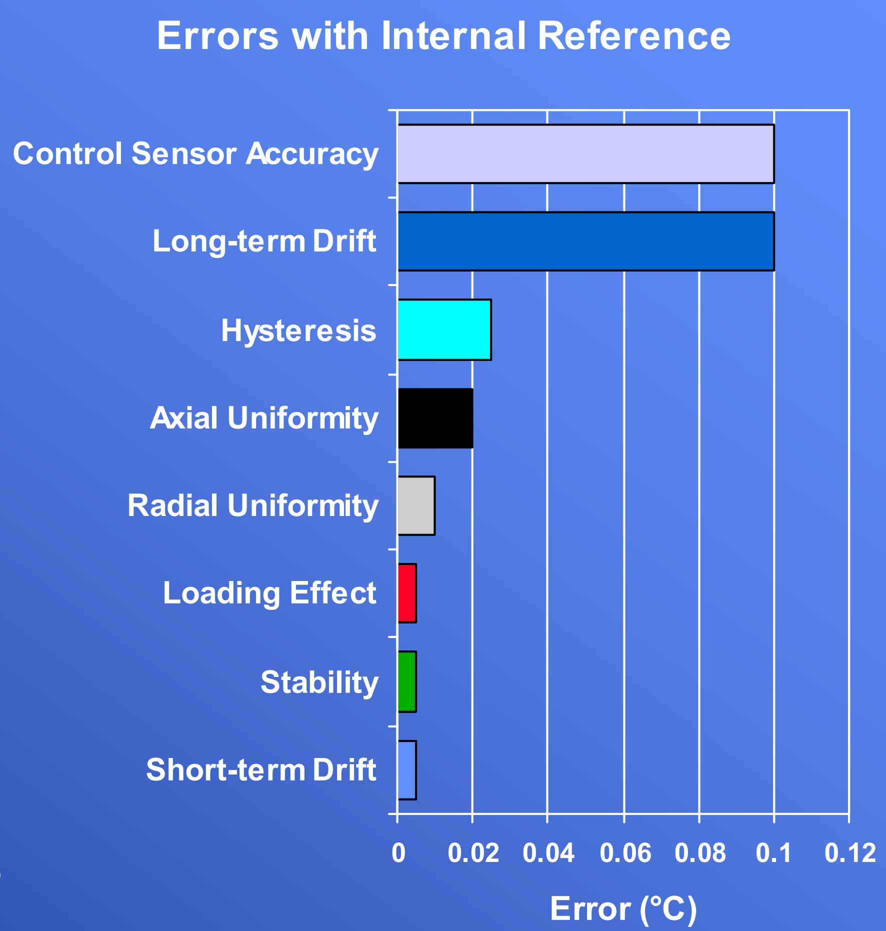
- Internal control sensor and display

  Well calibration uncertainty and procedure
  Hysteresis
  Probe drift
  Control electronics calibration
  Control electronics resolution
  Control measurement technique

FLUKE ®

Estimate of significance - recap





Note different scaling

Total uncertainty – reference probe

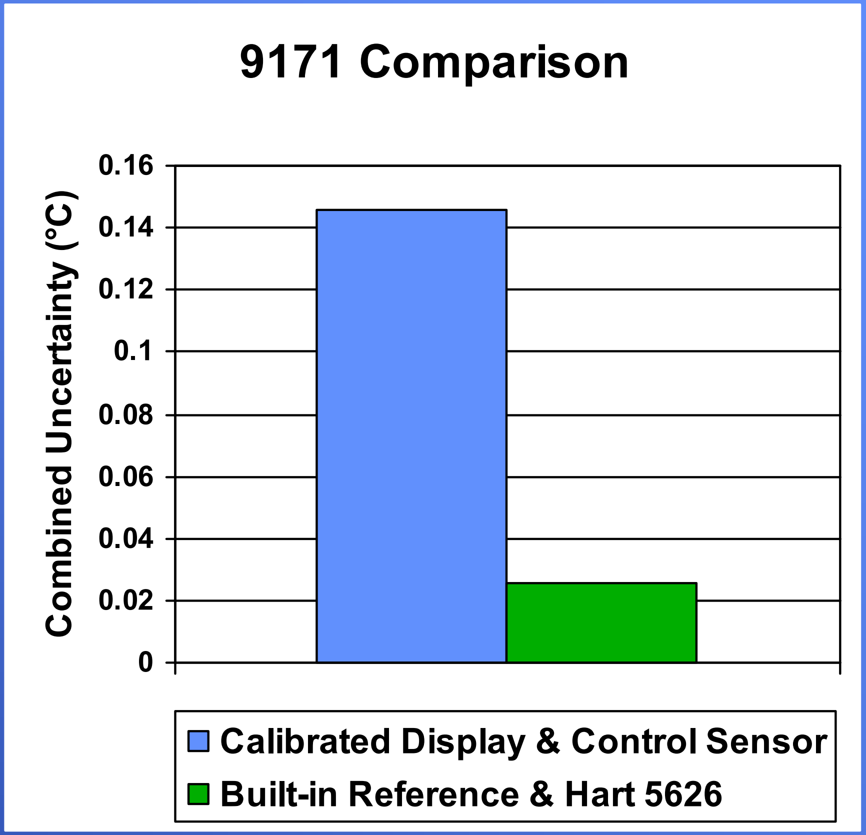
Hart 9171 at 0°C with built in Ref and Hart 5626 Probe			
	Specification (°C)	***Probability Distribution***	***Standard Uncertainty (°C)***
Axial Uniformity	0.020	Normal	0.010
Radial Uniformity	0.010	Rectangular	0.006
Loading Effect	0.005	Rectangular	0.003
Stability	0.005	Normal	0.003
Ref Probe Calibration	0.004	Normal	0.002
Ref Probe Drift & Hyst	0.003	Normal	0.002
Ref Probe Stem Conduction	0.002	Normal	0.001
Thermometer Accuracy	0.006	Rectangular	0.003
	Total Uncertainty (k=2)		**0.026**

Total uncertainty – internal reference

Hart 9171 at 0°C with internal reference and Display			
	Specification (°C)	***Probability Distribution***	***Standard Uncertainty (°C)***
Axial Uniformity	0.020	Normal	0.010
Radial Uniformity	0.010	Rectangular	0.006
Loading Effect	0.005	Rectangular	0.003
Stability	0.005	Normal	0.003
Short-term Drift	0.005	Normal	0.003
Hysteresis	0.025	Normal	0.013
Control Sensor Accuracy	0.100	Normal	0.050
Long-term Drift	0.100	Normal	0.050
	Total Uncertainty (k=2)		**0.146**

Comparison of modes of use

- All Metrology Wells have internal reference readout option
- With calibrated probe unmatched performance is achieved



Comparison

Compare cold Metrology Wells to dry wells

Combined Uncertainty (°C)			
Temperature	***9170 or 9171***	***Competitor 1***	***Competitor 2 (*)***
-45°C (9170)	0.1040	0.207	n/a
-35°C (9170)	0.0433	n/a	0.119
-30°C	0.0433	n/a	0.119
-25°C	0.0433	0.160	0.119
0°C	0.0256	0.160	n/a
50°C	n/a	0.160	0.119
140°C	0.0459	n/a	0.125
155°C (9171)	0.0641	0.161	n/a

Comparison

Compare mid temperature Metrology Wells to dry wells

Combined Uncertainty (°C)			
Temperature	***9172***	***Competitor 1***	***Competitor 2 (*)***
35°C	0.055	n/a	0.119
50°C	0.055	0.188	n/a
100°C	0.055	n/a	n/a
125°C	0.105	n/a	n/a
155°C	0.105	0.235	0.337
225°C	0.105	n/a	n/a
250°C	0.204	n/a	0.376
320°C	0.204	0.309	n/a
425°C	0.204	n/a	n/a

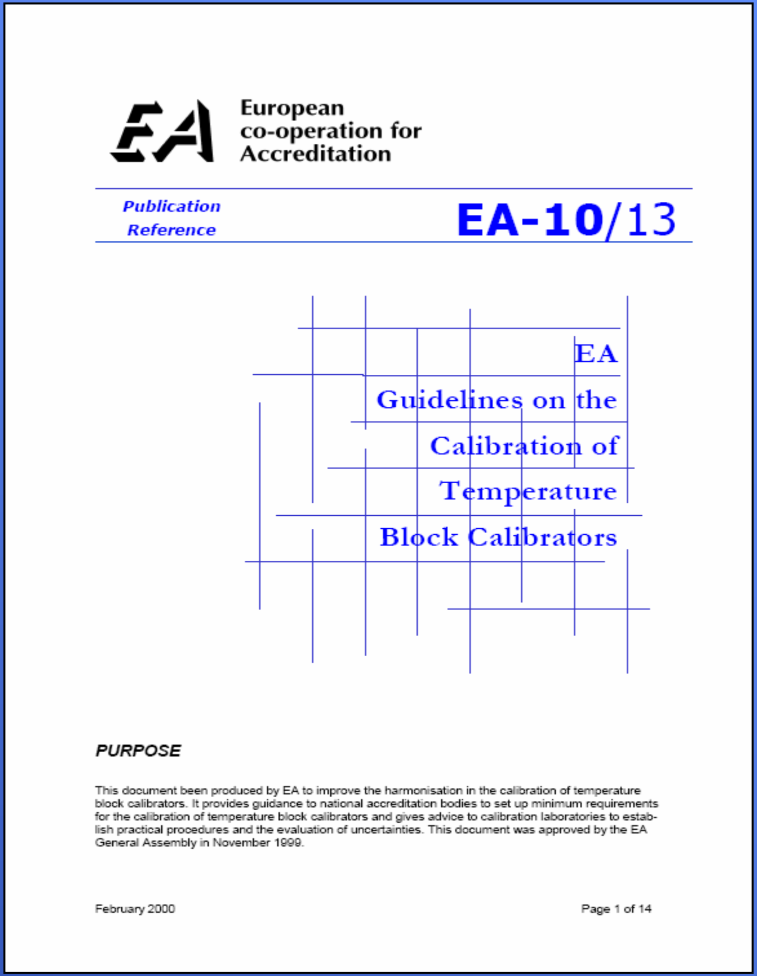
Comparison

Compare high temperature Metrology Wells to dry wells

Combined Uncertainty (°C)				
Temperature	***9173***	***Competitor 1***	***Competitor 2 (*)***	***Competitor 3 (*)***
35°C	n/a	n/a	0.127	0.133
50°C	0.104	0.214	n/a	n/a
275°C	n/a	n/a	0.182	0.176
320°C	0.257	0.630	n/a	n/a
425°C	0.257	n/a	n/a	n/a
550°C	0.408	n/a	0.844	0.349
650°C	0.408	1.019	n/a	n/a

EA Guideline

- EA-10/13 Guidelines on the Calibration of Temperature Block Calibrators
- ASTM guidelines are being written
  Hart's Tom Wiandt on this committee
- Several NMI's have published or are revising their guideleines



European co-operation for Accreditation

Publication Reference **EA-10/13**

EA
Guidelines on the
Calibration of
Temperature
Block Calibrators

PURPOSE

This document been produced by EA to improve the harmonisation in the calibration of temperature block calibrators. It provides guidance to national accreditation bodies to set up minimum requirements for the calibration of temperature block calibrators and gives advice to calibration laboratories to establish practical procedures and the evaluation of uncertainties. This document was approved by the EA General Assembly in November 1999.

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EA Guideline

- One of first Guidelines available
- Approved by EA General Assembly in 2000

  Document available free of charge from

  www.european-accreditation.org
- Provides technical and procedural guidelines and a suggested method for calculating uncertainty

EA-10/13 is not a standard it is a suggested guide to assessors and laboratories seeking European Accreditation