RTD Calibration: Why, When, and How

Bill

If you are experiencing audio problems
please call the teleconference number below

1-408-600-3600
Access code 933 072 339

Bill Bergquist, Sr. Applications Engineer
Jeff Wigen, National Account Manager

Jeff

What we will discuss

Terminology

What is calibration

- Why
  - Initial
  - Ongoing
- When
  - Sensor drift
  - Environment
  - Risk mitigation
- How
  - Temperature scales
  - Equations
  - Options
  - Methods

Calibration Equipment & Software

Terminology

- ITS-90 = International Temperature Scale of 1990
- IPTS-68 = International Practical Temperature Scale
- TPW – triple point of water 0.01°C or 273.16 K
- R_0 = resistance at 0°C
- SPRT = standard platinum resistance thermometer
- Dewar = insulated container
- IR = insulation resistance →
- K – Kelvin temperature scale (used for ITS-90)
- mK or milliK = .001 K
- NIST – National Institute of Standards and Technology
- NVLAP – National Voluntary Laboratory Accreditation Program
  - A2LA – American Association for Laboratory Accreditation

What is Calibration?

4

Calibration is performed to verify sensor/instrument performance.

Calibration is the process used to insure that a sensor/instrument maintains specification over time and changing ambient conditions.

Calibration is the process used to maintain traceability of parameters with reference to national/international standards.

Why

5

Initial Calibration

- New plant or equipment commissioning
- Verify vendor data – shipping and installation damage
  - Insure accuracy of measurements
- Recording data

Ongoing Calibration

- Minimize and control random and systematic errors
- Compare and complement the quality and reliability of measurements by comparison to international standards
  - Provide traceability to national standards, (e.g. NIST)
  - Meet Regulatory Requirements (FDA, NRC)
- Quality System requirements
  - Ensure consistent product quality
  - Safety
- Cost
  - Poor accuracy = wasted $$

Calibration should be performed when starting up a new facility or if a new piece of equipment is added. This insures that the instruments have not been damaged during shipping or installation and provides a baseline for comparison to subsequent calibrations.

How

7

Two types of RTD calibration

- Characterization
  - Calibrate at several temperatures and use equations for R vs. T
- Tolerance check
  - Compare resistance to defined R vs. T such as IEC 60751 or ASTM 1137
- Rule of thumb
  - If your minimum uncertainty of measurement is less than .1C you will want to use ITS-90. Otherwise you can use IPTS-68.

RTDs are calibrated to generate an R vs. T table or to determine if they are within a predefined tolerance. There is no adjustment to an RTD after it is built so any calibration is a check of the resistance at a given temperature.

How - Temperature Scales

Evolution of standard temperature scales

- IPTS-27 IPTS-48 IPTS-68 ITS-90

ITS-90 (International Temperature Scale)

- Released in 1990
- The official international scale
- In better agreement with thermodynamic values than the IPTS-68

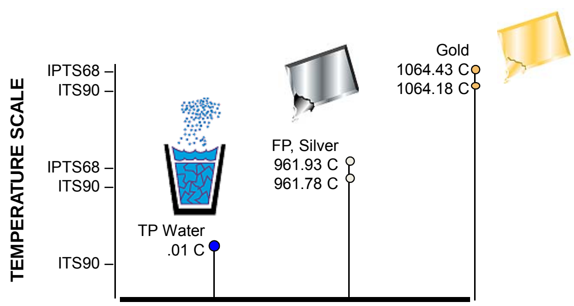
ITS-90 vs. IPTS-68

- ITS-90
  - Uses TPW
  - Most accurate
  - Complex equations
- IPTS-68
  - Simpler equations
  - Less accurate
  - Callendar-Van Dusen equation

In 1927 the International Bureau of Weights and Measures determined that a better standard was required for temperature and the International Practical Temperature Scale was born.

Since then, about every 20 years the scale has been refined to improve accuracy. The last revision occurred in 1990, the name changed to International Temperature Scale and the equations defining the R vs. T relationship were adjusted again for accuracy.

How - Temperature Scales



ITS90 has become more accurate at defining key temperature points than IPTS-68 as shown.

How - Equations

Callendar-Van Dusen Equation

$$R/Ro = 1 + \alpha [T - \delta (T/100 - 1) - \beta (T/100 - 1) (T/100)^3]$$

T = temperature (C)
R = resistance at temperature T
R_0 = resistance at the ice point
α = constant (gives the linear approximation to the R vs. T curve)
δ= constant
β= constant (b = 0 when T is >0 C)
The actual values for the coefficients,α, δ, and β are determined by testing the RTD at four temperatures and solving the equations.

IPTS-68 is still used for industrial applications because it is simpler to apply and still gives acceptable accuracy for numerous processes.

How - Calibration Options

11

Factory Calibration Options

- Matched Calibration
  - Matched with other probes
  - Matched to a transmitter
- Multiple Point Calibration
  - -196, -38, 0, 100, 200, 300, and 420 °C
- Matched to a Temperature Readout (meters)

Calibrating an RTD and adjusting the readout or transmitter accordingly is a cost effective method to improve measurement system accuracy. This eliminates most of the RTD interchangeability tolerance and can also minimize other instrument errors inherent in the system.

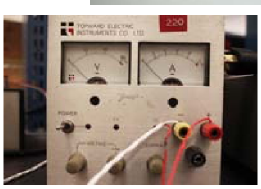
How – Calibration Options

12

Transmitters

Matched to RTD

- Improved system accuracy



Some of the equipment required for matching an RTD to a transmitter:
-Software and interface for PC programmable transmitters
-Decade box and ammeter for analog transmitters with adjustment potentiometers.

How - Methods

13

Methods of calibration

- Fixed point
- Comparison
  - Laboratory
  - Field

We'll look at two methods of calibrating an RTD. Of these, the comparison method is the most cost effective and widely used for industrial RTDs.

Fixed Point Calibration

Low level of uncertainty; i.e. 0.0002 °C reproducibility
Very Expensive ($3-5K)
Range: -259°C to 962°C
Hydrogen triple point to Silver freeze point
Fixed Point Cell

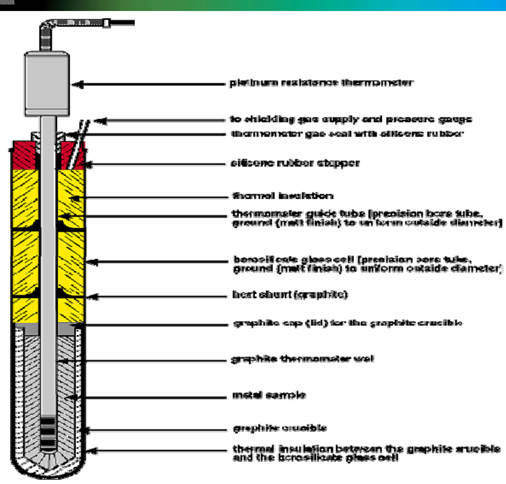
- High purity material, > 99.999% pure
- Sealed at standard pressure or open
- Quartz & Graphite construction

Fixed point calibrations are used for primary temperature standards to achieve the lowest possible uncertainties. It is a time consuming method and requires the use of expensive fixed point cells.

ITS-90 Fixed Points

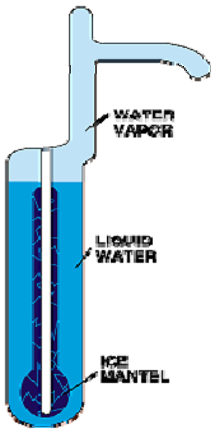
Material	Equilibrium State	Temp.(K)	Temp.(C)
equilibrium Hydrogen (e-H2)	TP	13.8033	-259.3467
Neon (Ne)	TP	24.5661	-248.5939
Oxygen (O2)	TP	54.3582	-218.7916
Argon (Ar)	TP	83.8058	-189.3442
Mercury	TP	234.3156	-38.8344
Water (H2O)	TP	273.16	0.01
Gallium (Ga)	MP	302.9146	29.7646
Indium (In)	FP	429.7485	156.5985
Tin (Sn)	FP	505.078	231.928
Zinc (Zn)	FP	692.677	419.527
Aluminum (Al)	FP	933.473	660.323
Silver (Ag)	FP	1234.93	961.78

Fixed Point Cell



Triple-Point-of-Water Cell

17



The triple point of water (TPW) cell may be the most commonly used type of fixed point and is used in ITS-90 calibrations. Water can exist as a solid, liquid, and vapor at 0.01°C and this device creates this temperature.

Comparison Calibration

18

Most common method

Comparison of unknown to known sensors

Multiple sensors can be calibrated at the same time

Equipment

- Meter, Standard PRT, Recorder, etc. (system)
  - All add to uncertainty level
- The standard PRT should have an accuracy at least four times greater than the unit under test

Comparison Calibration

19

More practical and less expensive than fixed point temperature calibration

Laboratory

- Typical uncertainty: 0.001°C to 0.01°C
- Very high accuracy reference resistance bridge, standard PRT, calibration baths, etc.
  - Uses some fixed point temperatures

Field

- Typical uncertainty: 0.05 to 0.5°C
- Accurate reference meters, secondary PRTs, baths or dry-wells
- Instruments are field compatible

Comparison calibrations can be performed in a laboratory or in the field. High accuracy can be obtained with careful selection of equipment. Durability is as important as accuracy when used for field calibrations. Equipment that cannot stand up to field use will drift quickly and not provide the expected measurement uncertainties.

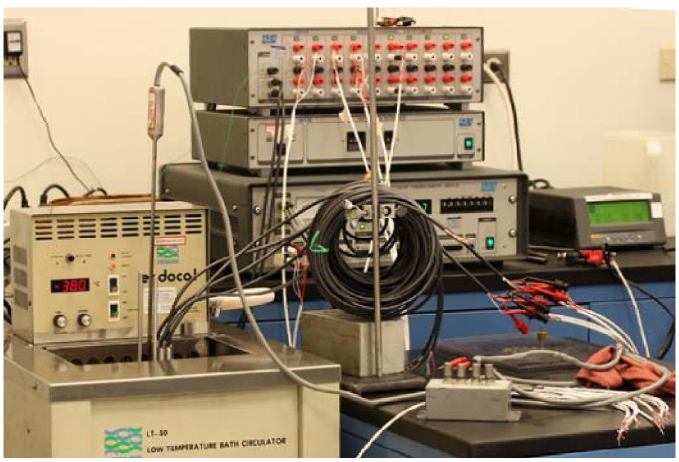
Calibration System

Standard and Secondary PRTs
Fluid bath, Metal (hot) block
Fixed Point Cell (triple pt. of H20)
Data Acquisition System

- Standard Resistor, Thermometry bridge

Typical equipment used for comparison calibration is a standard or secondary PRT, several temperature baths, and a data acquisition system.

Typical Comparison System Setup



This set-up features a -38C bath with a primary standard and test units, AC thermometry bridge, switchbox, and off the screen is a PC with data acquisition software.

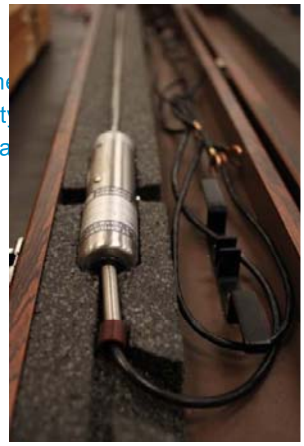
Equipment

A variety of equipment used for comparison calibration. Some equipment requires close control of ambient conditions for best accuracy. The lower right photo shows a temperature and humidity gauge with alarm and graphing history.

Standard PRTs

Specifications

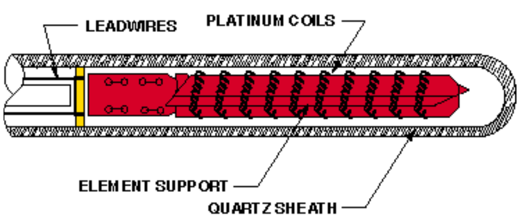
- Very fragile
- Use mainly in laboratory environme
- Highest accuracy, high repeatabilit
- -328 to 1983°F (-200 to 1084°C), a ±.0018°F (±.001°C)



This is NOT the type of device to use for field calibrations. It is extremely fragile and very expensive, about $10k with calibration.

Anatomy of an SPRT

Cross section

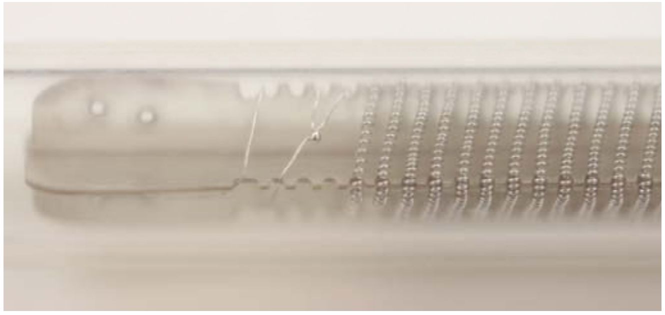


The insides of an SPRT. As you can see, the element coils appear very fragile and they are when supported in this manner. This is necessary to prevent any strain on them which will cause a shift in resistance.

Anatomy of an SPRT

Photo of an SPRT element inside its quartz sheath.

Anatomy of an SPRT



A little closer look.

Anatomy of an SPRT

Yes, the quartz sheath does break very easily and is one of the few things duct tape won't fix!

Secondary SPRT

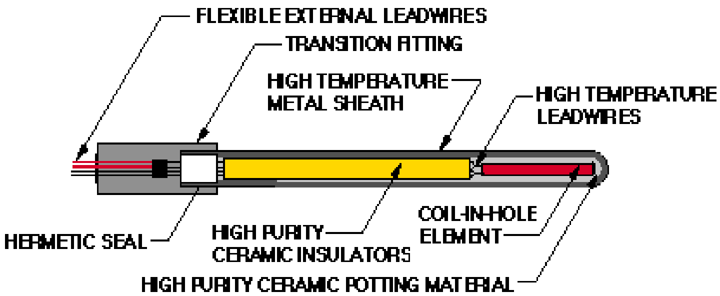
Specifications

- Can withstand some handling, although still fragile
- Very low hysteresis
- Laboratory and industrial environments
- Uses more cost-effective materials than Standard PRT
- -328 to 932°F (-200° to 500°C), Calibrated uncertainty of ±.063°F (±.035°C), K=2. Accuracy is ±.02°C at 200°C

The secondary standard is much more user friendly and can survive mild handling mishaps. It is less expensive than an SPRT typically around $1k with calibration.

Secondary SPRT

Cross Section



The insides are made from high purity ceramics sheathed with Inconel 600 tubing.

Secondary SPRT

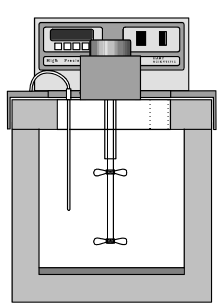
Sensor Specifications

- High Accuracy ±0.02 °C
- Hysteresis < 0.01 °C at 0 °C
- Annual Drift in use Up to 200 °C is 0.01 °C
- 9 second time constant

You do lose a little performance over the SPRT but for most comparison calibrations of industrial RTDs the secondary standard easily provides a 4x or even 10x accuracy over that of the test units.

Fluid Calibration Baths

Range: -80°C to 550°C
Fluids: Alcohol, Water, Silicon Oil, Salt
Stability: < ±0.001°C to ±0.05°C
Working depth: 12" to 18"
Working diameter: 4" or Larger



Front

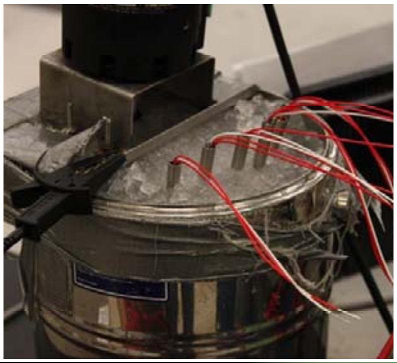
Baths typically have a stirring motor to help even out any temperature gradients.

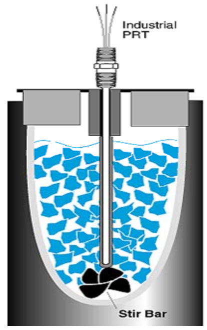
Ice Bath Calibration

32

Easy to Produce

Accuracy to ±.005°C (±.009°F)





The ice bath is the easiest and most accurate method of checking an RTD. Addition of a stirring motor insures even temperature throughout the insulated Dewar.

Ice is made from pure water, crushed, and packed into the Dewar. Purified water is added to fill in the gaps. Too much water and the ice will float which is not desirable.

Metal (hot) Block Baths

33

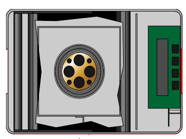
Range: -30°C to 700°C

Stability: ±0.02°C to ±0.05°C

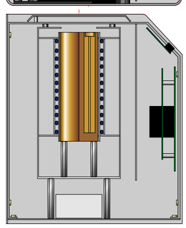
Working depth: 6”

Portable

Top View



Side View



A useful field calibration instrument that can be used for comparison calibration or read directly from the temperature display. They are rugged and portable.

Thermometer Readout

34

A readout device is needed to display temperature when performing a calibration

A typical readout device for field or laboratory use.

Lab Accuracy

Accreditation
Uncertainty
Scheduling

NVLAP® National Voluntary Laboratory Accreditation Program

SCOPE OF ACCREDITATION TO ISO/IEC 17025:2005

Burns Engineering Inc.
10201 Bren Road East
Minnetonka, MN 55343-9007
Mr. Chuck Bragg
Phone: 952-567-6427 Fax: 952-935-8782
E-mail: cbragg@burnsengineering.com
URL: www.burnsengineering.com

CALIBRATION LABORATORIES — **NVLAP LAB CODE 200706-0**

NVLAP Code: 20/A01 — ANSI/NCSL Z540-1-1994; Part 1 — Compliant

THERMODYNAMICS

NVLAP Code: 20/T07
Resistance Thermometry

Range in °C	*Best Uncertainty (±) in mK*	*Remarks*
High Quality PRT by comparison to SPRT		
-196	5.2	LN2 Bath
-80 to 20	5.1	Refrigerated Liquid Bath
0/0.01	3.4	Ice Bath
20 to 250	6.9	Heated Fluid Bath
250 to 500	17	Salt Bath
Digital Thermometer with PRT System by comparison with SPRT		
-196	5.2	LN2 Bath
-80 to 20	5.1	Refrigerated Liquid Bath
0/0.01	3.4	Ice Bath
20 to 250	6.9	Heated Fluid Bath
250 to 500	17	Salt Bath

2010-10-01 through 2011-09-30
Effective dates

Sally S. Bruce
For the National Institute of Standards and Technology

When using an outside lab for calibrations you can review their accreditation documents to see what uncertainty they offer. This shows a NVLAP accreditation and uncertainties ranging from 3.4 to 17 mK.

Also inquire about scheduling calibration to minimize your down time. Other things that are nice are reminders of calibration due date, and online access to calibration reports. They always seem to get lost.

Software

Calibration software
- Variety of software solutions
- DIY or partner with calibration provider
- Alert when calibration is due – plan and schedule
  - Minimize downtime

Accuracy of calibration equipment
- Requires regular calibration
  - Follow manufacturer's recommendations as a minimum

Summary

ITS-90, IPTS-68
- ASTM-1137, IEC-60751
- CVD – Calendar-Van Dusen

Calibrate to improve accuracy
- Comparison to standards
- Match transmitter to RTD
- Efficient energy usage and quality product

Traceability to standards
- Satisfy third party agencies

Maintain quality and safety

Equipment
- Equipment used limits sensor styles that can be tested

BURNS ENGINEERING

Thank you for attending!

Questions?

Use the chat window to send us a question now

Contact us later at 800-328-3871
or visit www.burnsengineering.com

BURNS ENGINEERING

BE educated

Join our Temperature Measurement Community

News: www.burnsengineering.com/BEnews/
Twitter: TempTalk
LinkedIn: Temperature Measurement Group

→ TempTalk on Twitter
twitter

→ Our Group on LinkedIn
LinkedIn

© Burns Engineering
Calibration: Why, When, and How
RTDology™