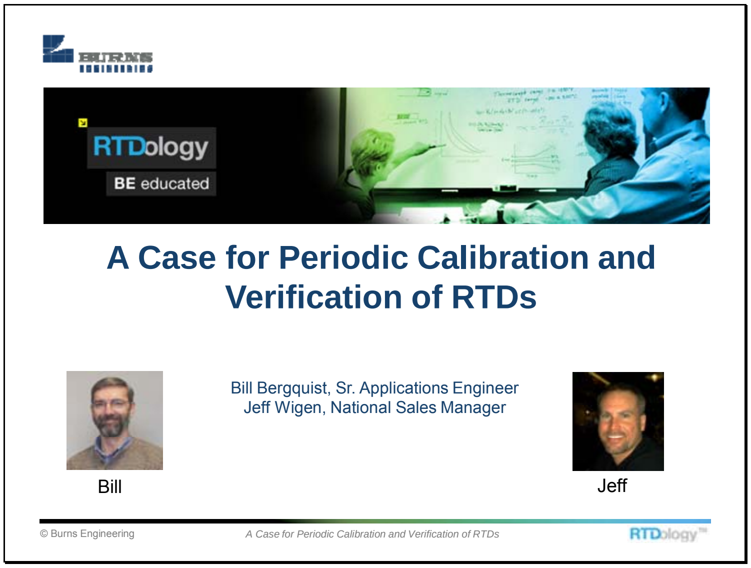


RTDology
BE educated

A Case for Periodic Calibration and Verification of RTDs

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

Bill

Jeff

What We'll Cover

- Terminology Refresher
- What is Calibration? Verification?
- Why you should do it
- When you should do it
- How exactly do you go about doing it

Terminology Refresher

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
R0 = 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

These are a few of the more common terms that are thrown around when talking about RTD calibration.

What is Calibration? Verification?

Calibration:

- Calibration is performed to verify sensor/instrument performance and characterize the R vs. T relationship
- Usually involves adjustment of the instrument however there typically is no adjustment to an RTD (can adjust the instrument to which it is connected)
- Maintain traceability of parameters with reference to national/international standards

Verification:

- A check of the RTD to see if it meets the ASTM E1137 or IEC 60751 standard R0, IR, and interchangeability tolerances
- Can be performed in the lab or field by comparison to a temperature standard, or measured with DMM

The term calibration is commonly used to describe the process of characterizing the resistance vs. temperature of an RTD although the process is not truly a calibration because no adjustments can be made to the RTD. The term characterization is more accurate.

A simpler form of this check is the verification process which includes a check at 0°C, and insulation resistance (IR) to see if the RTD performance falls within the ASTM and/or IEC standards.

A Case for Periodic Calibration/Verification

- No regular maintenance schedule for the measurement point
- Sensor began giving erratic readings
- Wasted energy
- Questionable product quality
- How long had this been a problem? Nobody knows for sure.

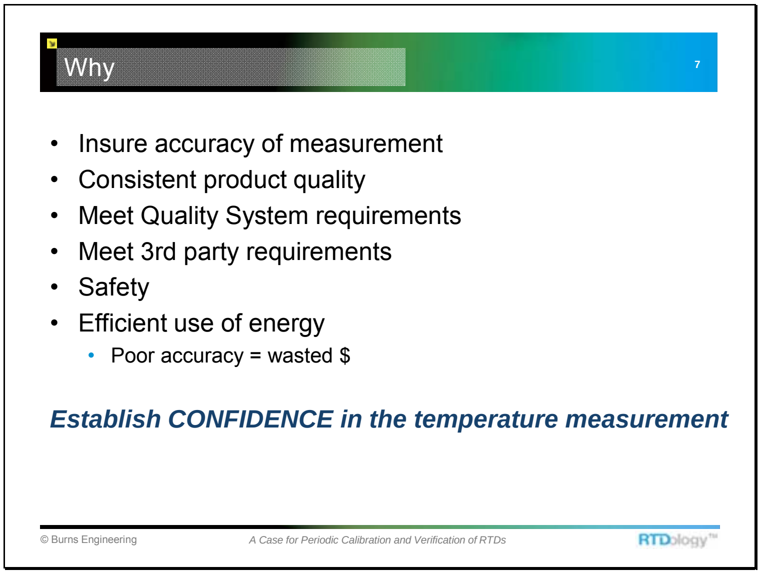
More than once I have heard the story of how the measurement point had been neglected because it had always worked okay and so it became ignored. That is, until one day it fails or the product quality is compromised. Then the hunt is on to find the problem. Down-time, trouble shooting, ruined or questionable product, part replacement, lost productivity, and on and on all add up to a large expense. Periodic verification of the RTD can prevent all that.

Energy Cost and RTD Accuracy

Process Fluid:	**Water**
Flow Rate:	**50 GPM**
Control Temperature:	**100 °F**
Energy Cost:	**6¢ / KW-hour**

Annual Cost of Energy Per °F Error
$3600

Verifying the RTD performance ensures high accuracy, product quality, and efficient use of your energy dollars.

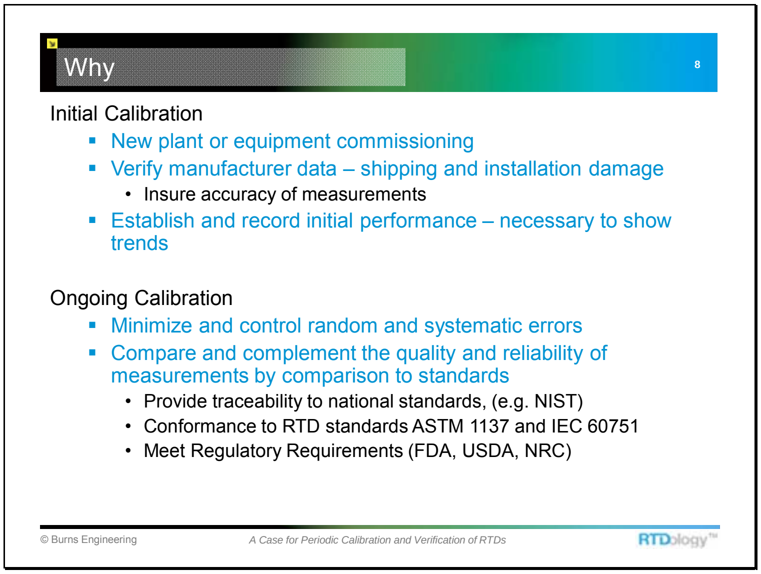


Why

- Insure accuracy of measurement
- Consistent product quality
- Meet Quality System requirements
- Meet 3rd party requirements
- Safety
- Efficient use of energy
  - Poor accuracy = wasted $

Establish CONFIDENCE in the temperature measurement

Accuracy can never be known with absolute certainty. It’s all about establishing your confidence in the accuracy of the measurement.



Why

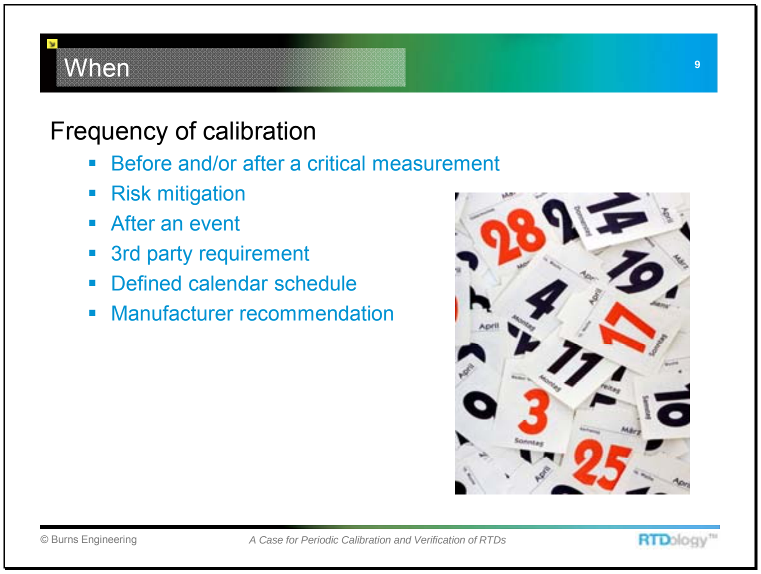
Initial Calibration

- New plant or equipment commissioning
- Verify manufacturer data – shipping and installation damage
  - Insure accuracy of measurements
- Establish and record initial performance – necessary to show trends

Ongoing Calibration

- Minimize and control random and systematic errors
- Compare and complement the quality and reliability of measurements by comparison to standards
  - Provide traceability to national standards, (e.g. NIST)
  - Conformance to RTD standards ASTM 1137 and IEC 60751
  - Meet Regulatory Requirements (FDA, USDA, NRC)

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

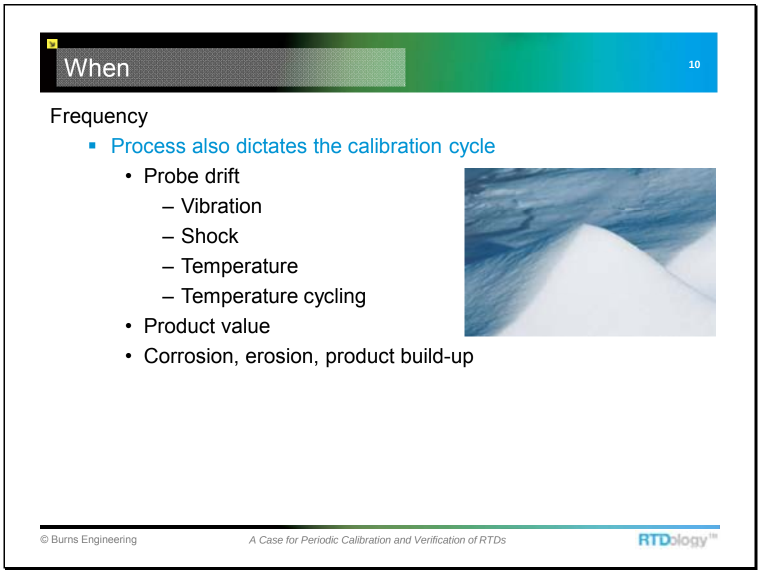


When

Frequency of calibration

- Before and/or after a critical measurement
- Risk mitigation
- After an event
- 3rd party requirement
- Defined calendar schedule
- Manufacturer recommendation

When? -- is one of the most frequently asked questions about calibration. There is no single answer for when; it all depends on the process and comfort level of the invested parties. Process conditions that affect the probe drift rate and the product value are the two main considerations. Consult with the manufacturer(s) of your system and they should be able to help you estimate the long term accuracy of their equipment based on your process conditions. After that it’s up to you to pick a frequency that meets your comfort level and that of any 3rd party watch-dogs that oversee your production facility. You may decide because of product value that a calibration is performed before and after each batch. Then if you desire, after 5 cycles are completed without a significant shift, the calibration cycle be doubled.

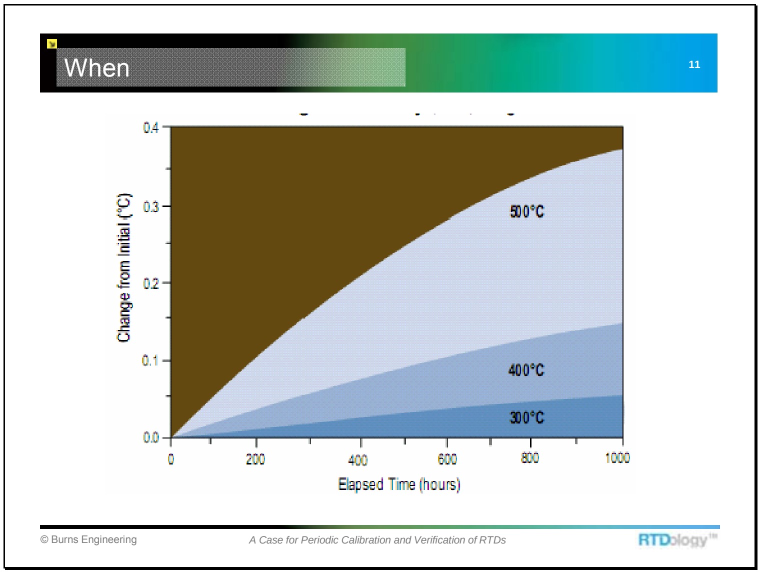


When

Frequency

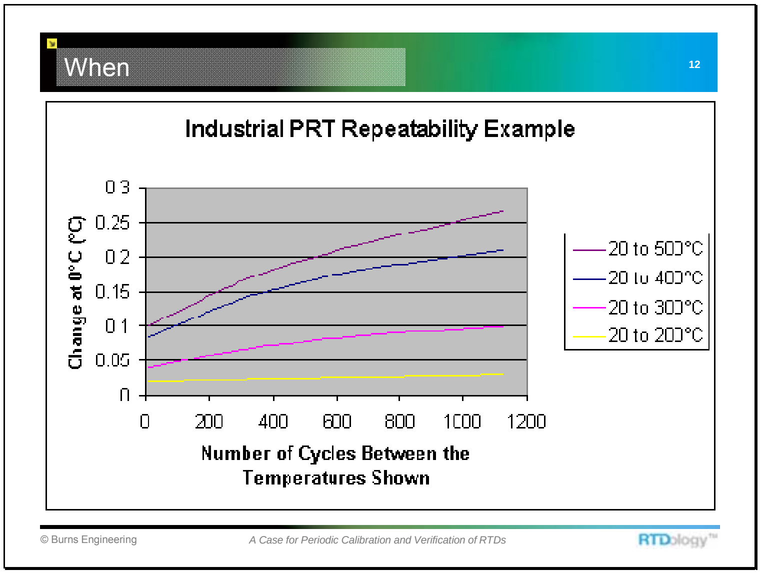
- Process also dictates the calibration cycle
  - Probe drift
    - Vibration
    - Shock
    - Temperature
    - Temperature cycling
  - Product value
  - Corrosion, erosion, product build-up

As certain as snowdrifts in January at the Burns factory in Minnesota; RTDs will drift over time. The amount depends on how the probe is used. Vibration, shock, temperature cycling, probe design, and service temperature have the most influence on the drift rate. Some RTDs can go years without measurable drift, and others may start to drift right away. The only way to know is to calibrate or verify the probe performance.



When

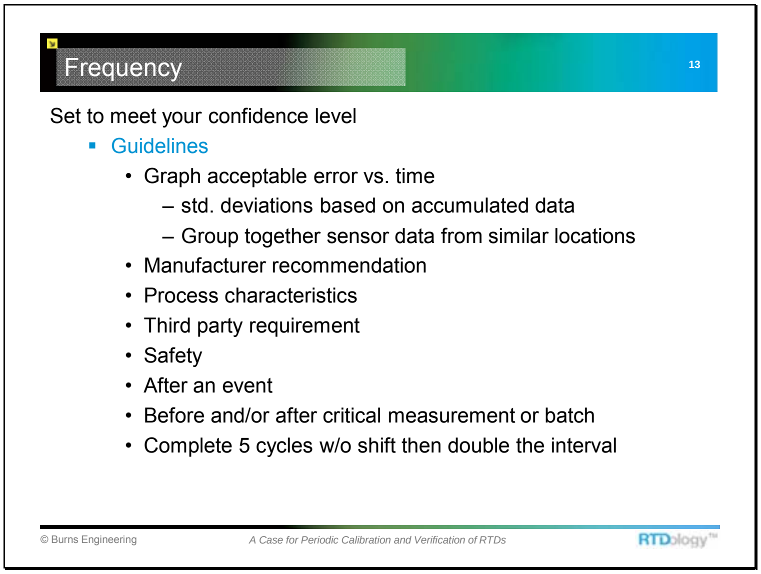
This graph shows the effect of service temperature on the drift rate. Temperatures below 300°C have little effect on the drift rate while higher temperatures can have a more significant effect. At 500°C after 1000 hours the probe can drift up to 0.35°C.



When

Industrial PRT Repeatability Example

Temperature cycling can have an affect on how well the RTD will repeat a measurement. Similar to the drift graph on the previous slide, the higher the temperature the higher the error. Cycling from 20 to 500°C shows repeatability of 0.25°C after 1000 cycles whereas cycling to 200°C shows only 0.03°C.



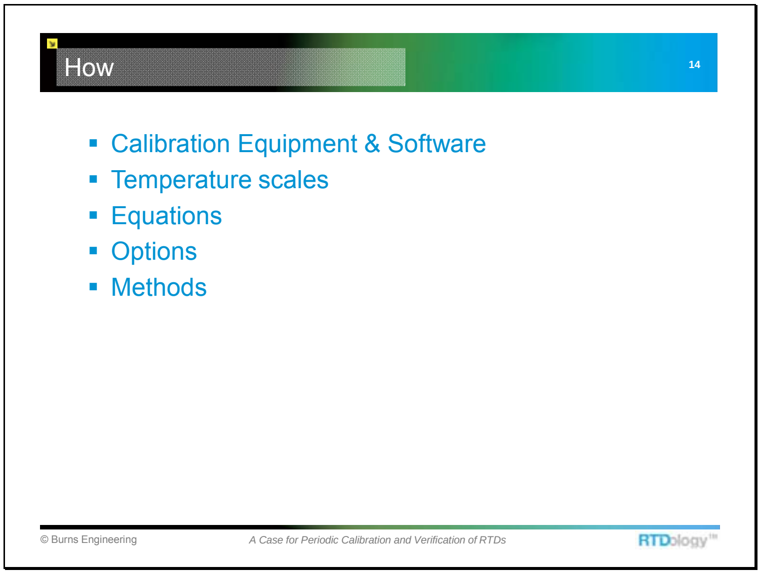
Frequency

Set to meet your confidence level

- Guidelines
  - Graph acceptable error vs. time
    - std. deviations based on accumulated data
    - Group together sensor data from similar locations
  - Manufacturer recommendation
  - Process characteristics
  - Third party requirement
  - Safety
  - After an event
  - Before and/or after critical measurement or batch
  - Complete 5 cycles w/o shift then double the interval

Frequency of calibration or verification is a decision that is made based on the factors listed here and the confidence level desired by you!

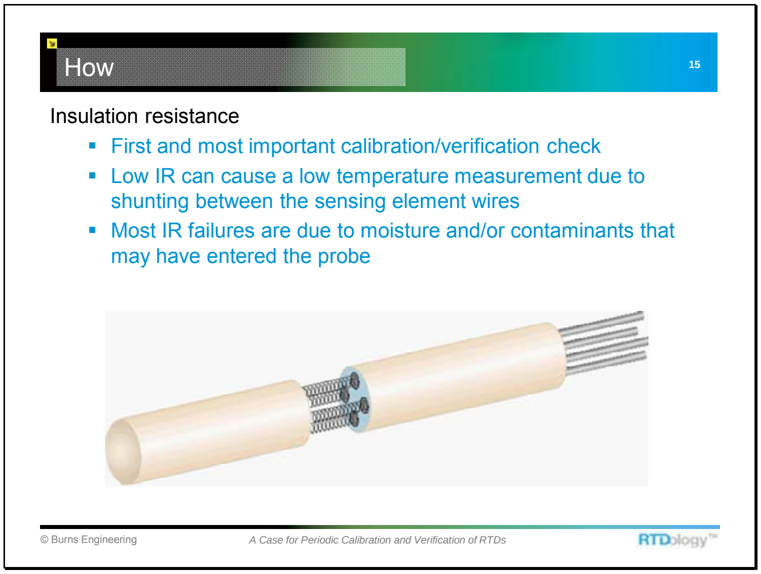
One tool that can help you is to group measurement point data from locations that have similar process characteristics. Construct a graph that shows acceptable error vs. time and select a std. deviation based on the accumulated data. That will give you a rough idea of where you might want to start with calibration frequency.



How

- Calibration Equipment & Software
- Temperature scales
- Equations
- Options
- Methods

Now that we know the “why” of calibration and verification we need to answer the “how” and look at some of the equipment and procedures.

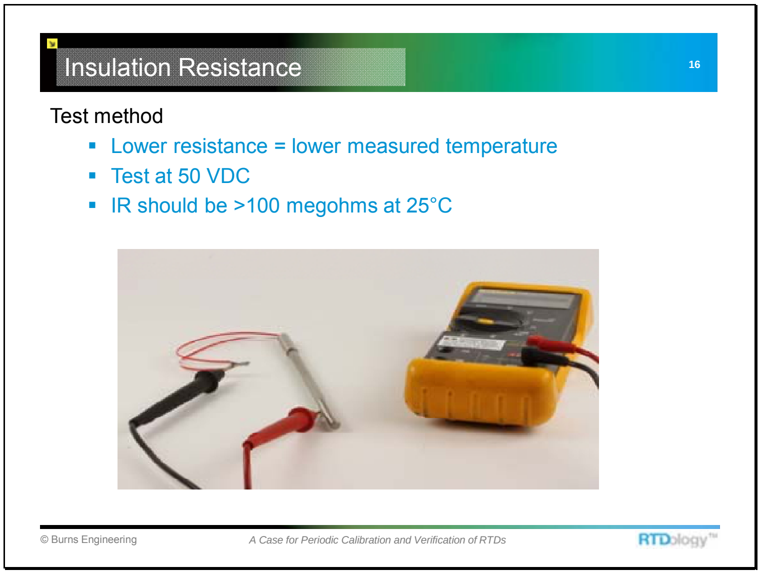


How

Insulation resistance

- First and most important calibration/verification check
- Low IR can cause a low temperature measurement due to shunting between the sensing element wires
- Most IR failures are due to moisture and/or contaminants that may have entered the probe

This is a typical wire wound sensing element. They are about 1" long and 1/16" diameter and are potted inside a stainless steel sheath. If moisture gets into the sheath and sensing element, the result can be a shorter path for the excitation current and the result is a low resistance measurement.

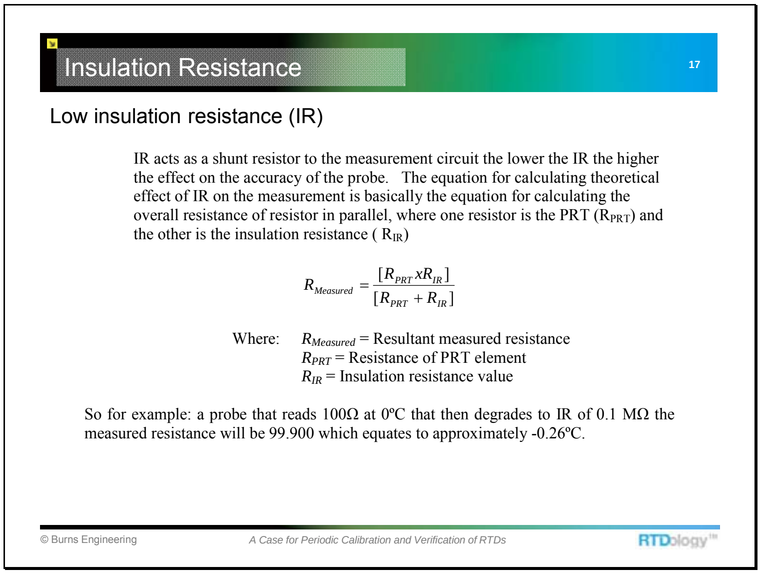


Insulation Resistance

Test method

- Lower resistance = lower measured temperature
- Test at 50 VDC
- IR should be >100 megohms at 25°C

IR decreases with an increase in temperature so at room temperature a value much higher than what is really needed for an accurate measurement is required. Industrial grade RTD accuracy is not significantly affected until the IR drops below a few megohms. The measurement is made by touching one lead of a megohmeter to the RTD leads and the other to the probe sheath. Some industrial grade probes are tested to higher levels to insure maximum performance at high temperatures.



Insulation Resistance

Low insulation resistance (IR)

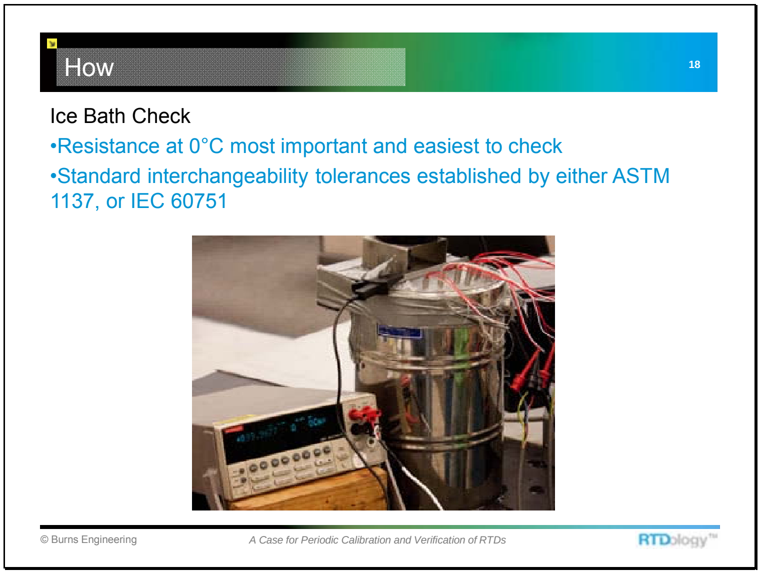
IR acts as a shunt resistor to the measurement circuit the lower the IR the higher the effect on the accuracy of the probe. The equation for calculating theoretical effect of IR on the measurement is basically the equation for calculating the overall resistance of resistor in parallel, where one resistor is the PRT (R_{PRT}) and the other is the insulation resistance (R_{IR})

$$R_{Measured} = \frac{[R_{PRT} x R_{IR}]}{[R_{PRT} + R_{IR}]}$$

Where: $R_{Measured}$ = Resultant measured resistance
R_{PRT} = Resistance of PRT element
R_{IR} = Insulation resistance value

So for example: a probe that reads 100Ω at 0ºC that then degrades to IR of 0.1 MΩ the measured resistance will be 99.900 which equates to approximately -0.26ºC.

For those of you that like a little math with your calibration, this example shows how to calculate the effect IR has on RTD accuracy.

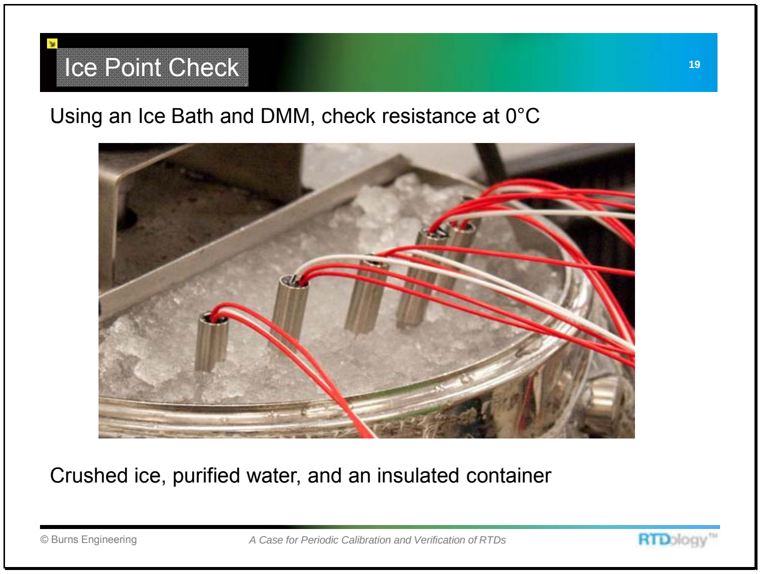


How

Ice Bath Check

- Resistance at 0°C most important and easiest to check
- Standard interchangeability tolerances established by either ASTM 1137, or IEC 60751

An ice bath is the easiest and most important temperature point to check. A properly made ice bath will have an accuracy of ± 0.002°C. How do I make one you ask? Read on…

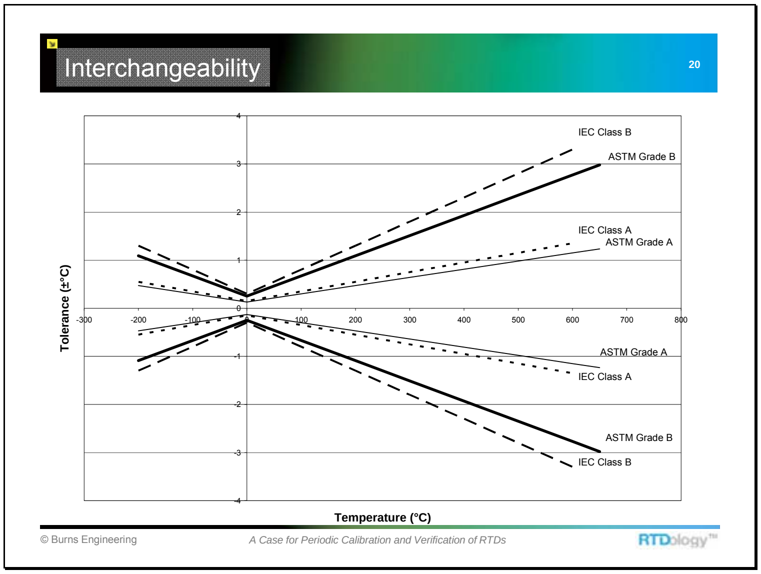


Ice Point Check

Using an Ice Bath and DMM, check resistance at 0°C

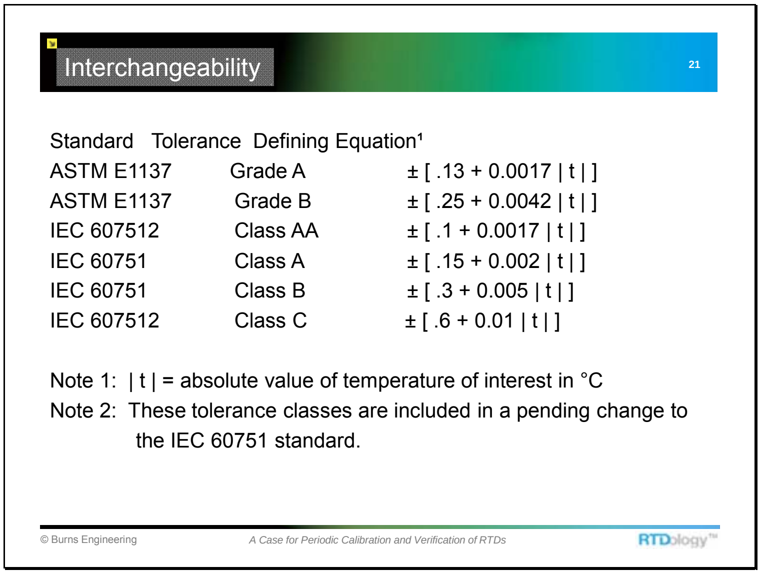
Crushed ice, purified water, and an insulated container

Crushed ice made with purified water is packed into an insulated container. Purified water is added to fill in the gaps. If the ice floats, you have added too much water. Adding a stirring feature to keep the water flowing around the ice minimizes temperature gradients within the bath. Each probe should be immersed at least 4”. Do not use the probe to beat a hole in the ice. You may damage the sensing element. Use a scrap probe or similar rod to form the holes.



Interchangeability

Interchangeability is the performance specification from the RTD standards that determine how closely the RTD matches a nominal R vs. T relationship. Try as we might, RTD manufacturers cannot build everything to exact nominal values. Note that the ASTM standard has slightly tighter tolerances for the two grades of sensors. All RTDs are built with the tightest tolerance at 0°C and as the temperature diverges from 0°C the tolerance increases. The vertical line on the graph represents 0°C and the tolerance on the y axis is expressed in ± °C from nominal.



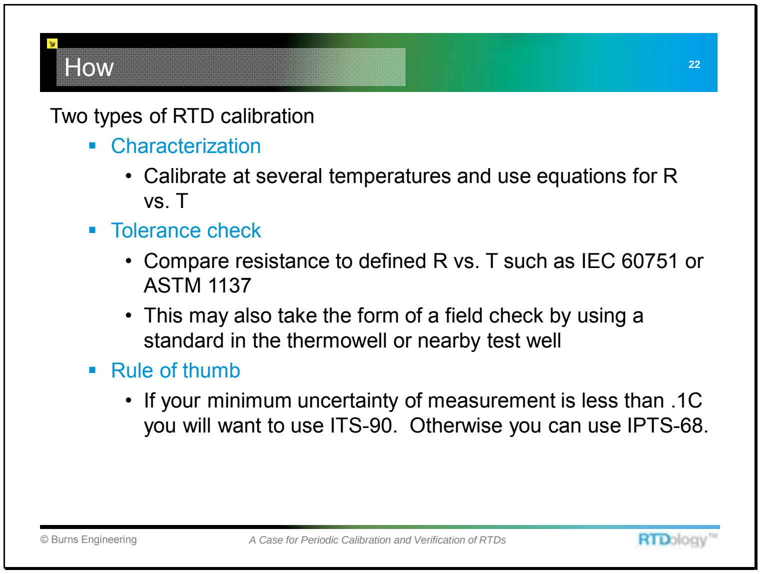
Interchangeability

Standard	Tolerance	Defining Equation[1]
ASTM E1137	Grade A	± [.13 + 0.0017 | t |]
ASTM E1137	Grade B	± [.25 + 0.0042 | t |]
IEC 607512	Class AA	± [.1 + 0.0017 | t |]
IEC 60751	Class A	± [.15 + 0.002 | t |]
IEC 60751	Class B	± [.3 + 0.005 | t |]
IEC 607512	Class C	± [.6 + 0.01 | t |]

Note 1: | t | = absolute value of temperature of interest in °C

Note 2: These tolerance classes are included in a pending change to the IEC 60751 standard.

These equations can be used to calculate the interchangeability at any temperature. Note that the temperature t is an absolute value in °C. The result is the interchangeability in ± °C.

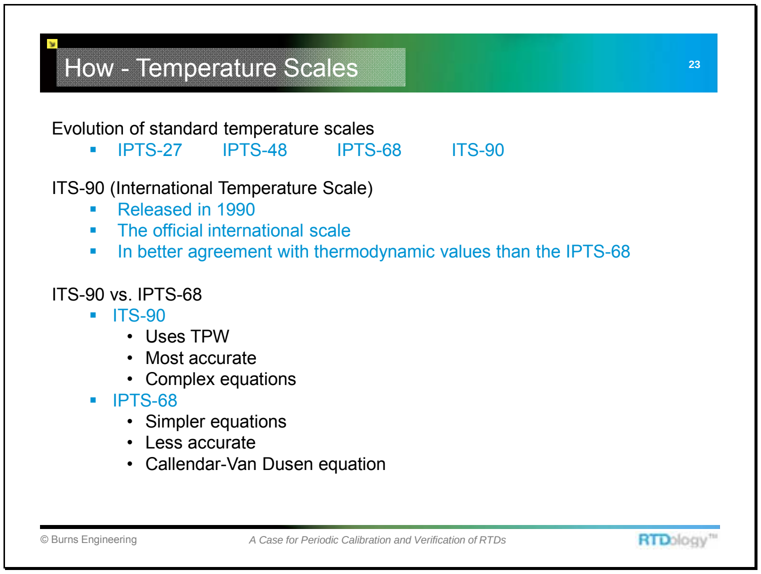


How

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
    - This may also take the form of a field check by using a standard in the thermowell or nearby test well
- 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

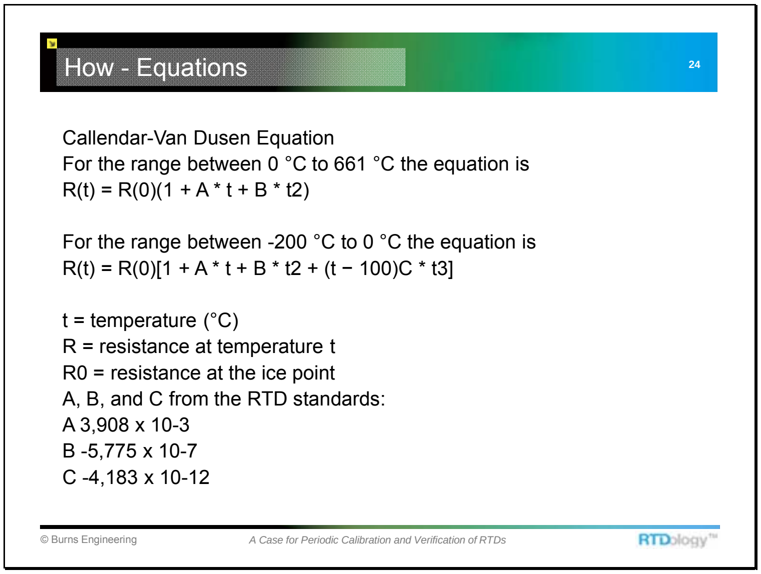
ITS-90 (International Temperature Scale)

- 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

Beginning in 1927 the International Bureau of Weights and Measures decided 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. In 1990 the name changed to International Temperature Scale and the equations defining the R vs. T relationship became more accurate.



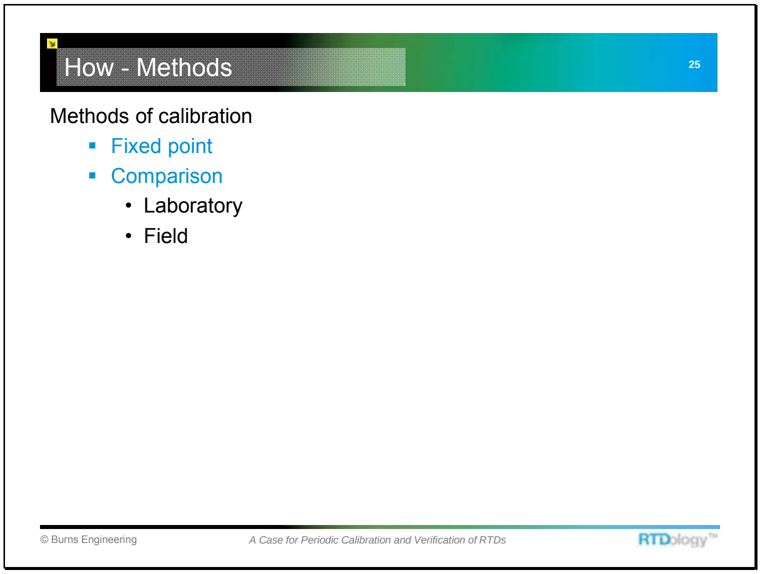
How - Equations

Callendar-Van Dusen Equation
For the range between 0 °C to 661 °C the equation is
R(t) = R(0)(1 + A * t + B * t2)

For the range between -200 °C to 0 °C the equation is
R(t) = R(0)[1 + A * t + B * t2 + (t − 100)C * t3]

t = temperature (°C)
R = resistance at temperature t
R0 = resistance at the ice point
A, B, and C from the RTD standards:
A 3,908 x 10-3
B -5,775 x 10-7
C -4,183 x 10-12

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

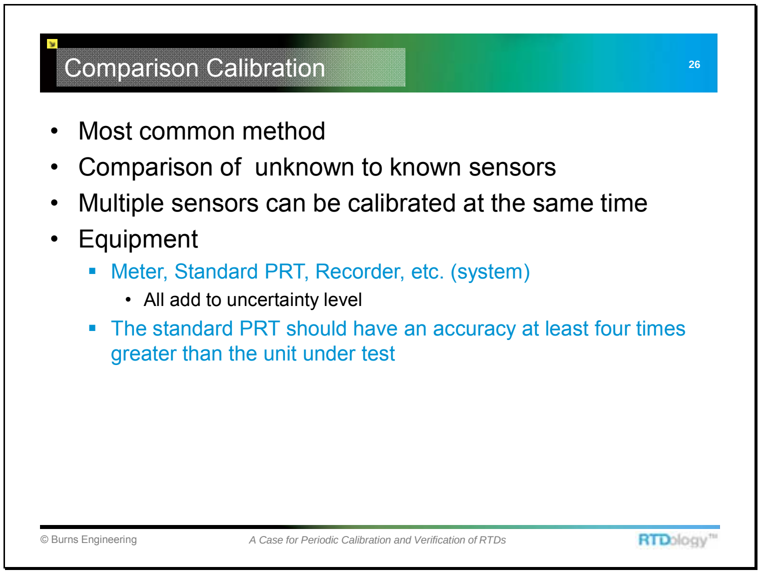


How - Methods

Methods of calibration

- Fixed point
- Comparison
    - Laboratory
    - Field

We'll look at two methods of calibrating RTDs. Of these the comparison method is the most cost effective and usable for most industrial RTDs.



Comparison Calibration

- 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

The most common method of RTD calibration or characterization is to compare it to a temperature standard that has a known uncertainty and traceability to a national standard such as those maintained by NIST. The standard must have at least 4 times better accuracy the test unit and up to 10 times is used frequently by labs.

Comparison Calibration

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

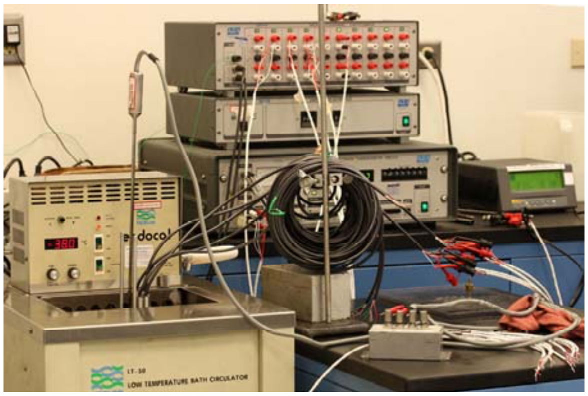
Comparison calibrations can be performed in a laboratory or in the field. High accuracy can be obtained with careful selection of equipment. Durability is as important as accuracy when used for field calibrations. Equipment that cannot stand up to field use will drift quickly and not give the expected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

Calibration System

- Standard and Secondary PRTs
- Fluid bath, Metal (hot) block
- Fixed Point Cell (triple pt. of H_20)
- Data Acquisition System
  - Standard Resistor, Thermometry bridge

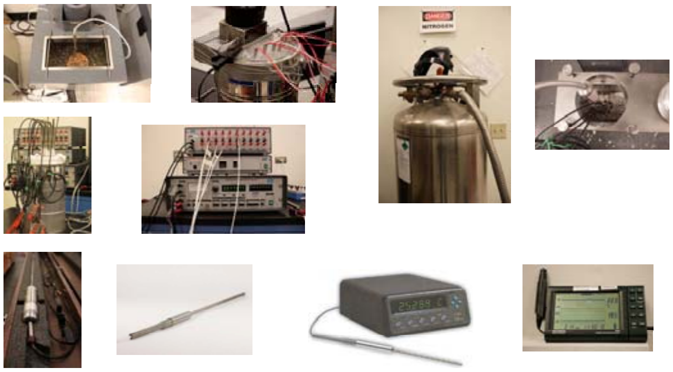
Typical equipment used for comparison calibration is a standard or secondary PRT, several temperature baths, and a data acquisition system.

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

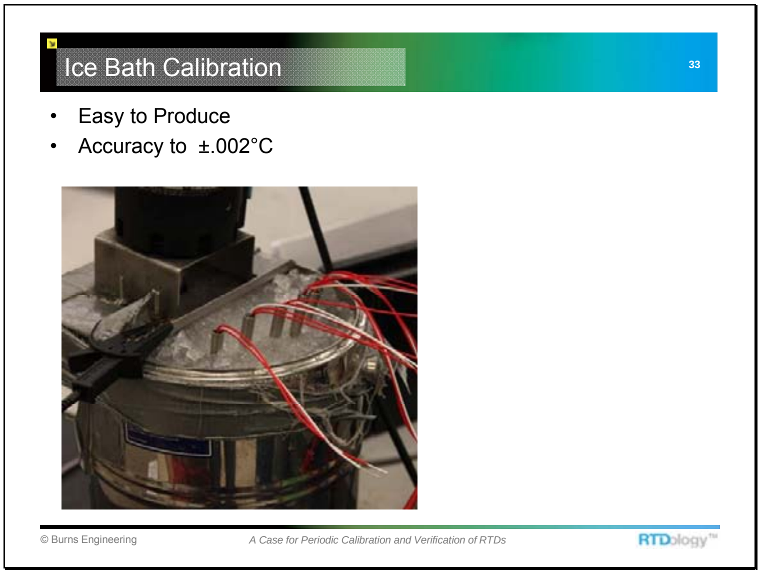
- Very fragile
- Used in laboratory environments
- Highest accuracy, high repeatability, low drift
- -328 to 1983°F (-200 to 1084°C), accurate to ±.0018°F (±.001°C)

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

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

Baths typically have a stirring motor to help even out any temperature gradients. Additional stability can be obtained by installing a metal block with holes in it sitting in the bath to hold the probes. Aluminum or copper are suitable materials for the block.

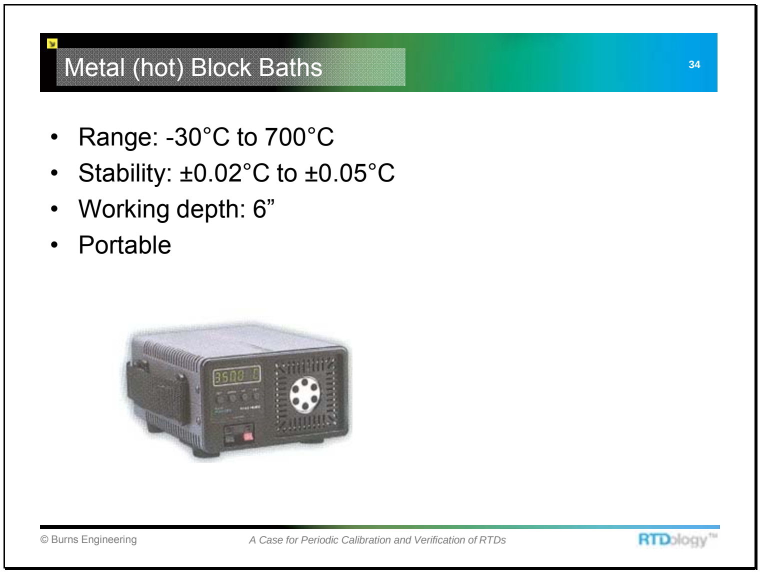


Ice Bath Calibration

- Easy to Produce
- Accuracy to ±.002°C

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.

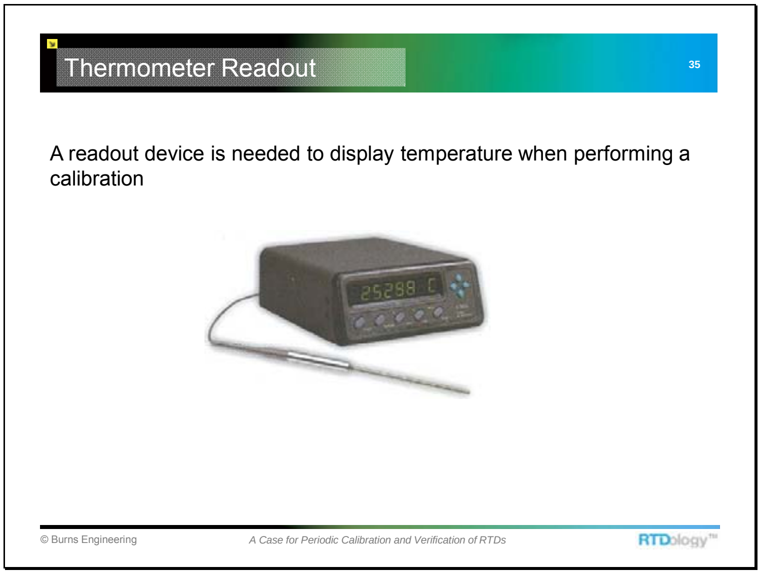
Ice is made from pure water, crushed, and packed into the Dewar. Purified water is added to fill in the gaps. Too much water and the ice will float which is not desirable.



Metal (hot) Block Baths

- Range: -30°C to 700°C
- Stability: ±0.02°C to ±0.05°C
- Working depth: 6”
- Portable

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

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

A typical readout device for field or laboratory use.

How - Calibration Options

Factory Calibration Options

- Matched Calibration
  - Match RTD to a transmitter
  - Matched to a Temperature Readout
- Multiple Point Calibration
  - -196, -38, 0, 100, 200, 300, and 420 °C

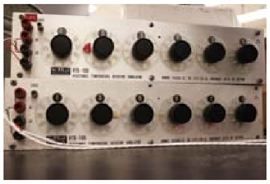
Calibrating an RTD and adjusting the readout or transmitter accordingly is a cost effective method to improve measurement system accuracy. This eliminates most of the RTD interchangeability tolerance and can also minimize other instrument errors inherent in the system.

How – Calibration Options

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.

Outside Calibration Service

Accredited Lab – such as A2LA, NVLAP

- Defined QA program
- Training
- Documentation

Complete solution

- RTDs
- Transmitters
- System

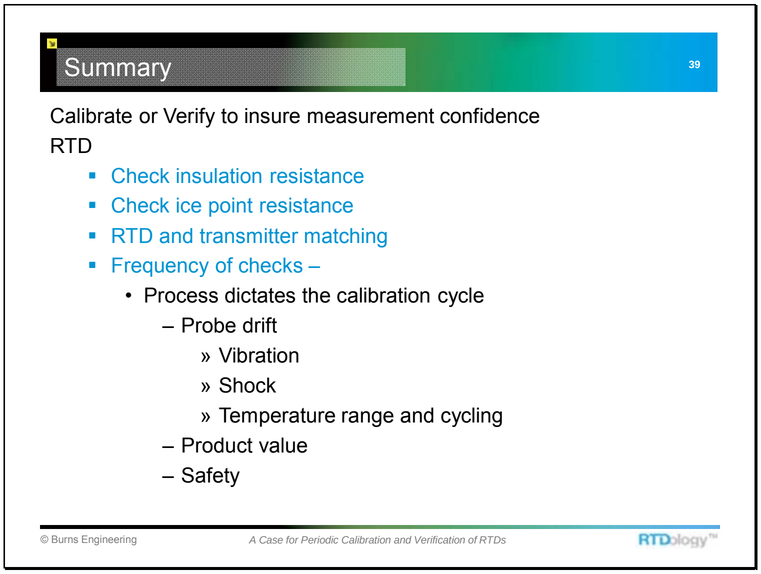
Scheduling

Experience

Support

Guarantee

Choosing a suitable lab can require some digging. Make sure they are accredited, their uncertainties match your needs, and that they can schedule the service to minimize your down time.



Summary

Calibrate or Verify to insure measurement confidence

RTD

- Check insulation resistance
- Check ice point resistance
- RTD and transmitter matching
- Frequency of checks –
  - Process dictates the calibration cycle
    - – Probe drift
      - » Vibration
      - » Shock
      - » Temperature range and cycling
    - – Product value
    - – Safety

A reasonable interval for making the calibration checks must be determined in collaboration with the RTD manufacturer and the process engineer.

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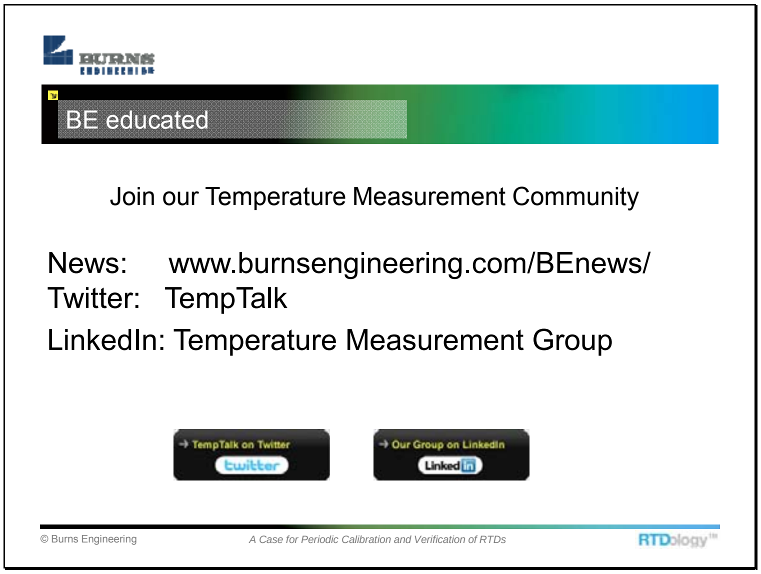
Thank you for attending!

Questions?

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



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