random NEWS

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An occasional
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HART SCIENTIFIC

Jim Triplett,
Chairman and CEO

Do You Know the Origins of the Y2K Question?

By Jim Triplett, Chairman and CEO

Did you know that there are galaxies in our universe that are more than 10 billion light-years apart? That's a really, really long way. Given the billions of light-years between these galaxies, one can only imagine how big the "big" was in the Big Bang. I've read papers saying the temperature at the exact moment of the bang was 5 billion degrees. That's hot, really hot!

However, I couldn't tell exactly how hot "hot" was because this particular author didn't specify if it was 5 billion degrees Celsius, Fahrenheit, or Kelvin. I was conflicted.

The conversion formula °C=K–273.15 is relatively simple. Now, subtracting 273.15 from 5 billion leaves you with… 5 billion mostly. So if it's 5 billion °C, it's a shade warmer than 5 billion K. Okay, I can live with that!

see JIM on page 12

Is Your Thermometer Accurate?

By Mingjian Zhao, Metrology Engineer, and Chris Juchau, Vice President

Whether you need a reliable reference thermometer for comparison calibrations or simply need to monitor a process very closely, the evaluation of a good thermometer seems to always come down to one question: "How accurate is it?"

The word "accurate" itself is ambiguous. While ±1°C may be accurate for some situations, others may require ±0.001°C or better. "Accuracy" is also a difficult concept because most metrologists reject it in favor of the preferred term "uncertainty." (Here we'll use the term "accuracy" since that still seems to be the question of greatest concern.)

The purpose of this article is to point out some important factors in evaluating the accuracy of a thermometer probe. Unless we evaluate all thermometers against the same scale, there is little basis for comparison. What seems like an apple may, in fact, be an orange.

Perhaps the most important consideration in thermometer accuracy is thermometer type. Thermometers have differing capabilities for accuracy based on their design, their construction, and the thermometric principles on which they operate. This makes each type of thermometer more or less susceptible to certain causes of measurement errors. The following chart shows four types of commonly used thermometers, the factors that detract from their accuracy, and their susceptibility to each of those factors. Following the chart is a brief discussion of each factor.

		Susceptibility			
Sources of Error		**SPRTs**	**PRTs/RTDs**	**Thermistors[†]**	**TCs**
Calibration		High	High	High	High
Stability Problems Over Time	Stability (repeatability)	Low	Medium	Low	High
	Drift (long-term)	Low	Medium	Low	Medium
Stability Problems Due to Thermal History	Hysteresis	Low	High	Medium	Low
	Oxidation	High	High	Low	High
	Insulating material	Medium	High	Low	Medium
	Hermetic seal	Medium	Medium	Medium	n/a
Measurement Issues	Lead-wire resistance	Low	High	Low	Low
	Reference-junction compensation	n/a	n/a	n/a	High
	Readout instrument	Medium	Medium	Low	High
Usage (immersion, fit, temperature range, mechanical shock, etc.)		High	High	Medium	Medium

[†] All thermistor references are to high-stability, bead-in-glass type thermistors.

Calibration - If your probe was calibrated, remember not all calibrations are the same. What uncertainties were included in the calibration? Was it done by fixed point or by comparison? In many cases, the uncertainty of a temperature sensor can be improved simply by its calibration.

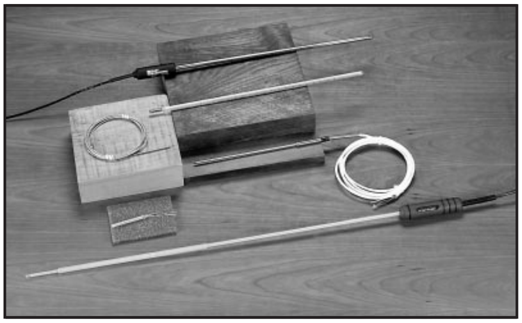
Short-term stability - Don't rely on your thermometer's calibration to cover the various forms of short-term stability. Many items listed below contribute to short-term stability and may be included in a stability or repeatability specification, separately listed, or—in the worst case—not accounted for at all.

Long-term drift - Instability becomes greater with time due to environmental effects, usage, and thermal history. One of the most important specifications for any thermometer is long-term stability after a stated amount of normal usage.

Hysteresis - For temperature probes, hysteresis refers to the probe's ability to repeat a given value when that value is approached from a different thermal direction. The largest contributor to hysteresis is the strain caused by the different thermal expansion properties of the sensor and its insulating material.

Oxidation - PRT and thermocouple elements are susceptible to oxidation at high temperatures. While this process can be reversed in PRTs by annealing, excessive annealing can negatively affect them. Manufacturers address this through the materials they use and by sealing a correct gas mixture around the sensor.

Insulating material - Electrical temperature sensors must be electrically isolated from their environment. A manufacturer's choice of insulating materials is therefore critical. For example, at high



Many types of sensors make good reference thermometers, but each has a different set of limitations and susceptibilities.

see ACCURATE on page 12

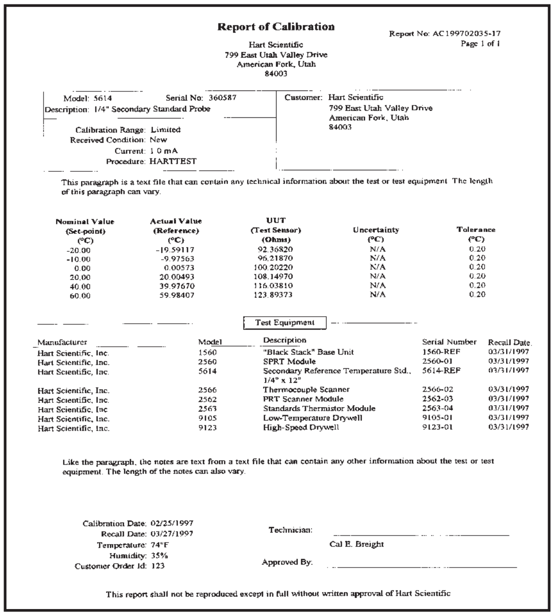
Calibration Report Requirements Found in ANSI/NCSL Z540-1

By Rose Heaton, Manager, Compliance Engineering

Do the calibration reports issued by your lab conform to current national and international standards? While quality standards are usually specific to individual industries, most industries' standards have their roots in current ANSI or ISO quality systems.

In 1994 the NCSL's TQM Committee on Calibration System Requirements published the ANSI / NCSL Z540-1, "Calibration Laboratories and Measuring and Test Equipment—General Requirements." ANSI's name was included in the standard's title when ANSI approved acceptance of the Z540 as an American national standard.

Though compliance to the Z540 is completely voluntary, it is widely acknowledged as the industry standard for "competence of calibration laboratories." Further, the Z540 was written to assure compliance with prevailing international standards found in ISO / IEC Guide 25 (soon to become ISO Standard 17025). Therefore, compliance with the Z540 generally means compliance with both national and international standards.



Report of Calibration

Report No: AC199702035-17
Page 1 of 1

Hart Scientific
799 East Utah Valley Drive
American Fork, Utah
84003

Model: 5614 Serial No: 360587
Description: 1/4" Secondary Standard Probe

Calibration Range: Limited
Received Condition: New
Current: 1 0 mA
Procedure: HARTTEST

Customer: Hart Scientific
799 East Utah Valley Drive
American Fork, Utah
84003

This paragraph is a text file that can contain any technical information about the test or test equipment The length of this paragraph can vary.

Nominal Value (Set-point) (°C)	Actual Value (Reference) (°C)	UUT (Test Sensor) (Ohms)	Uncertainty (°C)	Tolerance (°C)
-20.00	-19.59117	92.36820	N/A	0.20
-10.00	-9.97563	96.21870	N/A	0.20
0.00	0.00573	100.20220	N/A	0.20
20.00	20.00493	108.14970	N/A	0.20
40.00	39.97670	116.03810	N/A	0.20
60.00	59.98407	123.89373	N/A	0.20

Test Equipment

Manufacturer	Model	Description	Serial Number	Recall Date.
Hart Scientific, Inc.	1560	"Black Stack" Base Unit	1560-REF	03/31/1997
Hart Scientific, Inc.	2560	SPRT Module	2560-01	03/31/1997
Hart Scientific, Inc.	5614	Secondary Reference Temperature Std., 1/4" x 12"	5614-REF	03/31/1997
Hart Scientific, Inc.	2566	Thermocouple Scanner	2566-02	03/31/1997
Hart Scientific, Inc.	2562	PRT Scanner Module	2562-03	03/31/1997
Hart Scientific, Inc	2563	Standards Thermistor Module	2563-04	03/31/1997
Hart Scientific, Inc.	9105	Low-Temperature Drywell	9105-01	03/31/1997
Hart Scientific, Inc.	9123	High-Speed Drywell	9123-01	03/31/1997

Like the paragraph, the notes are text from a text file that can contain any other information about the test or test equipment. The length of the notes can also vary.

Calibration Date: 02/25/1997
Recall Date: 03/27/1997
Temperature: 74°F
Humidity: 35%
Customer Order Id: 123

Technician: ______________________
Cal E. Breight

Approved By: ______________________

This report shall not be reproduced except in full without written approval of Hart Scientific

All calibration reports issued by Hart or generated by Hart's Calibrate-*it software comply with the Z540 standard.*

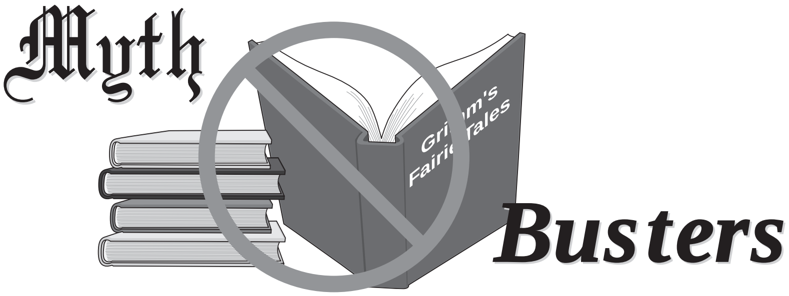
According to the Z540, each calibration certificate or report should include the following items:

- a title, e.g. "Calibration Report" or "Calibration Certificate";
- name and address of laboratory, and location where the calibration was carried out, if different from the address of the laboratory;
- unique identification of the certificate or report (such as serial number) and of each page, and the total number of pages;
- name and address of customer, where appropriate;
- description and unambiguous identification of the item calibrated;
- characterization and condition of the calibration item;
- date(s) of performance of calibration, where appropriate;
- identification of the calibration procedure used or unambiguous description of any nonstandard method used;
- reference to sampling procedure, where relevant;
- any deviations from, additions to, or exclusions from the calibration method, and any other information relevant to a specific calibration, such as environmental conditions;
- measurements, examinations, and derived results, supported by tables, graphs, sketches, and photographs as appropriate, and any failures identified;
- a statement of the estimated uncertainty of the calibration result (where relevant);
- a signature and title, or an equivalent identification of the person(s) accepting responsibility for the content of the certificate or report (however produced), and date of issue;
- where relevant, a statement to the effect that the results relate only to the items calibrated;
- a statement that the certificate or report shall not be reproduced, except in full, without the written approval of the laboratory;
- special limitations of use; and
- a traceability statement

End

For information on applying the Z540 to your lab, call Tom Wiandt or Rose Heaton at Hart Scientific (800-438-4278). Copies of the Z540 and the *Handbook for the Interpretation and Application of the Z540* can be obtained from NCSL (303-440-3339). Copies of ISO Guide 25 may be obtained from ANSI (212-642-4900).

Myth: System Calibration is the Most Effective Method for Calibrating Reference Thermometers



Hart Scientific manufactures ITS-90 fixed-point cells from the triple point of water to copper. Available in two sizes and two levels of sample metal purity, non-sealed (purgeable) cells, such as this copper cell, are also available from Hart's primary standards group.

By Tom Wiandt, Manager, Metrology Services

Reference thermometers, like virtually all sensing systems, consist of two elements. First, the actual sensing element (the transducer) exhibits a measurable change in some physical parameter as its temperature changes. For example, resistance thermometers such as SPRTs and thermistors produce an electrical resistance that changes in a nonlinear fashion with temperature. Thermocouples, similarly, produce a voltage that changes with temperature. Second, some type of readout device measures the output of the sensor, often converts the output to temperature, and displays a final number for the user.

In this type of basic system there are three major sources of error: the sensing element's ability to consistently produce the same output at the same temperatures, the readout's ability to measure the sensor's output accurately and consistently, and the readout's ability to convert the output to temperature in spite of the sensor's nonlinear behavior.

Typically, one or more of these errors will occur within the system over time and with usage. For example, a sensing element may oxidize or an electrical component may drift. Because neither sensors nor their readout devices behave perfectly over time, periodic adjustments are necessary through calibration to attempt to restore the system to its original, best-case performance.

This could be done in one of two ways. Each component of the system can be independently calibrated under the assumption that if each component performs correctly the entire system will perform correctly. Or a system calibration can be performed in which the probe is read during calibration by its own readout and its parameters in the readout are then modified to reflect accurate temperatures.

Many years ago, a system calibration was the only option because sensors were hard-wired to readouts. But even after this became less common, a system calibration clearly remained the preferred option. This is primarily because readouts were much less advanced than they are now.

Initially, measurement circuits were so poor at providing accurate and stable measurements (by today's standards) that it did little good to try to adjust them individually. Most of the errors caused by the electrical components making the measurements could only be reduced by frequent, time-consuming calibrations that plainly were not worth the time.

Also, the trim-pot (potentiometer) circuits used to model the sensor's behavior were likewise inadequate for characterizing the output of the sensors and translating it to a temperature. Many such circuits would allow a maximum of only three adjustments, which could not handle the 5th- or 6th-order polynomials commonly required by reference thermometers. Calibration could not address this and was not the issue.

To compensate for these problems, labs performed system calibrations. Temperature output from the entire system was adjusted using the trim-pots of the readout device; or thermometers were read by their own readouts and adjusted mathematically within the readout, thereby placing all system errors inside the coefficients of the sensor. In both cases, temperature-versus-temperature data resulted and traceability was ensured, but only for the system as a whole. Individual component drift could not be identified.

Today, technology is better. Both sensors and readout devices are more consistent and stable than ever before. Newer generation readouts use sophisticated auto-zeroing and current reversing measurement techniques as well as high-quality, high-stability components. These instruments measure very accurately and are limited mainly by noise and component stability. Frequent calibrations and adjustments are not necessary. Furthermore, they use microprocessors for the linearization task. The high-order polynomials can be used directly, and very precise "fits" result.

Because today's readout devices perform so well, most system errors reside in the sensing element. These errors result from a variety of causes ranging from oxidation to mechanical shock to normal drift and are best addressed by individually calibrating the probe in high-stability temperature sources. From these calibrations come precise coefficients for high-order polynomials. These coefficients can be entered directly into the readout device and handled with virtually no error. Additionally, the performance of today's readout devices makes them simple to calibrate, given adequate resistance or voltage sources. Therefore, there is little additional cost to separately calibrating both components of the system.

By calibrating each component individually, we now are able to address the major sources of system error, provide individual traceability for each component, and track changes in components over time. And we can do this through a relatively inexpensive process. While system data may be valuable for post-calibration verification of total system performance, system calibration is no longer the preferred method for maintaining system accuracy. *End*

Temperature Calibration Training

Hart's School of Temperature Calibration has been training temperature metrologists and technicians from around the world for almost three years. Here is our schedule of courses through September 2000. If you're interested in high-quality temperature calibration training in a relaxed atmosphere, give us a call. Kay McGrath, at 800-438-4278, can help you get registered for the course of your choice.

Realizing and Approximating ITS-90	September 13–15, 1999
Industrial Temperature Calibration	November 3–5, 1999
Temperature Metrology	February 7–9, 2000
Realizing and Approximating ITS-90	April 3–5, 2000
ITS-90 Realization Workshop	June 13–16, 2000
Industrial Temperature Calibration	August 7–9, 2000
Temperature Metrology	September 25–27, 2000

Solve the Calibration Report Mystery

When reference PRTs are calibrated, the calibration report usually gives resistance-versus-temperature data and ITS-90 coefficients but no in-tolerance or out-of-tolerance indications. How can you determine how far off your PRT is (in °C), how much your PRT has drifted (in °C), and whether or not it is in tolerance?

The data shows typical PRT calibration results and includes a big hint. Come visit our web site (www.hartscientific.com) for the solution and an explanation.

PRT Previous Calibration Data

Nominal Temperature (°C)	Actual Temperature (°C)	Measured Resistance (Ω)
–38.834	–38.8584	84.4070
0.010	0.0056	99.9942
156.599	156.5887	160.9384
231.928	232.0083	189.2545
419.527	419.5211	256.7888

PRT Current Calibration Data

Nominal Temperature (°C)	Actual Temperature (°C)	Measured Resistance (Ω)
–38.834	–38.8560	84.4059
0.010	0.0119	99.9915
156.599	156.5817	160.9302
231.928	232.0053	189.2483
419.527	419.5162	256.7812

To the Point

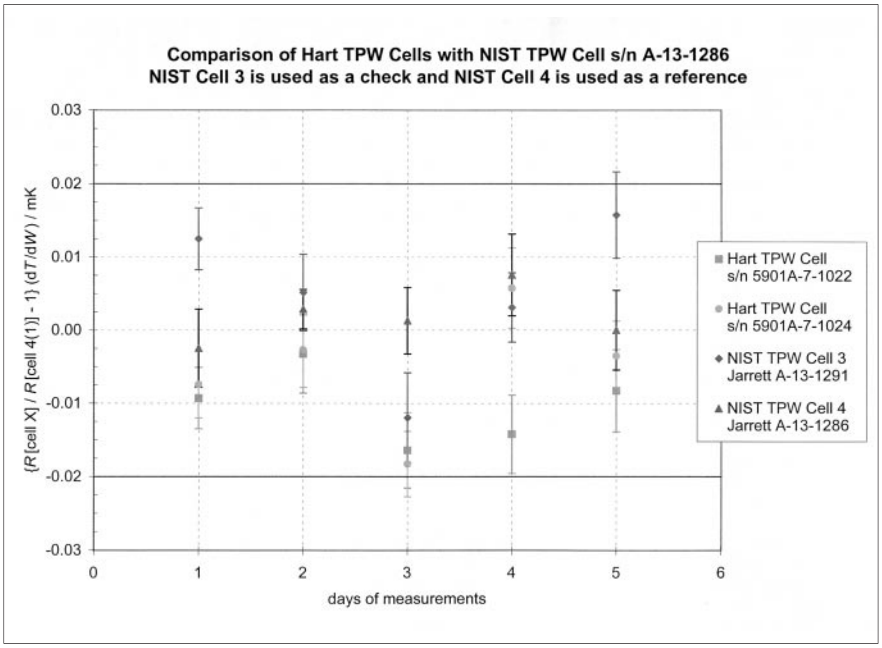
News on fixed points and primary standards development

NIST Issues Report on Hart's TPW Cells

NIST recently completed testing of two Hart-manufactured triple point of water cells and issued a report of their findings. While NIST is an independent laboratory and may not offer a qualitative opinion about these cells, the conclusion to be drawn from NIST's data is clear.

Two of Hart's Type A cells were submitted—serial numbers 7-1022 and 7-1024. Both were manufactured at Hart by our primary standards team led by Xumo Li. These cells were compared to NIST's "Cell 4" with an additional NIST cell ("Cell 3") used as a check standard. Each of the four cells was measured five times.

Hart's cell 7-1022 had an average reading 0.00001°C below the average reading of NIST's Cell 4 with a standard deviation of 0.000005°C. Cell 7-1024's average was 0.000005°C below the NIST cell with a standard deviation of 0.000009°C (see chart). NIST assigned an expanded uncertainty (k=2) of 0.00004°C on the realized value of its cell. *End*



NPL Issues Reports on Hart SPRT and Super Thermometer II

NPL, the national standards laboratory for the United Kingdom, issued its reports in March on a Hart 25-ohm quartz sheath SPRT and a Hart 1590 Super Thermometer II.

The SPRT (serial number 1201) was calibrated from –39 to 420°C at the triple points of mercury and water and the freezing points of tin and zinc. Gallium and indium points were used as check points.

R_{tp} measurements were taken before and after each fixed point. While the report does not include all the R_{tp} measurements, it does include the first and last measurements, which indicate stability during the test of ±0.0004°C. Resistance ratios at the triple point of mercury and the melting point of gallium were 0.8441585 and 1.1181269, respectively—well within the standards established by the ITS-90.

NPL then connected the SPRT to a Super Thermometer II (serial number 89023) and, referencing its 100-ohm internal resistor, took measurements with this system at the triple points of mercury and water and at the freezing points of indium, tin, and zinc (see table).

Hart's published accuracy specification for the 1590 is 1 ppm of resistance using an external resistor, and 6 ppm using an internal resistor. Plus or minus 6 ppm is equivalent to ±0.0015°C at the triple point of water if the 1590 is being used with a 25-ohm SPRT. *End*

t_{90}/ °C	Correction to Indicated Temperature (°C)
–38.8344	–0.0004
29.7646	–0.0007
156.5985	–0.0003
231.928	–0.0012
419.527	–0.0009

New Product Announcements

Model 1521 LLK Handheld Thermometer

Now you can get a handheld, battery-powered thermometer that reads thermistors to ±0.005°C and PRTs to ±0.025°C (for under $900). Not only that, the new 1521 LLK can use calibrated or uncalibrated probes interchangeably without any programming by the user.

Probes attach to the 1521 LLK using the innovative INFO-CON connector. The INFO-CON houses a tiny memory chip that stores all the information needed by the 1521—including the probe's type, calibration constants, serial number, and calibration expiration date. Simply plug in the probe and you're ready to take readings.

The 1521 reads probes in four different temperature scales with user-selectable resolution as high as 0.001°. No matter how your probe was calibrated—or even if it wasn't calibrated—the 1521 automatically reads it correctly.

Model 9107 Ultra-Cold Dry-Well

Reaching -45°C in a dry block calibrator may not seem like big news at first glance because almost every dry block manufacturer claims to achieve -40°C already. The catch is found in the fine print: "to achieve -40°C you need to use the instrument in an ambient of 5°C." Now that's cold!

The big news is that Hart's new 9107 Ultra-Cold Dry-Well is the only unit to achieve -45°C in a room that you can comfortably work in. It's accurate to ±0.1°C and stable to ±0.02°C over its entire range and includes two-digit resolution. Our specifications are achievable in your lab or on the factory floor, wherever sensors are calibrated.

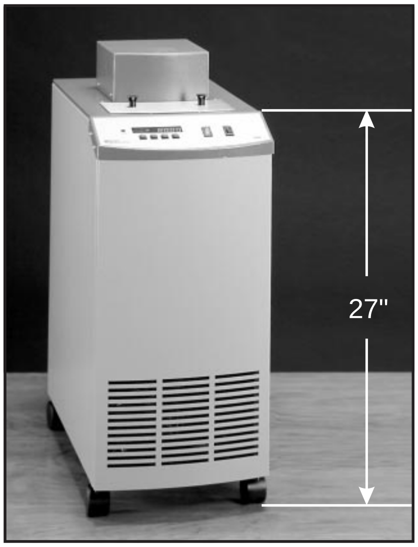
Now you can calibrate your freezers and other low-temperature devices on-site. Not to mention that your lab can reach a traceable -45°C in a small unit with high accuracy, high stability, and quick response.

Model 7380 Ultra-Cold Metrology Bath

Hart's new 7380 Metrology Bath reaches –80°C in less than 90 minutes and provides stability and uniformity of ±0.03°C, even at extreme temperatures. This is the first compact-size –80°C bath (12 x 24 x 30 inches) to deliver the precision performance necessary for true metrology applications.

The 7380 features a 1-gallon tank that provides 7 inches of immersion depth and over 14.5 square inches of access for plenty of throughput. Both ethanol and Halocarbon 0.8 Cold Fluid (which is available from Hart in 1-gallon quantities) deliver excellent performance in the 7380.

This bath is completely lab-friendly. It fits easily under a workbench or tabletop, includes rugged casters for easy movement, and is so quiet you can hardly hear it. Now there's a small, affordable, ultra-cold temperature source you can rely on from the leader in bath technology. *End*



Question: Exactly how "accurate" does my calibration equipment need to be?

By Chris Juchau, Vice President

Different industries and companies require unique standards that fit their specific quality programs. Even within the same laboratory, the answer to this question will likely vary with each piece of equipment calibrated. Nevertheless, there is a five-step process you can use for determining system requirements for general applications.

Step One: Know the required tolerance of the unit you're testing.

Different types of temperature sensors are used for many different purposes, each covering its own specific temperature range and each required to be accurate within its own specified tolerance. Since accuracy costs money, there's a good reason not to buy a system with more accuracy than you need for your sensors. Yet too little accuracy leads to poor—and sometimes costly—calibration results.

Step Two: Establish your uncertainty "budget" based on quality assurance standards.

Many lab standards call for conformity with ISO Guide 25 or ANSI / NCSL Z540-1, which require a test accuracy ratio (TAR) of 4:1. That is, the uncertainty of the entire calibration system should be four times better than the uncertainty of the unit under test. Many U.S. military programs, as well as the nuclear industry, also call for a 4:1 ratio. In the absence of clear guidelines within your company, the 4:1 ratio is probably the best approach due to its almost universal acceptance within U.S. industry.

It is important to note, however, that based on ISO requirements, most countries outside the U.S. call for detailed uncertainty analysis rather than simply relying on test accuracy ratios. TARs tend to rely on manufacturers' specifications, whereas an uncertainty analysis relies on a statistical examination of actual instrument performance.

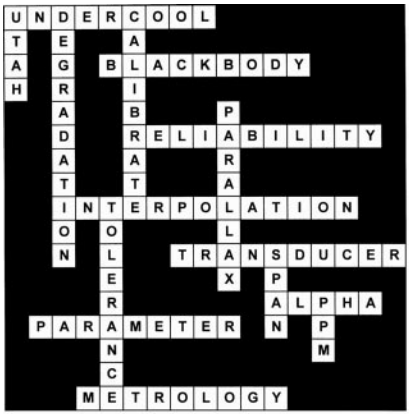
If we're calibrating a ±0.1°C thermometer, the total allowable "collective uncertainty" of our test equipment is ±0.025. This limit can be thought of as an uncertainty "budget." We must now make sure the components of our system uncertainty add up to a number within our budget.

Step Three: Identify all budget components and their uncertainties.

Suppose we are calibrating the above-mentioned thermometer in an oil bath using a secondary PRT standard. The test system consists of the bath, the PRT standard, and the readout device for the PRT. In this case, our individual uncertainties may consist of the various manufacturers' specs for PRT accuracy, readout accuracy, bath stability, and bath uniformity as shown in this table:

PRT accuracy	±0.015°C
Readout accuracy	±0.01°C
Bath stability	±0.005°C
Bath uniformity	±0.005°C

By preparing a table like this for any particular calibration system, we are prepared to calculate system uncertainty.



Solution to previous Random News crossword puzzle.

Step Four: Determine the best method for combining uncertainties.

If we simply add the numbers in the table, we get ±0.035°C, well above our budget of ±0.025°C. However, adding the numbers linearly means we're assuming that all four of our components are performing at the very edge of their specification and all in the same direction. While linear addition gives us 100% coverage of all possible error combinations, it is generally not a true reflection of the actual situation.

An alternative approach takes advantage of offsetting errors by converting "peak-to-peak" specifications to approximate standard deviations (by dividing them by $\sqrt{3}$), adding the components using the Root-Sum-Squares (RSS) method, and multiplying by 2 to give us 95% coverage, which in most quality systems is adequate. The following formula illustrates this method where a, b, c, and d represent the four numbers shown in the table above.

$$2 \times \sqrt{\left(\frac{a}{\sqrt{3}}\right)^2 + \left(\frac{b}{\sqrt{3}}\right)^2 + \left(\frac{c}{\sqrt{3}}\right)^2 + \left(\frac{d}{\sqrt{3}}\right)^2}$$

Using this method we get ±0.022°C—an adequate system for our thermometer. Even more accurate uncertainty analysis can be done by investigating the actual performance of each part of our system under normal usage conditions, but that is beyond the scope of this article.

Step Five: Address any over-budget situations.

If we come in under budget—great! But what if we're over budget? Assuming no instrument in the system can be eliminated, there are three alternatives: reduce the amount of uncertainty in one or more budget items, re-evaluate our "costs," or expand the uncertainty budget.

In this case, reducing the uncertainty contribution from a given budget item is not difficult, except that it requires better—usually more expensive—equipment. For example, our PRT standard could be calibrated using fixed points, or we could use a more accurate readout or a more stable temperature source.

Alternatively, we can re-evaluate component performance. A manufacturer says its bath is stable to ±0.005°C. How does it really perform? Perhaps by measuring stability periodically and maintaining a control chart, we can justify reliance on a smaller uncertainty, say ±0.003°C.

Lastly, we can look for more "budget." This comes back to our written quality assurance policies. Some companies' procedures allow for the contingency of not being able to meet a 4:1 TAR. In some circumstances, testing a particular unit to a reduced tolerance level may be acceptable. Each such situation must be evaluated in the context of laboratory policy.

Conclusion

Determining how "accurate" a temperature calibration system needs to be can be a complex process. As field sensors perform more like lab standards and quality assurance requirements become tighter, it is increasingly important for metrologists and calibration technicians to apply proper lab methodologies to the calibration of field sensors. Being familiar with company policies, the components of uncertainty, and various methods for evaluating and combining those uncertainties is critical to ensuring that we have enough "accuracy" in our system without creating unnecessarily expensive calibration systems. *End*

Hart Scientific Appoints Vice President for Metrology Products and Applications

American Fork, UT—July 5, 1999—Hart Scientific is pleased to announce the appointment of Bernard Morris as Vice President of Metrology Products and Applications. Prior to joining Hart, Bernard worked for ASL in executive marketing and management positions both in the U.S. and in the UK for more than 12 years.

Bernard has worked closely with many laboratories throughout the world and has extensive knowledge of thermometry and metrology products and their applications. At Hart he will focus on servicing primary and national laboratories around the world as well as on developing Hart's line of primary standards products.

If you are considering a resistance bridge, freeze-point cells, baths, or other equipment for your laboratory, and you want the best, talk to Bernard. *End*

Eliminate Dry-Well Errors with a Micro-Bath

By Tom Fisher, Vice President of Industrial Products and Applications

A micro-bath is a portable liquid bath used in many applications to increase calibration accuracy above that typically found in dry-well calibrators. Micro-baths perform better than dry-wells over a narrower temperature range.

Specification	High Performance Dry-Wells	Micro-Bath
Temperature Range	–45°C to 1200°C	–30°C to 200°C
Stability	±0.02°C	±0.015°C
Uniformity	±0.05°C	±0.02°C
Accuracy	±0.1°C	±0.4°C

Two of the most common contributors to dry-well errors are:

- Thermal contact between the unit under test (UUT) and the metal block
- Vertical gradients along the thermal block

Thermal Contact

With dry-wells, the air gap between the UUT and the heated metal well can cause thermal contact errors. These errors are more pronounced at higher temperatures. The larger the gap, the larger the potential error since air is not a good thermal transfer medium. It is impossible with a dry-well to reduce the air gap to zero.

Typically, the clearance between the UUT and the metal block should be 0.010". This is sometimes difficult to maintain consistently due to imperfections in the UUT's sheath. Probes with non-uniform sheath diameters pose contact problems in dry wells.

With a micro-bath, these errors are virtually eliminated. The UUT is immersed into a stirred fluid, thus making direct contact with the heated medium. No air gaps or fit errors exist when using a micro-bath.

Vertical Gradients

Vertical gradients are temperature differences along varying depths in a temperature-controlled well. Gradients are caused by heat conducting up the well and out into the air. The temperature sensor that completes the feedback loop to the controller in a dry-well block is located at the bottom of the block. Therefore, if the UUT is a significant distance from the control sensor and extends out into ambient air, heat will flow up its stem.

Vertical gradient errors are more pronounced at higher temperatures and in applications where the immersion depth is quite minimal. The closer the UUT is to the bottom of the metal well, the better the accuracy from a dry-well.

In a micro-bath vertical gradients are virtually eliminated. The stirred fluid is distributed throughout all areas of the tank during the calibration, keeping a uniform temperature around the UUT regardless of immersion depth. The fluid, which is the thermal transfer medium, maintains 100% consistent contact.

Bimetal thermometers are susceptible to vertical gradient errors in dry-wells because of their typically short immersion stems and large readout heads. This thermometer type is subject to large errors if calibrated improperly in a dry-well. When calibrated in a micro-bath, these popular thermometers can be immersed just a few inches into the medium without introducing vertical gradient errors.

In conclusion, micro-baths have solved many application problems that typically occur in dry-well calibrators. Dry-wells are still the most used field temperature calibration instruments because of their wide temperature range and portability. These new micro-baths are equally as portable but can offer improved performance. *End*

Y2K!

Products manufactured by Hart Scientific are Y2K-compliant. For details, read our official (and unofficial) statement on our web site at www.hartscientific.com.

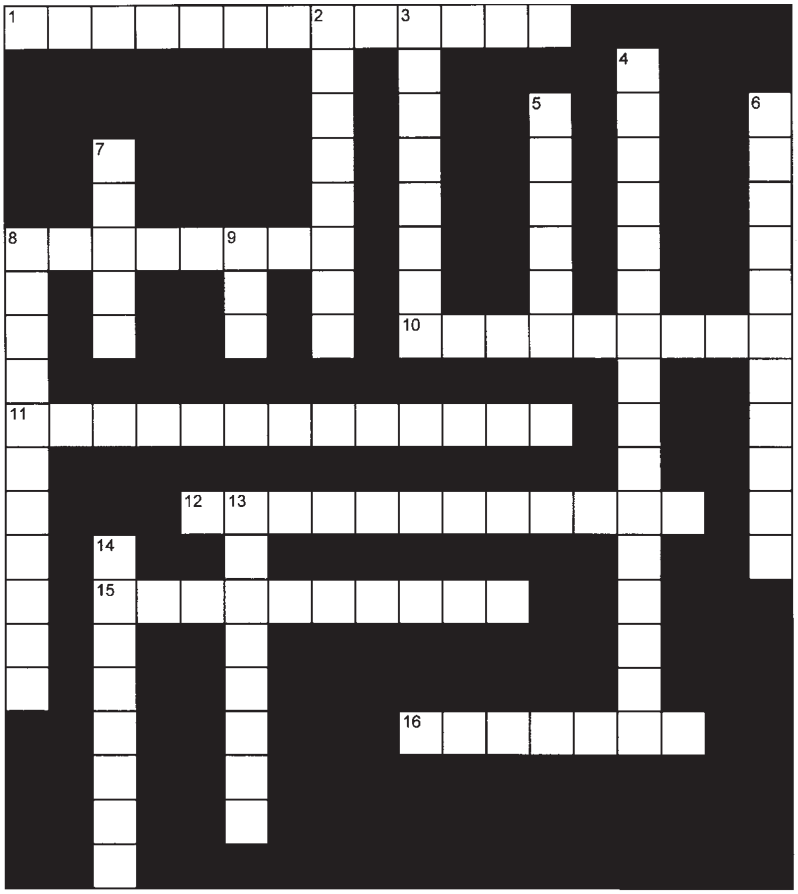
Crossword Puzzle

Across

1. Another name for ITS-90 comparison calibration technique
8. All-time NBA leader in steals (works near Hart Scientific)
10. A condition that occurs to SPRTs between 200°C and 500°C that can be reversed with annealing
11. Windows 98 program useful for data collection via RS-232
12. Type of thermocouple used to control top and bottom zones in a three-zone metrology furnace
15. The part of a refrigeration system that cools the bath tank
16. Type of refrigeration system typically used in baths that reach -60°C or lower (a.k.a. “two-stage”)

Down

2. Good, inexpensive bath fluid for temperatures from –100°C to 0°C
3. International temperature symposium held every three years
4. Controller parameter for adjusting bath stability
5. Peak to peak
6. Nonstandard distributions are statistically considered to be ___________
7. A stability-aiding device not necessary to reach published stability in a Hart bath
8. To correct for this, apply $R_0 = 2*R_1 - R_{1.414}$
9. ITS-90 fixed point with a very large supercool
13. Cause of different melting and freezing points for the same metal
14. DC current technique to eliminate thermal emfs



Calendar of Events

Hart Scientific Seminar
Realizing ITS-90 — Sept. 13–15

Sensors Expo
Cleveland's International Exposition Center — Sept. 14–16

ISA Tech Conference
Pennsylvania Convention Center — Oct. 5–7

Interkama
Duesseldorf, Germany — Oct. 18–23

Hart Scientific Seminar
Industrial Temperature Calibration — Nov. 3–5

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JIM *continued from page 1*

But if we're talking about degrees F, now we've got a problem! The formula is °F=1.8°C+32; so it takes 9 billion 32 degrees F to equal 5 billion degrees C. Units really count here! (That's what my high school algebra teacher kept telling me.)

Of course, there's another way to look at this. How did they (meaning the people who think about this every day) come up with 5 billion degrees anyway? No one had a truly rugged metal-sheathed SPRT capable of measuring temperatures in this range back at the time of the Big Bang. We've thought about making one ourselves (an SPRT, not a Big Bang), but it's a limited-use product and we would have to charge a lot of money for it. We would probably sell only one per millennium anyway.

Of course, if we built the sensor, we would have to calibrate it. Since we're not talking millikelvin accuracy here, I imagine we could get a traceable certificate with, say… plus or minus a hundred thousand degrees or so.

Now some 12 billion years later, cosmology scientists tell us the temperature of the universe is 2.725K, which is a few degrees less than the initial ambient of 5 billion degrees. The 2.725K figure fascinates metrologists all over the world. They want to know… Y2K?

That's your history lesson for today. Got any questions? *End*

ACCCURATE *continued from page 2*

temperatures, an SPRT using a quartz support system will perform better than an SPRT using mica.

Hermetic seal - The integrity of the temperature sensors discussed here can be compromised by exposure to air, water, or other environmental substances. While some of these effects can be eliminated through annealing, the better alternative is a reliable seal of the sensing element.

Lead-wire resistance - Measurements with two-wire RTDs include an error (sometimes very large) because the RTD's readout device cannot distinguish the resistance of the sensor from the resistance of the lead wires. Three-wire RTDs are better, but only four-wire RTDs can totally eliminate lead-wire effects.

Reference-junction compensation - The temperature at the measuring end of a thermocouple can be known precisely only if the temperature at the reference (or "cold") junction is known precisely. For this reason, a good reference junction is a must for your thermocouple standard.

Readout instrument - Of course, the accuracy of the sensor is irrelevant if the device reading the sensor is inadequate or out of calibration. Whether as a system or as separate components, both the sensor and the readout should be calibrated.

Usage - Mechanical shock, thermal shock, temperature range in use, immersion, and a host of other usage issues that are largely outside of manufacturers' control can all have dramatic impact on probe accuracy. Since all specifications were developed under certain usage assumptions, those specifications will not be correct if your usage pattern deviates too far from what the manufacturer intended. *End*