
HART
SCIENTIFIC
A Fluke Company
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5901

FROM THE PRESIDENT

Chris Juchau, President

Dear Customer,

Is it just me, or does time move faster the older you get? A lot has changed since our previous catalog was printed!

Most notably, Hart became part of the Precision Measurement Division of the Fluke Corporation. What does that mean? Well, it means we have to write a lot more reports each week. But aside from that, it means we're a better and stronger company with an even bigger worldwide presence. The world's tough economic conditions may persist for a while, but you know Hart Scientific will be there many years from now to support our products and your applications.

Speaking of support… Working with the rest of the Fluke organization, we opened or expanded five service centers in the past year. In Eindhoven, the Netherlands, we service heat sources such as baths, dry-wells, and furnaces. In Norwich, United Kingdom, we just opened a primary temperature laboratory. From there, we provide primary and secondary thermometer calibrations, readout calibrations, and readout repairs. UKAS accreditation has been applied for. We also now offer repair and basic calibration services in China and Singapore. No matter where you are, we're aiming to serve you better.

Here in American Fork, Utah, we've added service and metrology personnel. We've also opened a second temperature laboratory, so we now have separate primary and secondary labs, both offering accredited calibrations under NVLAP lab code 200348. We're also in the middle (at time of printing) of adding additional accredited processes within our scope of accreditation.

As always, you'll find a bunch of new products in our latest catalog. Those include primary standards, baths, and industrial calibrators. Our "Other Neat Stuff" section includes calibrators, resistance standards, and data acquisition products from Fluke, a humidity and temperature chamber from Thunder Scientific, and a very nifty handheld thermometer that's both accurate and intrinsically safe. All great stuff!

We also have some new faces in our catalog. We thought this year you might get a kick out of seeing them in their natural habitats so you can see what they do when they're not calibrating SPRTs or triple-distilling water. Before Fluke bought us, we had the best people in the temperature industry. We still do. But now there are even more of us!

Stay tuned. The future holds many more exciting product and service developments from Hart and Fluke. In the meantime, we always welcome your feedback. You can reach me—or any of us—through email (firstname.lastname@hartscientific.com) any time. Don't be bashful.

Oh, and if you know any good metrology jokes… We've been soliciting them on our web site for years, but for some reason haven't had much luck. Have you heard the one about the difference between the extroverted metrologist and the introverted metrologist? The answer—and a lot of truly useful information—can be found at www.hartscientific.com. Pay us a visit.

Take care—and enjoy the catalog!

Chris

NVLAP ACCREDITATION AT HART

In November 2000, Hart Scientific's temperature laboratory became officially accredited by the National Voluntary Laboratory Accreditation Program (NVLAP lab code 200348), which operates under the umbrella of NIST, the national metrology institute of the United States. Hart's lab accreditation was renewed for two years in early 2003. An abbreviated reproduction of our new scope of accreditation under ISO/IEC 17025 can be found on our web site at www.hartscientific.com.

NVLAP has signed Mutual Recognition Arrangements (MRAs) with the Asia Pacific Laboratory Accreditation Cooperation (APLAC) and the International Laboratory Accreditation Cooperation (ILAC). Signatories to the ILAC agreement include most of the world's developed nations (see sidebar on following page). In short, Hart's lab is recognized as an accredited laboratory in most countries in the world.


United States Department of Commerce
National Institute of Standards and Technology

NVLAP®

ISO/IEC GUIDE 25:1990
ANSI/NCSL Z540-1-1994
ISO 9002:1987

Certificate of Accreditation

HART SCIENTIFIC CALIBRATION LABORATORY
AMERICAN FORK, UT

is recognized under the National Voluntary Laboratory Accreditation Program for satisfactory compliance with criteria established in Title 15, Part 285 Code of Federal Regulations. These criteria encompass the requirements of ISO/IEC Guide 25 and the relevant requirements of ISO 9002 (ANSI/ASQC Q92-1987) as suppliers of calibration or test results. Accreditation is awarded for specific services, listed on the Scope of Accreditation for:

CALIBRATION LABORATORIES

David F. Alderman
For the National Institute of Standards and Technology

NVLAP Lab Code: 200348-0

What Is Accreditation?

Accreditation is the unbiased assessment by a third party of a laboratory's quality program and technical capabilities. The third party assesses the laboratory against a recognized standard. In December 1999, the new standard, ISO/IEC 17025, "General Requirements for the Competence of Testing and Calibration Laboratories," was adopted and has now replaced ISO Guide 25 as the accepted standard for accredited test and measurement laboratories.

Accreditation indicates that a laboratory has demonstrated that it functions within the parameters of the standard. While accreditation is not a guarantee of a laboratory's performance, it does provide a means for determining the laboratory's competence to perform particular types of tests or calibrations. The technical evaluation during an accreditation includes a review (by experts in the relevant discipline) of calibration procedures, calibration standards, traceability, uncertainty analysis, actual results, and statistical process control.

Laboratory accreditation has been a requirement in many countries for years. Nationally recognized accreditation bodies have provided customers with confidence in calibration certificates and reports by employing generally established standards set by the European (CEN) or international (ISO) standardization bodies. Accreditation in the United States is voluntary. Nevertheless, as more companies become ISO 9000 certified, accreditation is becoming a more common practice in the United States.

What Is the Scope of Hart's Accreditation?

The scope of Hart's accreditation is intended to satisfy the traceability and other requirements for ongoing company operations, research requirements, and customer support for both primary and secondary thermometry. In the United States, NVLAP and A2LA have already accredited hundreds of calibration laboratories. Hart's laboratory, however, is accredited for some of the lowest uncertainties of all commercial laboratories in the world. The following areas are included within Hart's scope of accreditation:

- Thermometric fixed-point cell certification
- SPRT calibration by fixed point
- Noble-metal thermocouple calibration by fixed point
- PRT calibration
- Thermistor calibration
- Reference resistor calibration (DC)
- Digital thermometer readout calibration
- Digital thermometer / probe system calibration

What's in It for You?

First, since accreditation involves a third party assessment of a laboratory's QA program and technical capabilities, it provides an impartial viewpoint of the competency of the laboratory. It also provides an unbiased assessment of the laboratory's standards, procedures, personnel qualifications, and traceability to an appropriate national laboratory. In the United States, this means traceability of all standards to NIST. By showing traceability to NIST, we show traceability directly to the ITS-90. In short, accreditation offers a lab's customers a high level of confidence in its quality and technical abilities.

Second, because ISO 9000 includes calibration requirements, many companies include accreditation for calibration suppliers as a mandatory part of their QA system. Often, accredited suppliers need only remit a copy of their accreditation scope in order to become an approved vendor. This eliminates the need for time-consuming, expensive audits and other supplier evaluation methods. Further, in cases where customers' audits are still necessary, the audits run smoother when accredited suppliers are used.

Continued

Third, accreditation has benefits for international customers. All recognized accreditation bodies have adopted ISO/IEC 17025 as the basis for accreditation of calibration and testing laboratories. Because these accreditations are based on the same standards, countries may enter into MRAs whereby an accreditation body in one country recognizes the accreditations done by a fellow MRA signatory in another country. This has the effect of easing some of the barriers that have historically hindered the flow of calibrated instruments across borders.

What's in It for Us?

Customer demand for laboratory accreditation has been rising for years. With many companies requiring their calibration services suppliers to be accredited, this demand is starting to reach a critical level. By becoming accredited, Hart is better positioned to serve a wide variety of customers. Additionally, the time and costs associated with providing repetitive audits to numerous customers will decline with accreditation.

NVLAP®

For the Scope of Accreditation
Under NVLAP Lab Code 200348-0

Perhaps the single greatest benefit of accreditation to Hart is the accreditation process itself. Hart employs some of the world's leading temperature metrologists. One such expert, Tom Wiandt, has done an outstanding job running our calibration lab since 1996. However, the opportunity to receive evaluation and criticism from industry peers is extremely valuable. Both the QA systems and the technical operating procedures were thoroughly examined. Issues were discussed and recommendations made and implemented. While the lab was already excellent, it is now the best it's ever been, and we have independent confirmation that we are qualified to do what we say we can do.

In the end, accreditation benefits both the accredited lab and its customers. Our processes and systems have been validated, our stated uncertainties scrutinized, and our traceability examined. At the same time, customers' confidence in our lab's quality system and technical capabilities has been independently substantiated. The complete scope, ranges, and uncertainties of Hart's accreditation are available for review on our web site at www.hartscientific.com.

Take a look. We make the world's finest temperature calibration equipment, and we know how to use it. We used it, in fact, to get our accreditation. Trust your critical calibration work to an accredited laboratory.

Signatory Organizations to the ILAC MRA

Australia	NATA	www.nata.asn.au
Austria	BMWA	guenter.friers@bmwa.gv.at
Belgium	BeltestOBE/BKO	BELTEST.fgov.be
Brazil	CGCRE	www.inmetro.gov.br
Canada	SCC	www.scc.ca
China, Hong Kong	HKAS	www.info.gov.hk/itc/hkas
China, People's Republic of	CNAL	www.cnal.org.cn
Chinese Taipei	CNLA	www.cnla.org.tw
Czech Republic	CAI	www.cai.cz
Denmark	DANAK	www.danak.dk
Finland	FINAS	www.finas.fi
France	COFRAC	www.cofrac.fr
Germany	DACH	dach@dach-gmbh.de
Germany	DAP	www.dap.de
Germany	DAR	www.dar.bam.de
Germany	DASMIN	www.dasmin.de
Germany	DATech	www.datech.de
Germany	DKD	www.dkd.info
India	NABL	www.nabl-india.org
Indonesia	BSN	www.bsn.or.id
Ireland	NAB	www.nab.ie
Israel	ISRAC	www.israc.gov.il
Italy	SINAL	www.sinal.it
Japan	IAJapan	www.nite.go.jp
Japan	JAB	www.jab.or.jp
Korea, Republic of	KOLAS	kolas.ats.go.kr
Netherlands	RvA	www.rva.nl
New Zealand	IANZ	www.ianz.govt.nz
Norway	NA	www.justervesenet.no/na
Portugal	IPQ	www.ipq.pt
Singapore	SAC	www.sac-ccreditation.org.sg
Slovakia	SNAS	www.snas.sk
South Africa	SANAS	www.sanas.co.za
Spain	ENAC	www.enac.es
Sweden	Swedac	www.swedac.se
Switzerland	SAS	www.sas.ch
Thailand	TISI	www.tisi.go.th
United Kingdom	UKAS	www.ukas.com
USA	A2LA	www.a2la.org
USA	ICBO	www.icboes.org
USA	NVLAP	www.nist.gov/nvlap
Viet Nam	VILAS	vol.vnn.vn

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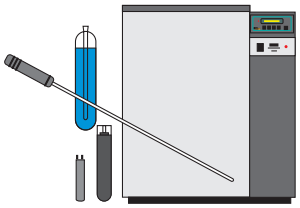

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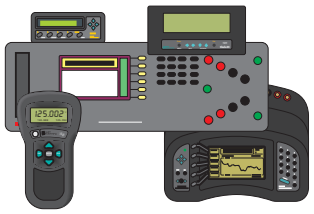

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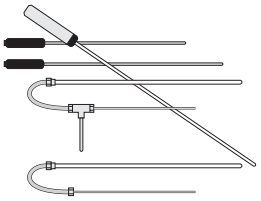

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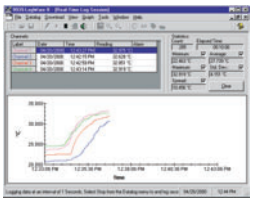

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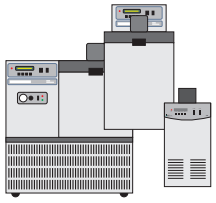

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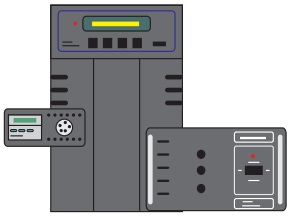

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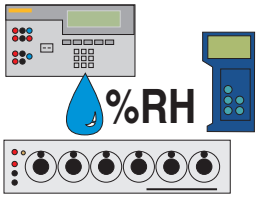

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	5681	25.5	–200°C to 661°C	8
	5683	25.5	–200°C to 480°C	
	5684	0.25	0°C to 1070°C	
	5685	2.5	0°C to 1070°C	
	5680	25.5	–200°C to 480°C	12
	5682	100	–200°C to 480°C	
	5698	25.5	–200°C to 661°C	11
	5699	25.5	–200°C to 661°C	13
	5686	25.5	–260°C to 232°C	14
	5695	25.5	–200°C to 500°C	
	5629	Au-Pt TC	0°C to 1000°C	15

Fixed-Point Cells	Model	Description	Temperature	Page
	5901	Triple Point of Water (TPW)	0.01°C	18
	5901A	TPW, NBS Design	0.01°C	
	5901B	Mini Triple Point of Water	0.01°C	
	5901C	TPW, 13.6 mm Well	0.01°C	
	5903	Melting Point of Gallium	29.7646°C	21
	5943	Melting Point of Gallium, SST	29.7646°C	
	5904	Freezing Point of Indium	156.5985°C	
	5905	Freezing Point of Tin	231.928°C	
	5906	Freezing Point of Zinc	419.527°C	
	5907	Freezing Point of Aluminum	660.323°C	
	5908	Freezing Point of Silver	961.78°C	
	5909	Freezing Point of Copper	1084.62°C	
	5924	Open Freezing Point of Indium	156.5985°C	
	5925	Open Freezing Point of Tin	231.928°C	
	5926	Open Freezing Point of Zinc	419.527°C	
	5927	Open Freezing Point of Aluminum	660.323°C	
	5928	Open Freezing Point of Silver	961.78°C	
	5929	Open Freezing Point of Copper	1084.62°C	
	5901B	Mini Triple Point of Water	0.01°C	30
	5914A	Mini Freezing Point of Indium	156.5985°C	
	5915A	Mini Freezing Point of Tin	231.928°C	
	5916A	Mini Freezing Point of Zinc	419.527°C	
	5917A	Mini Freezing Point of Aluminum	660.323°C	
	5918A	Mini Freezing Point of Silver	961.78°C	
	5919A	Mini Freezing Point of Copper	1084.62°C	
	5944	Mini Freezing Point of Indium	156.5985°C	
	5945	Mini Freezing Point of Tin	231.928°C	
	5946	Mini Freezing Point of Zinc	419.527°C	
	5931	Triple Point of Water X Cell	0.01°C	34
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	5900	Triple Point of Mercury	–38.8344°C	21

PRIMARY STANDARDS SUMMARY

Apparatus	Model	Features/Use	Page
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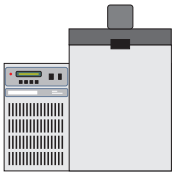
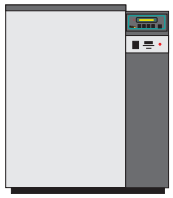
	7012	Maintains: triple point of water and gallium cells. Comparisons: –10°C to 110°C.	90
	7037	Maintains: triple point of water and gallium cells. Comparisons: –40°C to 110°C.	
	9210	Maintains: mini triple point of water and mini gallium cells. Comparisons: –10°C to 125°C.	32
	9230	Maintains: stainless steel gallium cell. Comparisons: 15°C to 35°C.	
	9260	Maintains: indium, tin, zinc, and aluminum cells. Comparisons: 50°C to 680°C.	
	9114	Maintains: indium, tin, zinc, and aluminum cells. Comparisons: 100°C to 680°C.	24
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	9116	Maintains: aluminum, silver, gold, and copper cells. Comparisons: 400°C to 1100°C.	
	9117	Anneals SPRTs, HTPRTs, and thermocouples to 1100°C. Protects them against contamination from metal ions.	26
	7196	Affordable substitute for a triple point of argon system. Provides for low-temperature comparison calibrations at approximately –196°C with uncertainties of 2 mK.	35
	5581	0.1 ppm accuracy for calibration of standard resistors and SPRTs. 13:1 measurement ratio allows resolution to 0.001 mK.	27
	742A	Excellent performance without oil or air baths. Values from 10 ohm to 100 megohm.	28
	5430	Highest stability oil-filled resistors (< 2 ppm/year drift). AC cal uncertainty to 3 ppm.	29

QUARTZ-SHEATH SPRTs

Quartz-Sheath SPRTs **Models 5681, 5683, 5684, and 5685**

- Drift rates as low as 0.0005 K
- Proprietary gas mixture ensures high stability
- Most experienced SPRT design team in the business

Choosing the right platinum thermometer as your primary standard may be the most critical purchase decision in your lab. Unfortunately, other manufacturers are pretty secretive about how their SPRTs are made. They won't tell you much more than you can already see by looking at one. Long-term reputation used to be a reliable indicator, but the leaders of a few decades ago have lost their original craftsmen and design scientists. There are only a few active SPRT design groups in the world today.

So how do you know you're making the best purchase? Self-proclaimed expertise shouldn't convince you. You should expect some sound evidence that the company is qualified in the ongoing science of SPRT development. At Hart we'll tell you how we make an SPRT. We'll let you talk to the people here who design, build, and calibrate SPRTs. Finally, when you buy one, if you don't like it, we'll take it back and return your money.

Hart has four quartz-sheath SPRTs covering the ITS-90 range of –200°C to 1070°C. The 5681 is used from –200°C to the aluminum point at 660.323°C. The 5683 is used from –200°C to 480°C with greater long term stability. The 5684 and the 5685 cover higher temperatures up to 1070°C and can be calibrated at the silver point.

Yes, they have all the features you would expect in a world-class SPRT. They have gold-plated spade lugs, a strain-relieved connection to the four-wire cable, convection prevention disks, the finest quartz glass available, delustered stems, and the purest platinum wire available.

The purity of a thermometer's platinum wire is critical to meeting ITS-90 requirements. Maintaining that purity over the life of the thermometer impacts long-term stability. The quartz glass tube of the SPRT should be properly sealed to prevent contamination of the platinum sensor. Others use mechanical assemblies and epoxy seals. These introduce additional materials to the thermometer's internal environment and can be prone to mechanical failure, risking exposure of the platinum to impurities.

Theoretically, the best seal would be a direct seal between the quartz glass and the platinum wire. However, the quartz glass used in thermometer sheaths has a very small coefficient of expansion while platinum has a much larger coefficient of expansion. If you simply sealed the sheath's glass to the platinum wire, these different rates of expansion would result in a poor seal as the assembly is exposed to changing temperatures.

We've figured out a way to match the expansion coefficients of the glass sheath and the platinum wires. We do it by creating a graduating seal that's made of 18 separate pieces of glass, each with a different coefficient of expansion. The expansion and contraction rate of the final piece of glass matches that of the platinum, resulting in an overall seal that prevents gas leakage and impurity penetration for at least 20 years.

Fusing each piece of glass to the next is a painstaking process. Sure it costs us extra! But the results are worth it.

There's more!

We use only pure quartz glass materials for the cross frames, disks, and tubes. We don't use mica or ceramic materials. We have a special glass-treating process to increase the resistance of the quartz to devitrification and remove more impurities than the typical cleaning process.

We've done some research to find the best-performing balance of argon to oxygen in the tube. Some oxygen in the sheath is necessary to minimize the danger of the platinum being poisoned by foreign metals at high temperatures, but too much oxygen at temperatures below 500°C accelerates the oxidation process affecting the integrity of the platinum. We've got a balance that provides exactly the right protection for the platinum.

Specifications	5681	5683	5684	5685
Temperature Range	–200°C to 661°C	–200°C to 480°C	0°C to 1070°C†	0°C to 1070°C†
Nominal R_{TPW}	25.5Ω		0.25Ω	2.5Ω
Current	1 mA		14.14 mA	5 mA
Resistance Ratio	W(302.9146 K) ≥ 1.11807 and W(234.3156 K) ≤ 0.844235		W(302.9146 K) ≥ 1.11807 and W(1234.93 K) ≥ 4.2844	
Sensitivity	0.1Ω/°C		0.001Ω/°C	0.01Ω/°C
Drift Rate	< 0.002°C/100 hours at 661°C (typically < 0.001°C)	< 0.001°C/100 hours at 480°C (0.0005°C typical)	< 0.003°C/100 hours at 1070°C (typically < 0.001°C)	
Sensor Support	Quartz glass cross		Quartz glass strip with notches	Quartz glass cross
Diameter of Sensor Pt Wire	0.003" (0.07 mm)		0.016" (0.4 mm)	0.008" (0.2 mm)
Protective Sheath	Quartz glass, Diameter: 0.28" (7 mm), Length: 20.5" (520 mm)		Quartz glass, Diameter: 0.28" (7 mm), Length: 26.8" (680 mm)	

†The official maximum temperature of an SPRT as a defining interpolation instrument of the ITS-90 is 961.78°C, but these types of SPRTs were found to be stable up to at least 1070°C. The annealing temperature during the stability test was 1085°C. The lower temperature limit of these types of SPRTs can be as low as –200°C. In general, it is suggested that a 25-ohm SPRT be used below 0°C.

Each of these seemingly small things adds up to better uncertainties and less drift. Hart's SPRTs typically drift less than 0.001°C per year.

5681: –200°C to 661°C

This 25-ohm thermometer is the workhorse of the ITS-90 ranges. It can be calibrated for any of the subranges from the triple point of argon to the freezing point of aluminum. The 5681 meets the ITS-90 requirements for resistance ratios as follows:

$$W(302.9146\ K) \geq 1.11807$$
and
$$W(234.3156\ K) \leq 0.844235$$

5683: –200°C to 480°C

While SPRTs traditionally cover temperatures to the aluminum point (660°C), most measurements occur between –100°C and 420°C. The 5683 SPRT covers this range and more, from –200°C to 480°C, and does so with long-term stabilities that extended range SPRTs can't match. Typical drift is less than 0.5 mK after 100 hours at 480°C.

5684 and 5685: 0°C to 1070°C

ITS-90 extended the use of the platinum thermometer from 630°C to 962°C. The 0.25-ohm HTPRT sensor uses a strip-shaped support made from high-purity quartz glass. The 2.5-ohm model uses a quartz glass cross frame. Stability after thermal cycling is excellent, and the design is reasonably tolerant of vibration. Choose from 0.25-ohm or 2.5-ohm nominal R_{TPW} values. In addition to meeting the resistance ratio requirements shown above, these thermometers meet the following additional criterion:

$$W(1234.93\ K) \geq 4.2844$$

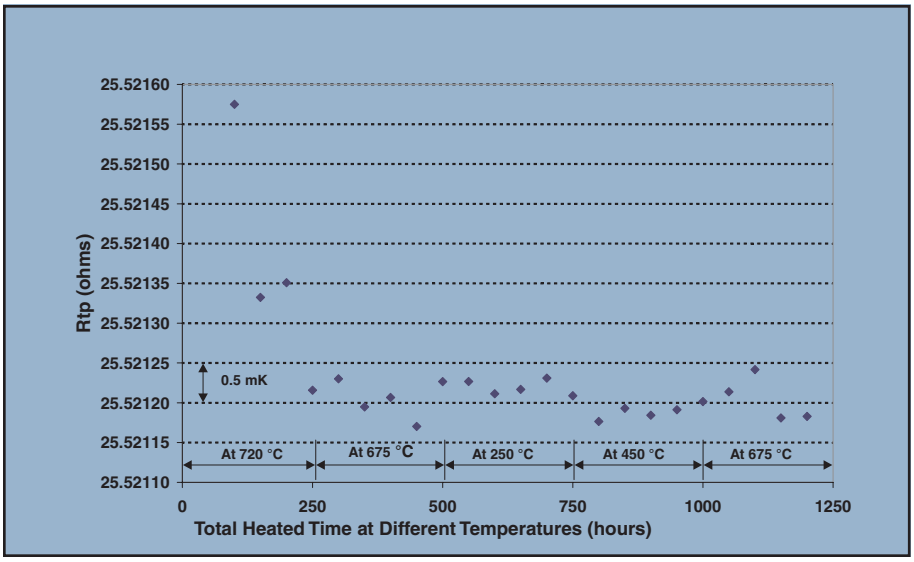
After all, this really is about W!

Ordering Information

5681-S	SPRT 25.5Ω, 661°C†
5683-S	SPRT 25.5Ω, 480°C†, Ultrastable
5684-S	SPRT 0.25Ω, 1070°C†
5685-S	SPRT 2.5Ω, 1070°C†

†Maple carrying case included

See page 156 for SPRT calibration options.



A typical stability graph of a 5681 SPRT (#71122). Units are calibrated or shipped to customers after about 250 hours of annealing.

A close-up of a 25-ohm spiral-wound helix SPRT element.

Technical Tip

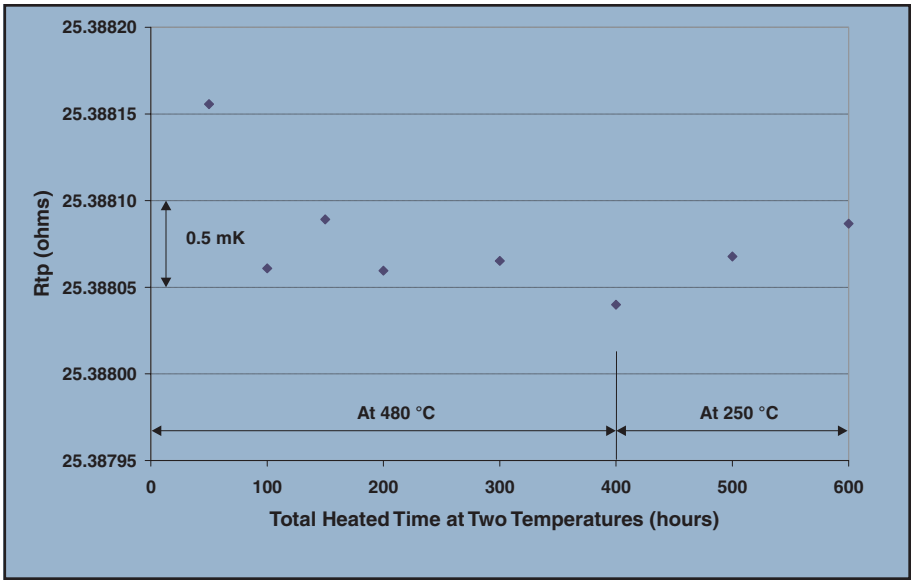
All Platinum Is Not the Same

Platinum resistance thermometers (PRTs) are made from a variety of platinum sensor wire. The differences in the wire affect the thermometers' performance. The two most important variations are purity and thickness.

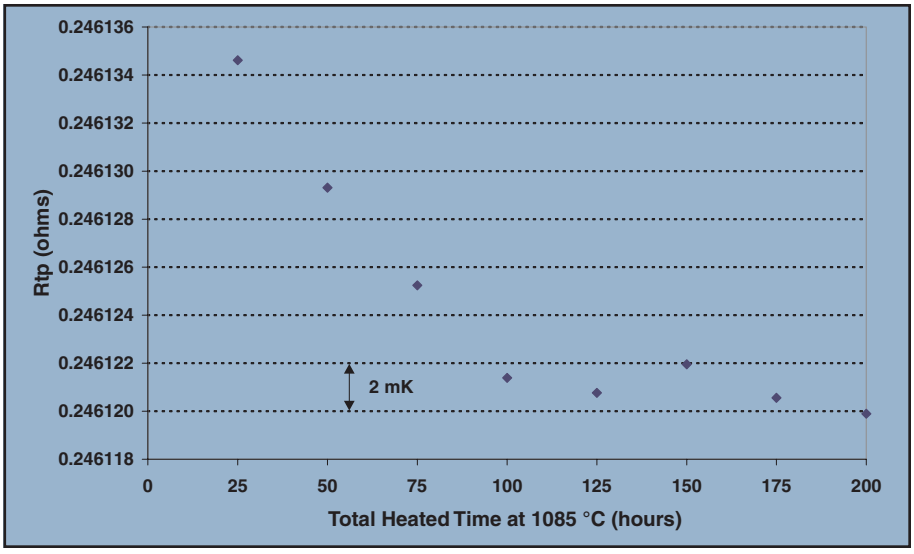
According to IPTS-68 requirements, platinum purity was measured by its "alpha," or average change of resistance per degree. Alpha 0.00385 was common for industrial thermometers, and alpha 0.003925 was common for SPRTs. ITS-90, in contrast, measures platinum quality with ratios of their resistance at certain fixed points (gallium, mercury, and/or silver) to their resistance at the triple point of water (R_{TPW}). Those meeting the ITS-90-specified ratios are considered SPRT quality.

The thickness of the platinum wire affects its resistance and is indicated by a nominal resistance value at the triple point of water. The thicker the wire, the lower its nominal resistance. 100 ohms at R_{TPW} is common for industrial sensors, and 25 ohms at R_{TPW} is typical for SPRTs.

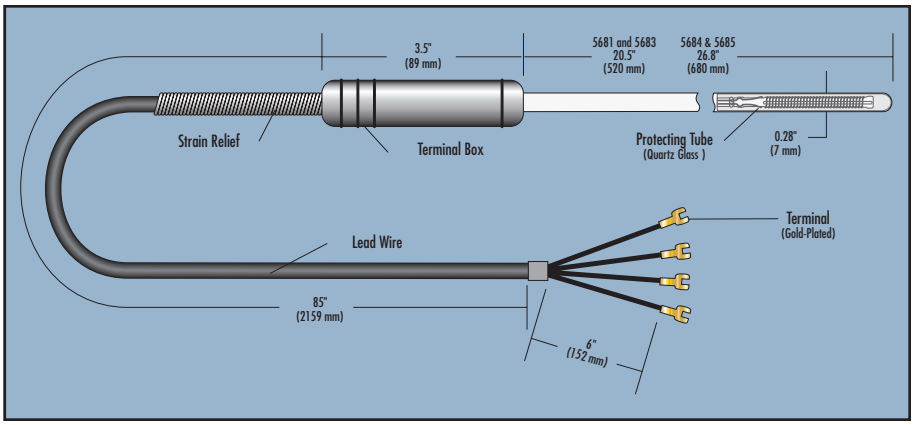
Which is best for your application? All things equal, lower resistance PRTs are generally more stable because of their thicker sensor wire. However, low-resistance PRTs require higher resolution readout devices to handle the small changes in resistance per degree. The advantages gained by using low-resistance PRTs are not significant in most applications. If they're needed, however, be sure you have the right device to read them.



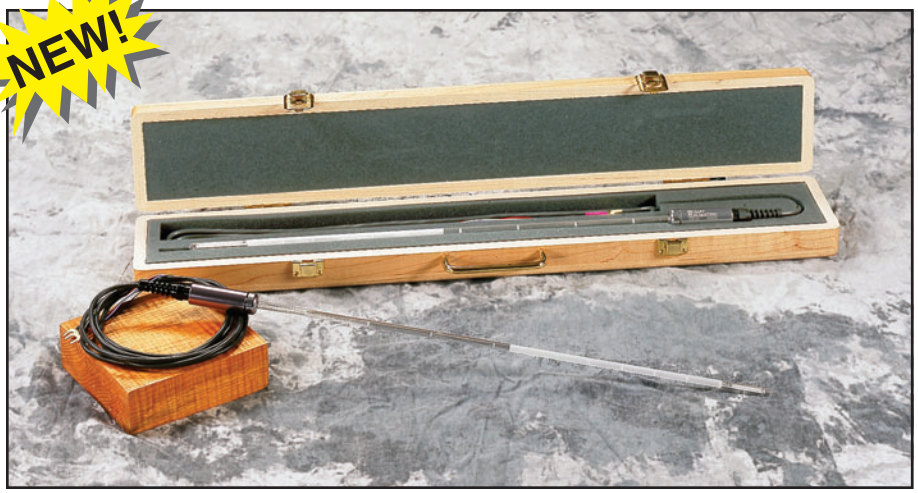
A typical stability graph of a 5683 SPRT (#4002). Units ship (or are calibrated) after about 100 hours of annealing.



A typical stability graph of a 5684 SPRT (#1011). Units ship (or are calibrated) after about 100 hours of annealing.



WORKING STANDARD SPRT — Model 5698



Working Standard SPRT — Model 5698

- Fully conforms to ITS-90 SPRT guidelines
- Drift rate typically less than 0.003°C
- Multiple calibration options by fixed point
- Unmatched performance-to-price-ratio

SPRTs. Art or science? It takes, in fact, quite a bit of both. The one thing *not* involved is mystery. That's why Hart SPRTs always include detailed published specifications, including drift rates.

Our newest SPRT is no exception. It was designed by the same Hart metrologists who have created a dozen different SPRT designs used in national labs around the world. And it performs just like we say it does.

The new Model 5698 Working Standard SPRT is a true SPRT. It meets the ITS-90 ratio requirements for SPRTs and includes a Hart-designed, completely strain-free platinum sensor. With a 485-mm quartz sheath, this 25-ohm SPRT covers a temperature range from –200°C to 661°C. Long-term drift, which we define as the change in output resistance at the triple point of water after 100 hours at 661°C, is (after converting to temperature) less than 6 mK—typically less than 3 mK.

The 5698 is the perfect companion to a Hart Super-Thermometer such as the Model 1590, which reads 25-ohm SPRTs to within 1 mK at 0°C and includes a number of convenient features for working with SPRTs. Requiring 1 mA of excitation current, the 5698 can also be used easily with a Hart *Black Stack,* or even a Chub-E4 Thermometer.

If you need your SPRT calibrated by a reputable calibration lab, we offer appropriate calibration options by fixed-point in our NVLAP-accredited lab. Our calibration prices are as reasonable as our instrument prices, so you get maximum value from your SPRT.

Why buy critical temperature standards from companies unwilling to publish complete specifications? At Hart, we not only provide excellent post-purchase support so you have the best possible ownership experience, we provide you all the information we can *before* you purchase—including detailed performance specifications.

Maybe there is some art mixed with our science. But that doesn't mean we keep secrets. Trust your lab standards to Hart Scientific.

Specifications

Temperature Range	–200°C to 661°C
Nominal R_{TPW}	25.5Ω (±0.5Ω)
Current	1.0 mA
Resistance Ratios	W(234.315K) ≤ 0.844235 W(302.9146K) ≥ 1.11807
Sensitivity	0.1Ω/°C
Drift Rate	< 0.006°C/100 hours at max temperature (typically < 0.003°C)
Diameter of Pt Sensor Wire	0.003" (0.07 mm)
Protective Sheath	Quartz Glass Diameter: 0.28" (7 mm) Length: 19.1" (485 mm)
Lead Wires	Four sensor wires

Ordering Information

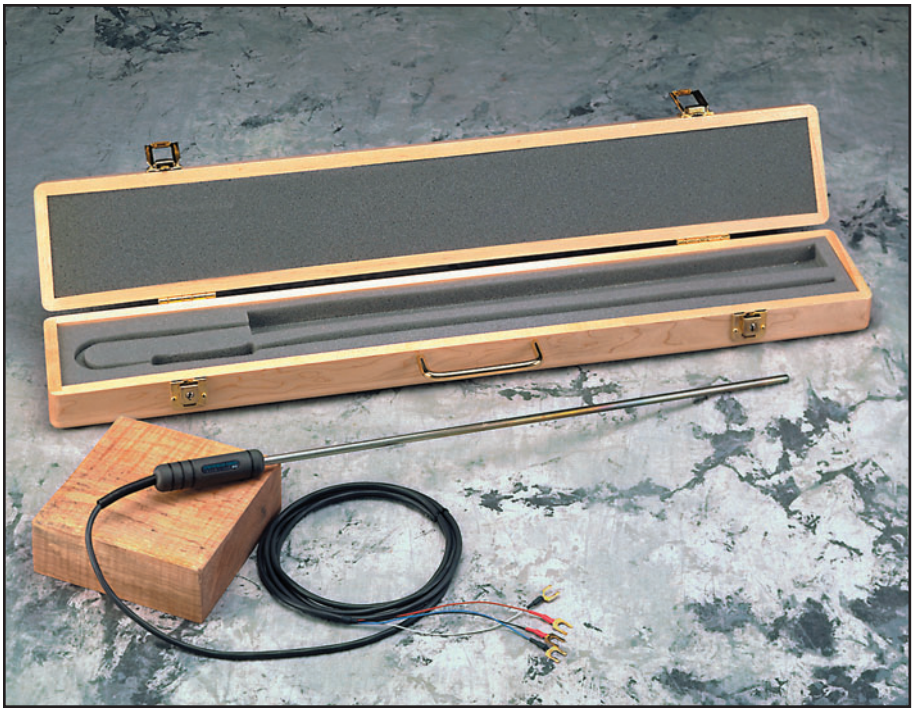
5698-25 25Ω Working Standard SPRT†

†*Maple carrying case included*

See page 156 for SPRT calibration options.

Peter (UK primary standards lab) plays temperature scales and musical scales with equal precision.

WORKING STANDARD METAL-SHEATH SPRTs Models 5680 and 5682



Working Standard Metal-Sheath SPRTs Models 5680 and 5682

- Inconel sheaths allow use in harsh environments
- Affordable true primary standards
- Meet all ITS-90 requirements from –200°C to 480°C

Want a metal-sheathed SPRT? We've got two great options for you.

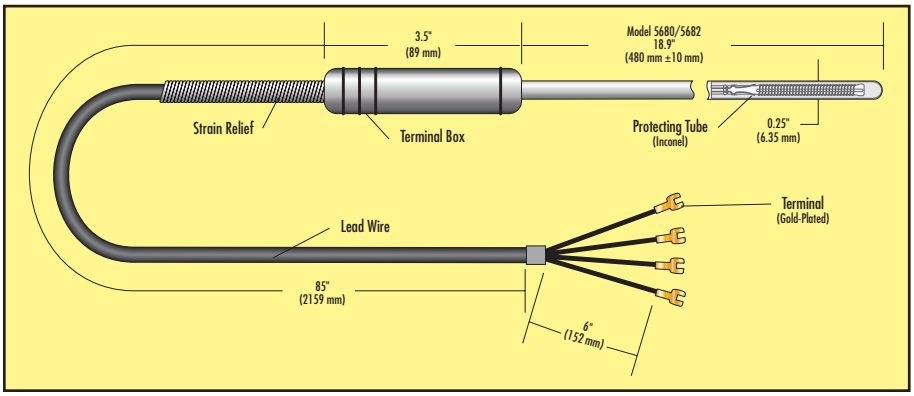
While the temperature range of metal-sheath SPRTs is narrower than that of quartz-sheath SPRTs, they're perfect for salt baths, baths that require metal blocks for increased stability (Hart baths don't need metal blocks), and dry-wells.

Even if you don't have a special use for them such as a salt bath, the price and performance of these standards allow you to use them in other situations that are inappropriate for quartz models.

The element in these SPRTs is made from high-purity platinum with a unique ceramic shield for high-temperature work. The quality construction of these SPRTs produces drift rates typically less than 0.005°C at 0°C after 100 hours at 480°C. This is excellent repeatability for an SPRT in this price range. In fact, this isn't just excellent reproducibility, stability, and reliability—the performance of these SPRTs is so good that no other company in the business can match it for this price.

Hart offers a variety of calibration options, including fixed-point calibrations in our own lab. At Hart, we'll give it to you any way you want it!

Why use a lesser instrument when you can have the true performance of an SPRT for about the same investment? There's no reason to put off buying SPRT-quality measurement ability or having competent backup to your quartz-sheath sensors.



Specifications

Temperature Range	–200°C to 480°C
Nominal R_{TPW}	**5680**: 25.5Ω (±0.5Ω) **5682**: 100Ω (±1.0Ω)
Current	**5680**: 1 mA **5682**: 0.5 or 1.0 mA
Resistance Ratio	W(234.315K) ≤ 0.844235 W(302.9146K) ≥ 1.11807
Sensitivity	**5680**: 0.1Ω/°C **5682**: 0.4Ω/°C
Drift Rate	< 0.01°C/100 hours at 480°C (typically < 0.005°C)
Repeatability	< 2 mK
Diameter of Pt Sensor Wire	**5680**: 0.003" (0.07 mm) **5682**: 0.0016" (0.04 mm)
Protective Sheath	Inconel Diameter: 0.25" (6.35 mm) Length: 19.1" (485 mm)
Lead Wires	Four sensor wires plus grounding wire

Ordering Information

5680-S	25Ω Working Standard Metal-Sheath SPRT†
5682-S	100Ω Working Standard Metal-Sheath SPRT†

†Maple carrying case included

See page 156 for SPRT calibration options.

Read about our accredited calibration services on page 156.

EXTENDED RANGE METAL-SHEATH SPRT — Model 5699

Extended Range Metal-Sheath SPRT — Model 5699

- Measures temperatures as high as 661°C
- Inconel and platinum sheaths guard against contamination
- Less than 8 mK/year drift
- Fifth wire provides shielded ground

SPRTs designed by Hart Scientific are known for their outstanding reliability and minimal long-term drift. They have been calibrated by national (and other primary) laboratories and proven repeatedly to outperform competitive models. Now Hart's 5699 Extended Range Metal-Sheath SPRT combines all the advantages of a Hart-designed sensor with the protective sheathing materials that allow your SPRT to be used in virtually any furnace or bath with temperatures as high as 661°C.

Designed and manufactured by our primary standards metrologists, the strain-free sensing element in the 5699 meets all ITS-90 requirements for SPRTs and minimizes long-term drift.

After one year of regular usage, drift is less than 8 mK (2–3 mK is typical). Even lower drift rates are possible depending on care and handling. A fifth wire for grounding is added to the four-wire sensor to help reduce electrical noise, particularly for AC measurements. Finally, you can get an improved version of an old industry-standard Inconel-sheathed SPRT.

The 5699 is constructed with a 0.219-inch-diameter Inconel sheath for high durability and fast response times. Inside the sheath, the sensing element is protected by a thin platinum housing that shields the sensor from contamination from free-floating metal ions found within metal environments at high temperatures. Reduced contamination means a low drift rate—even after hours of use in metal-block furnaces at high temperatures.

If you choose not to calibrate the 5699 yourself, a wide variety of options is conveniently available from Hart's own primary standards laboratory, including fixed-point calibrations covering any range between –200°C and 661°C.

At Hart we use SPRTs every day. We design them, build them, calibrate them, use them as standards, and know what it takes to make a reliably performing instrument. Why buy from anyone else?

Specifications

Temperature Range	–200°C to 661°C
Nominal R_{TPW}	25.5Ω (±0.5Ω)
Current	1 mA
Resistance Ratio	W(302.9146K) ≥ 1.11807 W(234.3156K) ≤ 0.844235
Sensitivity	0.1Ω/°C
Drift Rate	< 8 mK/year (2–3 mK/year typical)
Repeatability	< 1 mK
Diameter of Pt Sensor Wire	0.003" (0.07 mm)
Lead Wires	Four sensor wires plus grounding wire
Protective Sheath	Inconel Diameter: 0.219" ±0.005" (5.56 mm ±0.13 mm) Length: 19" (482 mm)
Insulation Resistance	> 100 MΩ at 661°C > 1000 MΩ at 20°C

Ordering Information

5699-S Extended Range Metal-Sheath SPRT†

†Maple carrying case included

See page 156 for SPRT calibration options.

Technical Tip

Maximize Your SPRT's Performance

Amazingly high accuracies can be obtained from a good SPRT if it is handled correctly. Expanded uncertainties as low as a few tenths of a millikelvin at 0°C are possible provided you do the following:

- Avoid physical shock or vibration to your SPRT. An SPRT is a delicate instrument, highly susceptible to mishandling.
- Make a measurement at the triple point of water after each measurement. Use the resistance ratio W(t) rather than the absolute resistance to calculate the temperature.
- Measure at two different input currents and extrapolate the results to determine the value at zero power. This will eliminate the often-ignored effects of self-heating.

GLASS CAPSULE SPRTs — Models 5686 and 5695

Glass Capsule SPRTs — Models 5686 and 5695

- Temperatures from –260°C (13K) to 500°C
- Stability typically 0.001°C over a 100°C range
- Miniature capsule package eliminates stem conduction

Sometimes you would like to make SPRT measurements but traditional SPRTs are too long or awkward for a particular application. Hart Scientific makes two versions of our miniature glass capsule SPRTs, which are perfect for cryogenics, calorimetry, and other metrology work requiring small SPRTs.

Both models are true SPRTs. The high-purity platinum wire is hand-wound on a glass cross frame in a strain-free design. The glass capsule is designed to match the thermal expansion of the platinum wire to ensure a true seal at all operating temperatures. The capsules are pressure sealed and come protected in their own maple case. Both models comply completely with ITS-90 and have the following resistance ratios:

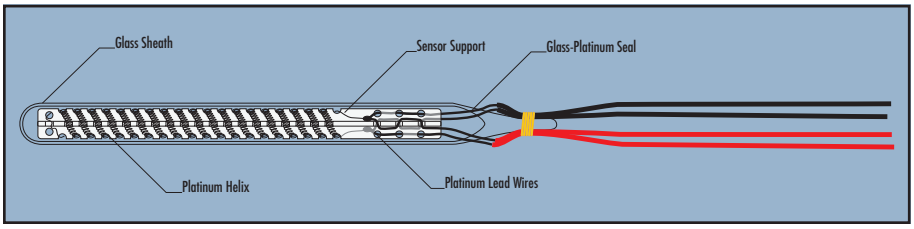
$$W(302.9146K) \geq 1.11807$$

and

$$W(234.3156K) \leq 0.844235$$

The 5686 covers temperatures from –260°C to 232°C, so it's perfect for cryogenic applications. It is 5.8 mm in diameter and 56 mm long.

The 5695 is designed for high-temperature applications requiring a small SPRT. Its unmatched range is from –200°C to 500°C and its size is 5.2 mm by 68 mm.



These SPRTs are small but meet customary SPRT performance for reproducibility, reliability, and stability. They solve many of the problems associated with taking precision measurements in situations unsuitable for traditional-length SPRTs. These are excellent calibration instruments.

Specifications

Temperature Range	**5686**: –260°C to 232°C (13K to 505K) **5695**: –200°C to 500°C (73K to 773K)
Nominal R_{TPW}	25.5Ω
Resistance Ratio	W(302.9146K) ≥ 1.11807 W(234.3156K) ≤ 0.844235
Drift Rate	< 0.01°C per year over the entire range; typically 0.001°C per year over a range of 100°C
Filling Gas	**5686**: helium **5695**: argon and oxygen
Lead Wires	Four platinum wires, 3 cm long
Size	**5686**: 5.8 mm dia. x 56 mm long (0.23" x 2.2") **5695**: 5.2 (+0.4) mm dia. x 68 mm long (0.2" [+0.016"] x 2.7")

Ordering Information

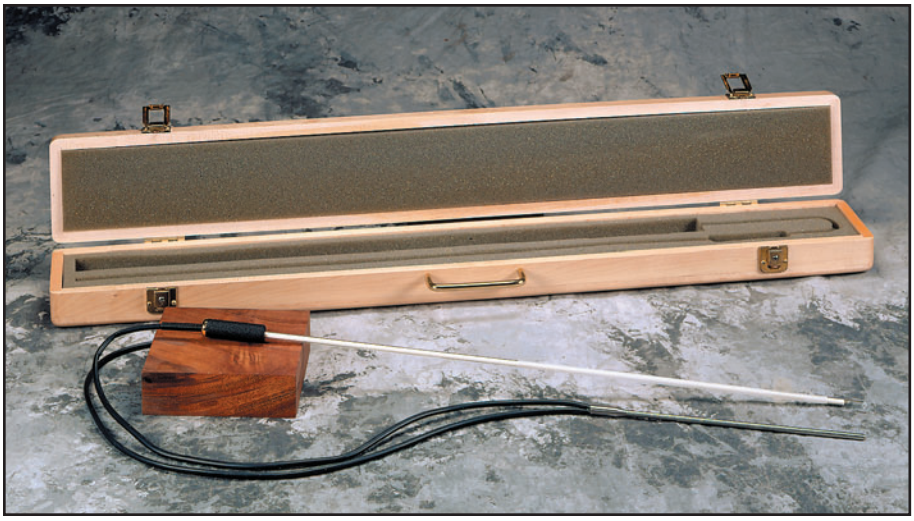
5686-B	Glass Capsule SPRT, –260°C to 232°C
5695-B	Glass Capsule SPRT, –200°C to 500°C

†Maple carrying case included

See page 156 for SPRT calibration options.

Get the latest product information at www.hartscientific.com

GOLD-PLATINUM THERMOCOUPLE Model 5629



Gold-Platinum Thermocouple Model 5629

- Calibration uncertainty of ±0.02°C to 1000°C
- Fixed-point calibration included
- Stability better than ±0.02°C

Hart Scientific not only makes the finest SPRTs in the world, we make the best standards-level thermocouple. Following the designs of NIST and NRC, the Model 5629 Gold-Platinum Thermocouple performs to a level that rivals most high-temperature SPRTs but is easier to use and more affordable.

Until now, type S or type R thermocouples have often been used as high-temperature laboratory standards. Unfortunately, they both use a platinum-rhodium alloy. At temperatures above 500°C, rhodium oxidizes faster than platinum. This degrades the homogeneity of the thermocouple wire, reducing the accuracy of the standard.

The 5629 Gold-Platinum Thermocouple uses no alloys. Both the gold and platinum wires are 99.999% pure, and because these are the most stable of all metals from 0°C to 1000°C, long-term stability is excellent.

Each thermocouple we ship includes a NVLAP-accredited fixed-point calibration at the freezing points of tin, zinc, aluminum, and silver. From that, we derive two deviation coefficients that, in conjunction with the NIST function, provide maximum accuracy. With an expanded calibration uncertainty of ±0.02°C (k=2), the gold-platinum thermocouple is a true laboratory standard.

Gold-platinum thermocouples are also exceptionally stable. The 5629 repeats within ±0.02°C after numerous repetitions throughout its range of 0°C to 1000°C.

Of course each 5629 includes a reference junction enclosed in stainless steel. We use high-grade copper extension wires meticulously selected for low EMF characteristics. At 9 inches long, our reference junction is longer than average to ensure sufficient immersion with low heat loss in a zero-point temperature source.

High-temperature SPRTs (HTPRTs) define ITS-90 to 961.78°C. Though not as stable and accurate as a high-quality HTPRT, the 5629 has a number of qualities that make it an effective substitute. Most obvious is price. Not only does an HTPRT cost more than a gold-platinum thermocouple, a fixed-point calibration costs thousands of dollars. With the 5629, a fixed-point calibration is included.

Gold-platinum thermocouples are easier to handle than HTPRTs. They're less susceptible to damage from metal ion contamination and mechanical shock.

The 5629 Gold-Platinum Thermocouple is simply phenomenal, and we don't mind saying so. Try one. If you're not happy, return it in good condition and we'll refund your money.

Specifications

Temperature Range	0°C to 1000°C
Thermocouple Materials	99.999% pure gold, 99.999% pure platinum
Sheath Materials	Measurement junction of quartz glass, reference junction of stainless steel
Calibration	Freeze points of tin, zinc, aluminum, and silver included; coefficient values included with certificate
Calibration Uncertainty	±0.020°C (expanded uncertainty [k=2] over entire range)
Stability	±0.020°C typical
Measurement Junction Sheath Dimensions	7.0 mm diameter x 600 mm length
Reference Junction Sheath Dimensions	5.56 mm diameter x 229 mm length
Minimum Immersion	16" (406 mm)
Accuracy	Accuracy will vary according to usage techniques and conditions. Under reasonably good conditions, uncertainties of ±0.02°C can be expected.

Ordering Information

5629-X	Gold-Platinum Thermocouple (four-point NVLAP-accredited calibration by fixed point and maple protective case included)

X = termination. Specify "B" (bare wire) or "W" (generic copper-to-copper TC connector).

Read about our calibration training courses on page 153.

WHY BUY PRIMARY STANDARDS FROM HART?

Setting up a primary temperature standards lab is no small project. Decisions must be made about temperature range, uncertainty requirements, the types of standards you need, and the companies that can supply your standards. Whose products are reliable? Which company backs up its performance claims? Who provides after-sale support and training? Who really demonstrates the most integrity throughout your ownership experience? After all, substantial investments are being made, and in many cases the credibility of your lab can be affected by the outcome.

So why does Hart Scientific claim to be the world's best supplier of primary temperature standards? Because our products have been tested over and over again by national labs around the world and proven to outperform their specs. Because the people who design and build primary temperature standards at Hart have been designing and building primary temperature standards longer than any other supplier in the world. We not only manufacture primary standards, we perform basic research and innovate with new primary standards designs. No other company offers the high-quality training and post-sale support that we do. No one!

Metal Fixed-Point Cells

For realizing the ITS-90 temperature scale, Hart's metal fixed-point cells provide performance you can trust, and we supply the data with each cell to prove it. Hart's fixed-point cells benefit from more than 20 years of experience in research, design, and manufacturing. Four types of cells are available: traditional size cells, "mini" quartz cells, new "mini" metal-cased cells, and small stainless steel "X" cells. All four provide outstanding performance.

Each Hart cell is carefully assembled, tested, and supplied with an assay of metal-sample purity. Every traditional size cell further undergoes more rigorous testing to a CCT-based procedure in our NVLAP-accredited lab, where we realize at least three freezing curves and perform a detailed "slope analysis" to confirm cell purity. If you'd like this more thorough "slope analysis" for a "mini" quartz, new "mini" metal-cased, or small stainless steel "X" cells, we offer that as an option. And if you still want more, we can also supply comparison data with our own reference cells that have been independently tested at NIST.

No other commercial company has as much experience in the development of fixed-point cells as Hart. Hart's own Xumo Li was a key contributor to the development of the ITS-90 scale. That's one reason you'll find Hart cells in many of the national metrology institutes around the world.

Water Triple Point Cells

Like our metal fixed-point cells, Hart's triple point of water cells come in traditional and "mini" quartz sizes as well as small stainless steel, which can be realized in a dry-well calibrator. Our traditional cells have been tested at NIST (see chart on facing page) and are within a few micro-Kelvin of NIST's cells.

If you're new to primary temperature standards and are considering a water triple point cell, one of our cells is sure to meet your requirements. We offer training through our seminars, insurance for our glass cells, and our stainless steel cell just can't be broken!

Maintenance Apparatus

Maintaining fixed-point cells requires high-stability apparatus with tight gradient control so plateaus last longer and your work is more productive. Every Hart maintenance apparatus, including our metrology furnaces and fluid baths, uses temperature controllers designed and manufactured by Hart. These controllers are widely recognized for their unmatched stability and uniformity control.

For metal fixed-point cells, choose from one-zone, three-zone, or heat-pipe furnaces for regular or mini cells. Optional equilibration blocks fit into the furnaces for annealing and comparison calibrations. Don't let the competition try to tell you that a furnace fitted with process controllers can provide the same performance as a furnace fitted with controllers designed specifically for high-stability temperature control. With a Hart furnace you'll get longer cell plateaus with smaller gradients than you will from any other furnace on the market.

SPRTs

SPRTs are the only acceptable ITS-90 interpolation devices from the triple point of hydrogen (13.8033 K) to the freezing point of silver (961.78°C). While most SPRT manufacturers lost their design capabilities years ago, Hart continues to develop new innovative designs with the lowest drift rates.

Hart manufactures quartz SPRTs in four different temperature ranges, including capsule SPRTs for low temperatures, an ultra-stable SPRT for the range to 480°C, and a new "working-standard" SPRT for the range to 660°C. Our metal-sheath SPRTs include a 25.5-ohm, contamination-resistant SPRT, so you finally have a choice of suppliers. Hart SPRTs are the standards of choice for many national metrology institutes around the world.

Thermometry

Traditionally, SPRT measurements have been made using expensive, difficult-to-use bridges. If you need 1 ppm accuracy, there's nothing that provides a better price/performance ratio than Hart's Model 1590 Super-Thermometer. The 1590 Super-Thermometer provides bridge accuracy at a fraction of the cost and provides a multitude of features that improve your productivity. With a Super-Thermometer, there is virtually no learning curve. It's so easy to use that you'll be making measurements within minutes after switch-on.

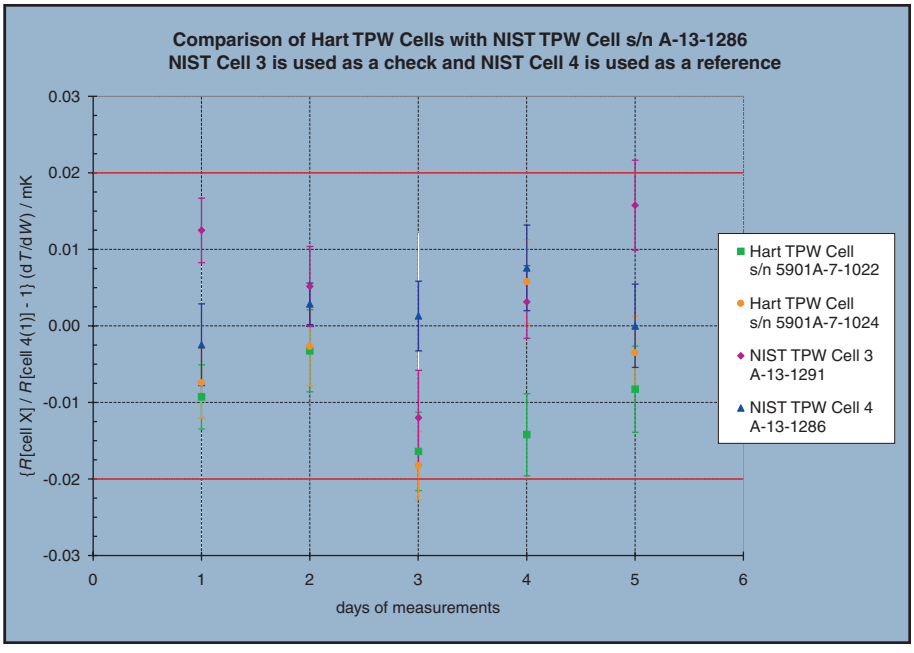
If you truly need 0.1 ppm performance, the 5581 MIL Bridge offers conventional DC measurement with a wide range. It's perfect for temperature metrology work and for labs looking to combine temperature with electrical resistance standards.

Xumo Li, Hart's Vice President of Technology Development and Metrology

Training

Once you've determined which primary standards products you need and you've made a major investment, what about training and after-sales support? Hart's temperature school offers a fun and unique seminar that provides all the answers to your toughest questions. Our 2½-day "Realizing and Approximating ITS-90" seminar provides all the theory and some first-rate practical, hands-on experience to get you started. You'll learn some key temperature theory from former national lab scientists and take part in practical experiments with our lab staff. If you want more, talk to us about individual ITS-90 training, where you can work alongside our cal lab staff in Hart's primary standards lab, performing practical realizations on the cells that you just purchased.

We've been making and using primary temperature standards for many years, and we understand the issues you face in your lab. Our own lab is accredited (NVLAP lab code 200348-0) and our uncertainties are among the best in the world. When you buy primary standards, don't compromise the quality of the products, the reputation of your supplier, or the level of service and training they can provide.



TRIPLE POINT OF WATER CELLS

Triple Point of Water Cells **Models 5901 and 5931**

- Easy-to-use, low-cost primary standards
- Very accurate — uncertainty better than ±0.0001°C
- Five shapes and sizes to choose from

Did you know that you can get an ITS-90 primary standard for less than $1,100?

You should be frequently using this low-cost reference to make sure your thermometer standards are in tolerance.

The TPW is an intrinsic standard that does not need recalibration. It is the most accurate standard you can use, and you can learn to use it in an afternoon.

The ITS-90 assigns the TPW a value of 0.01°C (273.16 K). Hart cells achieve this temperature with an expanded uncertainty of less than 0.0001°C. If you own a reference thermometer, you really should have a TPW cell to get the most out of your investment.

If you calibrate secondary standards, the TPW is one point you can calibrate by primary fixed-point method rather than less accurate comparison methods. If you're using a reference thermometer to comparison-calibrate industrial thermometers, you can make sure your reference isn't drifting by frequently checking it at the triple point of water.

Hart makes five triple point of water cells to suit your needs. A NVLAP-accredited cell intercomparison option is available for each one. Intercomparison includes comparing the equilibrium value of the cell against that of a Hart reference cell.

Hart's original **5901** cell is used by many national temperature labs around the world. It has a wide mouth for facilitating freezing of the mantle using crushed dry ice. The rubber foot lets you rest the cell on your ice bath or holding fixture for extra stability and protection while you're using it.

The Hart **5901A** is a full-size cell designed after the original NBS cell, which had a glass support arm. While the arm does not impact performance in any way, some users prefer this design because it facilitates lifting and carrying the cell. The arm can be used as a hook for supporting the cell in an ice bath. The handle is also used as a McLeod gauge for a strictly qualitative check of trapped air in the cell.

The Hart **5901B** is a smaller cell that's easy to handle, accommodates shorter sensors, and can be maintained in an automatic maintenance device (see page 32). Despite this cell's diminutive size, it is made with the same materials and technology used to make the larger cells. The 5901B has an expanded uncertainty of 0.0002°C and a well diameter of 8 mm.

The Hart **5901C** is designed like Hart's original 5901 cell with the exception of the well size, which is 13.6 mm rather than the standard 12 mm. It's a full 380 mm deep and has an expanded uncertainty of 0.0001°C.

All these cells are cylindrical borosilicate glass filled with highly pure water. Hart's newest TPW cell is the **5931**. It uses a stainless steel shell so it's virtually unbreakable. It can be easily realized and maintained in a bath or dry-well calibrator and provides uncertainty better than ±0.001°C. (See page 34.)

A simple, time-saving method can be used with each Hart TPW cell for forming the ice necessary to generate the triple point. The smaller 5901B and 5931 models use the supercool-and-shake method, creating an ice slush, which remains stable all day. For the larger cells, the Model 2031 Immersion Freezer creates an ice mantle virtually automatically. Just fill the condensing reservoir of the 2031 with dry ice and alcohol, insert it into the cell, and return in under an hour to find a well-formed ice mantle. (A convenient method using LN_2 is also available.)

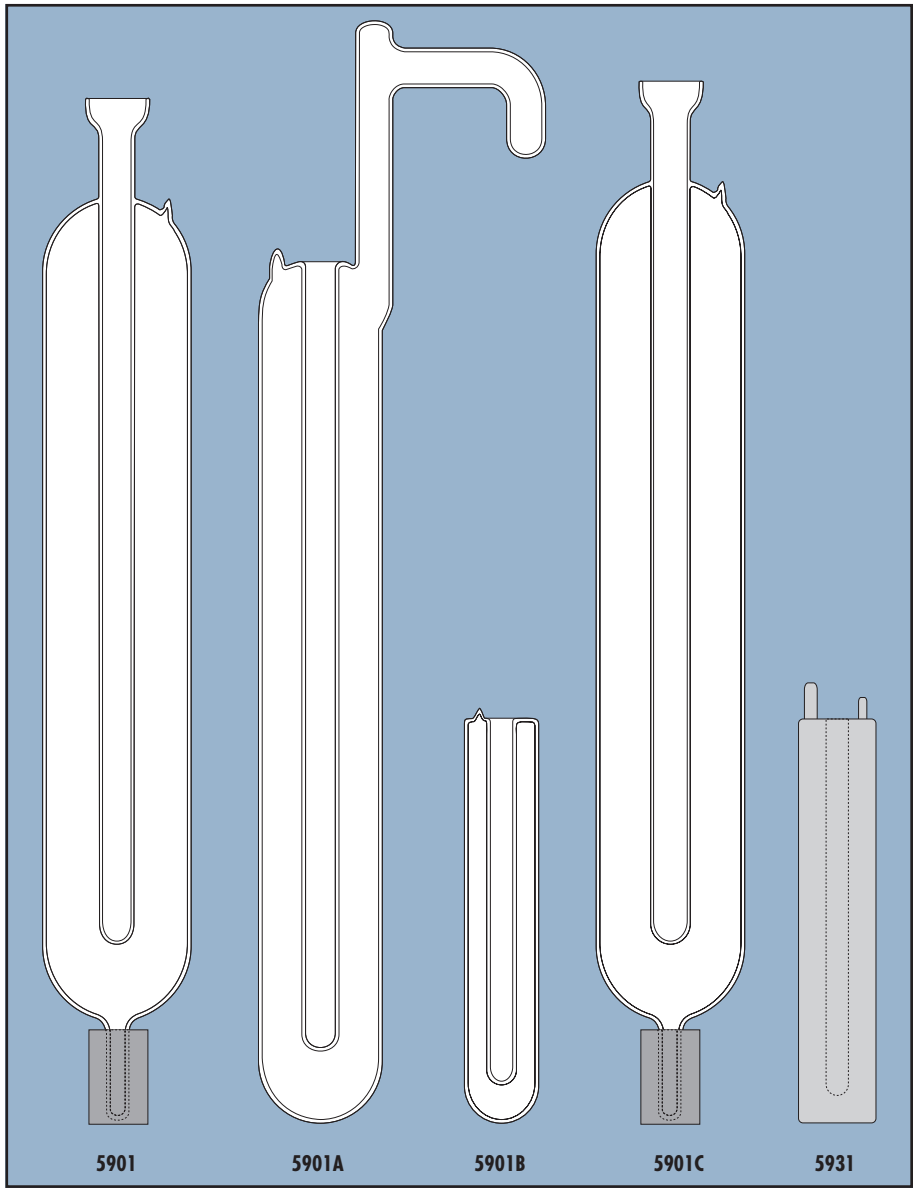
We also have baths for maintaining your water triple point cells. Not only will your cells be ready to use when you need them, but they're much safer if you maintain them in one of our constant-temperature baths.

Ordering Information

5901	TPW, 12.6 mm I.D.
5901A	TPW, 12.6 mm I.D., with handle
5901B	TPW, mini quartz, 8 mm I.D.
5901C	TPW, 13.6 mm I.D.
5931	TPW, SST X Cell, 6.35 mm I.D.
INSU-5901	TPW Insurance, one year
7312	TPW Maintenance Bath (see page 20)
7012	Bath, Deep Mid-Range (see page 90)
2028	Dewar (for TPW ice bath)
9210	TPW (5901B) Maintenance Apparatus (see page 32)
2031	"Quick Stick" Immersion Freezer
1904-Tpw	Accredited Cell Intercomparison
2067-D	TPW Stand, large black
2066-D	TPW Stand, small black
3901-11	TPW Bushing, 5901/5901A to 7.5 mm
3901-12	TPW Bushing, 5901/5901A to 7/31"
3901-13	TPW Bushing, 5901/5901A to 1/4"
3901-21	TPW Bushing, 5901C to 7.5 mm
3901-22	TPW Bushing, 5901C to 7/31"
3901-23	TPW Bushing, 5901C to 1/4"

The 2028 Dewar has inside dimensions of 7.75" diameter by 19.5" depth (20 x 50 cm), and outside dimensions of 9.75" diameter by 24" depth (25 x 61 cm).

Specifications	5901	5901A	5901B	5901C	5931
Expanded Uncertainty (k=2)	< 0.0001°C	< 0.0001°C	< 0.0002°C	< 0.0001°C	< 0.001°C
Reproducibility	0.00002°C	0.00002°C	0.00005°C	0.00002°C	0.0001°C
Dimensions	60 mm O.D. x 380 mm long, 12.6 mm I.D.	50 mm O.D. x 450 mm long, 12.6 mm I.D.	30 mm O.D. x 180 mm long, 8 mm I.D.	60 mm O.D. x 380 mm long, 13.6 mm I.D.	24 mm O.D. x 127 mm long, 6.35 mm I.D.
Immersion Depth (water surface to well bottom)	260 mm	260 mm	117 mm	260 mm	86 mm



TPW MAINTENANCE BATH — Model 7312

TPW Maintenance Bath **Model 7312**

- Maintains TPW cells for up to two months
- Includes immersion freezer for simple cell freezing
- Independent cutout circuit protects cells from breaking

For frequent use of traditional-size triple point of water cells, nothing helps save you time and hassle like a good maintenance bath. The Model 7312 Triple Point of Water Maintenance Bath keeps your cells up and running reliably for weeks at a time—even during heavy usage—and comes at a price you'll love.

The 7312 accommodates two TPW cells and includes three pre-cool wells for properly cooling probes prior to measurements within the cells. Stability and uniformity are each better than ±0.006°C, so your cells stay usable for up to eight weeks. Whatever method you use for building your ice mantles, you can be assured they'll last in a 7312 bath.

An independent safety circuit protects your water cells from freezing and breaking by monitoring the temperature of the bath and shutting down its refrigeration system should the bath controller fail. Noise-reduction techniques in the manufacturing process ensure your bath doesn't add excessive noise to your lab.

With a temperature range from –5°C to 110°C, this bath can also be used for comparison calibrations—particularly of long-stem probes—or maintenance of gallium cells. An optional gallium cell holding fixture fits two cells, which in a 7312 bath can maintain their melting plateaus for up to two weeks.

In fact, the 7312 comes with a time-saving Model 2031 Immersion Freezer so you can build your ice mantles quickly and hands-free. Just fill the 2031's condensing reservoir with dry-ice and alcohol, insert it into the cell, and get some other work done while your ice mantle forms in less than an hour. (Alternatively, LN_2 may be used.)

If you're using traditional-size TPW cells, don't take the time to create an ice mantle only to watch it melt quickly as it sits in a bucket of ice. Maintain your cells the right way in a Hart 7312 TPW Maintenance Bath.

Specifications

Range	–5°C to 110°C
Stability	±0.001°C at 0°C (alcohol-water mix) ±0.004°C at 30°C (alcohol-water mix)
Uniformity	±0.003°C at 0°C (alcohol-water mix) ±0.006°C at 30°C (alcohol-water mix)
TPW Duration	Six weeks, typical (assumes correctly formed ice mantle)
Set-Point Accuracy	±0.05°C at 0°C
Set-Point Repeatability	±0.01°C
Display Resolution	±0.01°C
Set-Point Resolution	±0.002°C; 0.00003°C in high-resolution mode
Access Opening	4.75" x 3.8" (121 x 97 mm)
Immersion Depth	19.5" (496 mm)
Volume	5 gallons (19 liters)
Communications	RS-232 included
Power	115 VAC (±10%), 60 Hz or 230 VAC (±10%), 50 Hz, specify
Size	12" W x 24.5" D x 32.25" H (305 x 622 x 819 mm)
Weight	75 lb. (34 kg)

Ordering Information

7312	TPW Maintenance Bath (includes TPW Holding Fixture, Immersion Freezer, and RS-232 Interface)
2001-IEEE	Interface, IEEE-488
2029-5903	Gallium Cell Holding Fixture
2031	"Quick Stick" Immersion Freezer

Hart's 2031 "Quick Stick" Immersion Freezer offers unmatched convenience and simplicity in forming the triple point of water ice mantle.

ITS-90 FIXED-POINT CELLS

ITS-90 Fixed-Point Cells

- Best cell uncertainties commercially available
- Every ITS-90 fixed point available from mercury to copper
- Plateaus last days (gallium for weeks and TPW for months)
- Manufactured and tested by Hart's primary standards scientists

Hart scientists have designed and tested ITS-90 fixed-point cells for many years. Not only do we manufacture all the major fixed points, our metrologists have written extensively on the theory and use of cells and have created new designs covering a range of applications no other company can match.

Our testing of fixed-point cells is also unmatched. The scope of our accreditation includes the testing of ITS-90 fixed-point cells. Each cell may be purchased with this intercomparison option, which includes comparing the equilibrium value of your cell against that of a reference Hart cell.

Traditional Freeze-Point Cells

If you want true primary temperature standards capability, you want metal freeze-point cells that are very close to the theoretical freezing temperature and provide plateaus that are both stable and long lasting.

Hart's metal freeze-point cells are the culmination of more than 20 years of primary standards experience. No other company has as much experience in the development of metal fixed-point cells as Hart. That's why you'll find Hart cells in many national metrology institutes around the world.

Each Hart cell is carefully constructed in our ultra-clean, state-of-the-art lab, using high-density, high-purity graphite crucibles containing metal samples with purity of at least 99.9999% (six 9s) and in many cases 99.99999% (seven 9s). The crucible is enclosed within a sealed quartz glass envelope that is evacuated and back-filled with high-purity argon gas. A special sealing technique is used to seal the cell at the freezing point. We measure and record for you the precise pressure of the argon gas to ensure the most accurate corrections for pressure.

Once manufactured, all Hart cells are tested and supplied with an assay of metal-sample purity. Every traditional size ITS-90 cell further undergoes more rigorous testing in our primary standards lab where we realize melt-freeze curves and perform a detailed "slope analysis" to confirm cell purity. If you want more data, we'll give you an optional intercomparison with our own reference cells.

Gallium Cells

Gallium cells are a great reference for validation of instruments subject to drift (like SPRTs) and they're important for calibrating sensors used near room or body temperatures, in environmental monitoring, and in life sciences applications.

Hart makes two traditional-size gallium cells. The Model 5943 Gallium Cell is sealed in a stainless steel envelope. High purity gallium (99.99999%) is enclosed in a plastic and metal shell. The stainless steel container is then filled with pure argon gas at one standard atmosphere at the melting-point temperature.

Gallium expands on freezing by 3.1%, requiring the cell to have flexible walls. Unlike some manufacturers' cells, which are made from PTFE enclosure materials,

In addition to our stainless steel-encased gallium cell, the Model 5903 Gallium Cell, enclosed in traditional Pyrex glass, offers plateaus that can last for weeks when maintained in a Hart metrology bath.

ITS-90 FIXED-POINT CELLS

Specifications

Model	Fixed Point	Style	Assigned Value (°C)	Outside Diameter	Inside Diameter	Total Outside Cell Height	Depth‡	Cell Uncertainty (mK, k=2)	Certification (mK, k=2)†
5900	Mercury	Stainless Steel	–38.8344	31 mm	8.2 mm	470 mm	200 mm	0.2	0.25
5903	Gallium	Traditional Quartz Glass	29.7646	42 mm	8 mm	300 mm	150 mm	0.08	0.1
5904	Indium	Traditional Quartz Glass	156.5985	48 mm	8 mm	285 mm	195 mm	0.7	0.7
5905	Tin	Traditional Quartz Glass	231.928	48 mm	8 mm	285 mm	195 mm	0.5	0.8
5906	Zinc	Traditional Quartz Glass	419.527	48 mm	8 mm	285 mm	195 mm	0.9	1.0
5907	Aluminum	Traditional Quartz Glass	660.323	48 mm	8 mm	285 mm	195 mm	1.3	1.8
5908	Silver	Traditional Quartz Glass	961.78	48 mm	8 mm	285 mm	195 mm	2.4	4.5
5909	Copper	Traditional Quartz Glass	1084.62	48 mm	8 mm	285 mm	195 mm	10.1	12.0
5910	Gold	Traditional Quartz Glass	1064.18	48 mm	8 mm	285 mm	195 mm	2.5	4.5
5924	Indium	Open Quartz Glass	156.5985	50 mm	8 mm	596 mm	195 mm	0.7	0.7
5925	Tin	Open Quartz Glass	231.928	50 mm	8 mm	596 mm	195 mm	0.5	0.8
5926	Zinc	Open Quartz Glass	419.527	50 mm	8 mm	596 mm	195 mm	0.9	1.0
5927A-L	Aluminum	Open Quartz Glass (long)	660.323	50 mm	8 mm	696 mm	195 mm	1.3	1.8
5927A-S	Aluminum	Open Quartz Glass (short)	660.323	50 mm	8 mm	596 mm	195 mm	1.3	1.8
5928	Silver	Open Quartz Glass	961.78	50 mm	8 mm	696 mm	195 mm	2.4	4.5
5929	Copper	Open Quartz Glass	1084.62	50 mm	8 mm	696 mm	195 mm	10	12.0
5943	Gallium	Stainless Steel	29.7646	38.1 mm	8.2 mm	250 mm	168 mm	0.1	0.1

†Certifications at lower uncertainties are available for national laboratories.
‡Depth is measured from the bottom of the thermometer well to the top of the pure reference material.

our cells don't need pumping and refilling because they're not gas permeable. In fact, we guarantee our cells will maintain their uncertainty of < 0.1 mK for at least five years. Realization and maintenance of the cell is automated with our Model 9230 Maintenance Apparatus (see page 32). This apparatus will provide melting plateaus up to eight days and a convenient control to automatically achieve a new melt plateau each week with an investment of just five minutes. Never has the maintenance of a world-class gallium cell been easier.

Hart's 5903 is sealed in a borosilicate glass envelope, uses similar manufacturing techniques, and provides similar low uncertainties; and when maintained in a Hart Model 7012 or 7312 maintenance bath, your melting plateaus will last as long as 14 days—that's *days,* not hours.

Water Cells

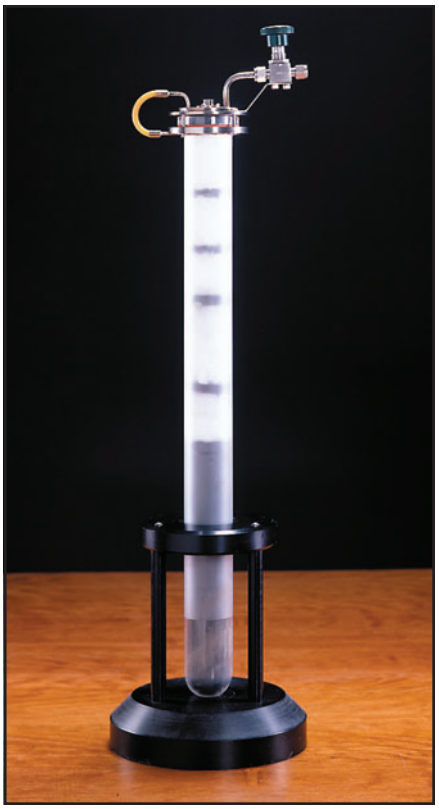
While simple ice baths are often used as a calibration point at 0°C, their limitations include gradients, purity problems, repeatability issues, and variances in construction and measurement techniques. Triple point of water cells not only solve these problems, they represent the most used temperature on the ITS-90, and they're inexpensive to own and use.

Hart makes three traditional size TPW cells (see page 18) that have been repeatedly proven in national labs to surpass their published uncertainty specification of ±0.0001°C. Ice mantles may be formed using dry ice, LN_2, or immersion freezers and can last for up to two months when maintained in our 7012 or 7312 baths.

Open Metal Cells

Made from the same materials and with the same manufacturing techniques as their sealed counterparts, Hart's new series of "open" metal fixed-point cells include a high quality valve for connecting to a precision pressure-handling system within your lab. Using such a system, the cell can be evacuated, charged and purged several times with a pure inert gas, then charged again to a regulated pressure level while measurements are made with the cell.

Once assembled and tested, each Hart ITS-90 open cell further undergoes more rigorous testing in our lab, unlike cells from some manufacturers who provide their open cells as a *kit* of parts, without any test data.

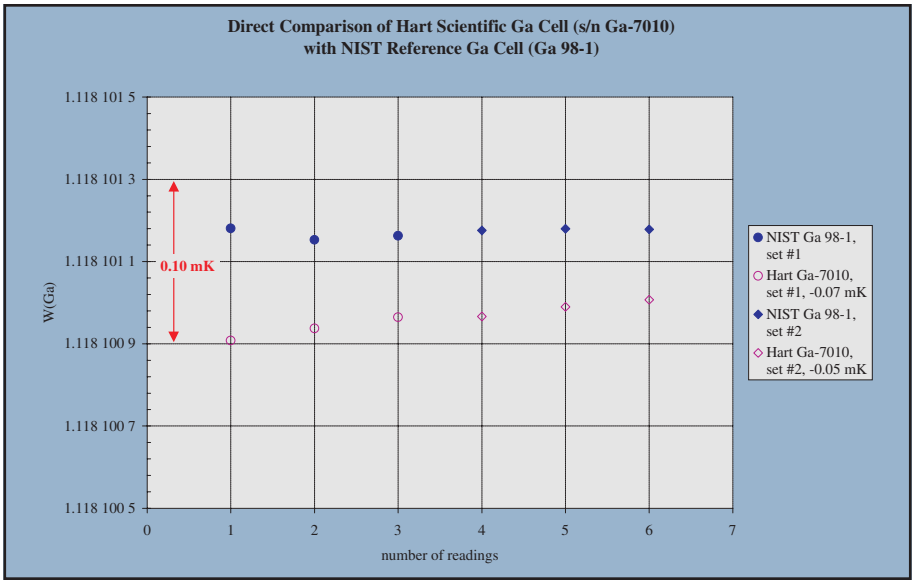


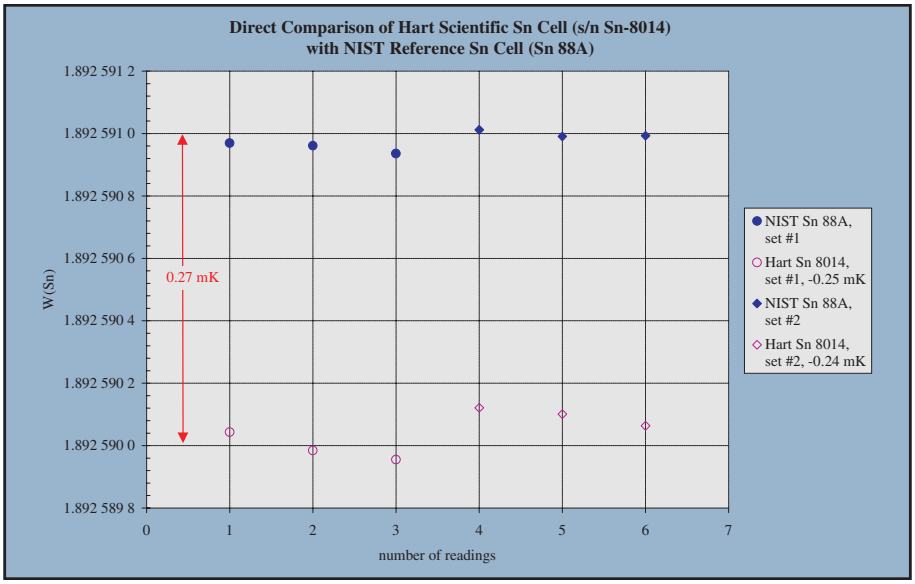
Open cells allow users to minimize the uncertainty from pressure corrections by regulating cell pressures themselves.

Because open cells allow users to measure the pressure within the cell, uncertainties due to pressure corrections may be minimized. Use of open cells is now being suggested by the CCT, and open cells can be used for demanding temperature-versus-pressure applications as well as precision SPRT calibrations.

The height of these cells has been extended to allow easy access to the gas valve while the cells are in use. Pure quartz-wool insulation and four high-purity graphite discs prevent heat loss from the metal sample to the pressure regulation system while optimizing vertical temperature gradients within the cell. Each cell has an outside diameter of 50 mm and a height of 600 mm (silver and copper cells are 700 mm tall).

When it comes to primary temperature standards, Hart supplies more equipment than all of our competitors put together. If your goal is to reduce uncertainty, start by buying from the company that supports its products better than any other metrology company in the world. Why trust your primary standards to any other company?





Technical Tip

What Is the Uncertainty of My Cell?

Fixed-point cells are artifact standards, which embody reproducible physical phenomena. The uncertainty associated with these artifacts can be viewed in two ways.

The first way is the theoretical uncertainty based on the purity of the constituent components only. Uncertainty computed in this manner can be considered an ideal view. Because these purity figures are often not based on traceable measurements, their value in the calibration laboratory is questionable.

The second way is the tested or guaranteed uncertainty, which represents observed performance under real (not ideal) conditions. These figures represent what has actually been observed in the laboratory and what can be expected in use. Although the theoretical uncertainty may be useful, the actual uncertainty is what influences our measurements.

Hart's published specs are guaranteed and can be verified through an optional accredited certification in our primary temperature lab.

Ordering Information

5900	Mercury Cell, Stainless Steel
5903	Gallium Cell, Traditional Pyrex Glass
5904	Indium Cell, Traditional Quartz Glass
5905	Tin Cell, Traditional Quartz Glass
5906	Zinc Cell, Traditional Quartz Glass
5907	Aluminum Cell, Traditional Quartz Glass
5908	Silver Cell, Traditional Quartz Glass
5909	Copper Cell, Traditional Quartz Glass
5910	Gold Cell, Traditional Quartz Glass
5924	Indium Cell, Open Quartz Glass
5925	Tin Cell, Open Quartz Glass
5926	Zinc Cell, Open Quartz Glass
5927A-S	Aluminum Cell, Open Quartz Glass, Short
5927A-L	Aluminum Cell, Open Quartz Glass, Long
5928	Silver Cell, Open Quartz Glass
5929	Copper Cell, Open Quartz Glass
5943	Gallium Cell, Stainless Steel
1904-X	Accredited Cell Intercomparison
2931-LG	Protective Wood Case, traditional cells

Read about our calibration training courses on page 153.

FREEZE-POINT FURNACES

Freeze-Point Furnaces **Models 9114, 9115, and 9116**

- Designed for long plateaus
- Automated controllers, RS-232 included
- Top access to high-stability Hart controllers
- External cooling coils

Several companies manufacture freeze-point furnaces. Most of these furnaces are of adequate theoretical design and of reasonable quality. Most are priced similarly. However, there is a difference that can't be seen from specifications or price, and that's how well the furnace performs with the freeze-point cells they're designed to maintain.

Establishing and maintaining a freeze-point plateau is what these furnaces are supposed to be about. Nothing they do is more important than this performance issue.

Hart Scientific makes three freeze-point furnaces that, when combined with Hart freeze-point cells, produce the longest plateaus in the industry. A Hart furnace and cell can establish plateaus that range from 24 to 40 hours or more.

Fixed-point furnaces can also be used for comparison calibrations and for annealing. In these processes, stability and uniformity are very important, and nothing speaks more about stability and uniformity than the length of the plateaus produced by the furnace. No other furnace beats a Hart furnace where it counts.

All three of these furnaces have external cooling coils for circulation of tap water at less than 60 PSIG and approximately 0.4 GPM to reduce heat load to the lab. They also come with RS-232 ports and have equilibration blocks available for comparison calibrations. IEEE-488 interface packages are also available if that's your preference.

One of Hart's three fixed-point furnace models will meet your needs. Remember, the length of the plateau is the best measure of a furnace's performance. Call us for performance data on actual cell freezes and test data on furnace gradients.

Model 9114

This furnace has a range of 100°C to 680°C, which includes the indium, tin, zinc, and aluminum fixed points all in one furnace.

The Model 9114 furnace has an inlet for use of clean dry air or inert gas to initiate the supercool of a tin cell. Other furnaces require the user to remove the hot and fragile tin cell from the furnace by hand before cooling. In a Hart furnace, you simply turn on your gas, monitor your cell during its supercool, and turn the gas off when the freeze begins.

The Model 9114 is a three-zone furnace with the best in Hart digital controller technology. Hart designs and builds proprietary controllers that have a reputation of being the best in the business. All of our fixed-point furnaces use them to achieve excellent stability and uniformity.

For easy access and visibility, all three zones are controlled from the top of the unit. The primary controller can be set in 0.01°C increments, and actual temperature is readable to two decimal places.

The freezing and melting process can be automated using eight preset, user-programmable temperature settings. The top and bottom zones are slaved to the primary zone using differential thermocouples. A high-temperature PRT acts as the main control sensor for the best accuracy, sensitivity, and repeatability.

Model 9115

The Model 9115 Sodium Heat Pipe Furnace is specifically designed for maintenance of aluminum and silver freeze-point cells.

It has a temperature range of 550°C to 1000°C with gradients of less than ±0.1°C throughout. The sodium heat-pipe design provides a simple yet uniform single heating zone that ensures very uniform changes in states during heating and cooling.

Melting, freeze initiation, and plateau control for a variety of freeze-point cells are possible by entering up to eight set-points and ramp and soak rates. The controller displays temperature in degrees C or F, and temperature feedback is done via a thermocouple. Freeze-point plateaus

Specifications	9114	9115	9116
Temperature Range	100°C to 680°C	550°C to 1000°C	400°C to 1100°C
Temperature Stability	±0.03°C	±0.3°C	±0.5°C
Temperature Uniformity	±0.05°C (±0.1°C in the pre-heat well)	+0.1°C	less than +0.5°C
Set-Point Accuracy	±0.5°C	±3.0°C	
Set-Point Resolution	0.01°C	0.1°C	
Display Resolution	0.01°C	0.1°C below 1000°C 1°C above 1000°C	
Thermal Safety Cutout Accuracy	±5°C	±10°C	
Heater Power	End Zones: 1000 W each (at 230 VAC nominal) Primary Zone: 1500 W	2500 W	End Zones: 800 W each (at 230 VAC nominal) Primary Zone: 900 W
Exterior Dimensions	33" H x 24" W x 16" D (838 x 610 x 406 mm)		
Power Requirements	230 VAC (±10%), 50/60 Hz, 1 Phase, 12 A maximum		
Weight	203 lb. (92 kg)	180 lb. (82 kg)	150 lb. (68 kg)

of 8 to 10 hours are typical, and 24 hours is possible under controlled conditions.

External cooling coils are included for circulation of tap water to reduce chassis temperature and heat load to the lab. Temperature cutouts protect your SPRTs and the furnace from exposure to excessive temperatures.

Model 9116

With a temperature range up to 1100°C, covering the copper point, this furnace may also be optimized for zinc, aluminum, silver, and gold fixed points.

The freezing and melting process may be automated using eight preset, user-programmable temperature settings. The top and bottom zones are slaved to the primary zone using differential thermocouples. A thermocouple acts as the main control sensor for the best accuracy, sensitivity, and repeatability.

The 9116 has all of the standard features found on other Hart freeze-point furnaces, including external cooling coils and an RS-232 port.

Ordering Information

9114	Metrology Furnace (includes Cell Support Container)
2125	IEEE-488 Interface (9114 only)
2126	Comparison Block, 9114
2940-9114	Cell Support Container, 9114
2127-9114	Alumina Block, 9114
2941	Mini Freeze-Point Cell Basket Adapter
9115	Sodium Heat Pipe Furnace (includes Cell Support Container)
2940-9115	Cell Support Container, 9115
2127-9115	Alumina Block, 9115
9116	Three-Zone Freeze-Point Furnace (includes Cell Support Container)
2940-9116	Cell Support Container, 9116
2127-9116	Alumina Block, 9116

Read about our accredited calibration services on page 156.

Protect platinum thermometers from metal ion contamination with a low-cost alumina block.

Specifications - 2127

Dimensions	**2127-9114:** 54 mm x 510 mm **2127-9115:** 62 mm x 510 mm **2127-9116:** 54 mm x 510 mm
Wells	Three: 8 mm ID x 488 mm
Immersion Protection	Last 156 mm in alumina
Well-to-Well Uniformity	10 mK at 660°C in 9114
Temperature Range	Up to 1100°C

ANNEALING FURNACE Model 9117

Annealing Furnace **Model 9117**

- Guards against contamination
- Anneals both SPRTs and HTPRTs
- Fully programmable

You've spent some serious money to equip your lab with some of the finest SPRTs in the world because they're the most accurate temperature measurement instruments you can buy. Now that you've got them, part of your job is to keep them performing at their highest levels. You can do that with a Hart Model 9117 Annealing Furnace.

All HTPRTs and SPRTs are subject to mechanical shock no matter how carefully you handle them. This shock changes the resistance characteristics of the platinum and shows up as temperature measurement errors. Annealing relieves the stress on the platinum sensor caused by mechanical shock and is recommended prior to any calibration of an SPRT.

In addition to removing mechanical strain, annealing also removes the oxidation from sensors that have been used for long periods at temperatures between 200°C and 500°C. Oxidation impacts the purity of the element and therefore the accuracy of temperature readings. Oxide is easily removed by annealing at 660°C for one or two hours.

During the annealing process, contamination must be controlled. At temperatures above 500°C, the lattice structure of a quartz sheath is transparent to metal ions. The thermometer must be cleaned and all contaminating materials removed from its sheath. Annealing should only be done in a furnace that's designed to avoid emitting metal ions during its heating cycle. Hart solves this problem in its 9117 furnace by using an alumina block that is specially designed to guard against contamination.

The furnace also has a programmable controller specifically designed for the annealing process.

As a manufacturer of SPRTs, Hart metrologists understand every aspect of SPRT use and calibration procedures, including the annealing process. We use this furnace in our own lab, so we know exactly how well it works.

Specifications

Temperature Range	300°C to 1100°C
Stability	±0.5°C
Uniformity	±0.5°C at 660°C ±1.0°C at 1000°C
Power	230 VAC (±10%), 50/60 Hz, 12 A, 2500 W
Display Resolution	0.1°C below 1000°C 1°C above 1000°C
Display Accuracy	±5°C
Thermal Wells	Five: 8 mm diameter x 430 mm long
Controller	PID, ramp and soak programmable, thermocouple sensor
Over-Temp Protection	Separate circuit protects furnace from exceeding rated temperature limit
Exterior Dimensions	34" H x 13.5" W X 13.5" D (863 x 343 x 343 mm)
Weight	61 lb. (28 kg)
Communications	RS-232

Ordering Information

9117	Annealing Furnace (includes Model 2129 Alumina Block)
2129	Spare Alumina Block, 5 wells

MEASUREMENTS INTERNATIONAL BRIDGE — Model 5581

Measurements International Bridge — Model 5581

- Measurement uncertainty to ±0.025 mK
- Uses conventional standard resistors

Several companies manufacture high-quality resistance bridges for both AC and DC applications. All of these bridges can take measurements at the 0.1 ppm level, and research has shown that all of them compensate well for any theoretical inaccuracies predicted in their design.

We like the MI bridge because we feel confident about its measurements, and its software gives us more information than we can get from the other instruments. While it's true we do use the other bridges for certain functions we undertake in our lab, including some experimental testing, we use the MI bridge every day for fixed-point calibrations of SPRTs.

The 5581 Bridge performs a true auto-balancing procedure to nine significant digits. As the check proceeds, the bridge steps through an internal comparison of the transformer's windings, the results of which are recorded to track its performance over time.

Another function of this bridge is its real-time uncertainty analysis program. In this mode you enter external uncertainty factors such as the uncertainty of your resistor, and the 5581 combines your information with its own uncertainties to compute a system uncertainty for your measurement.

The optional Windows-control software offers history logging and regression analysis along with uncertainty analysis and the auto-self-check feature. The program also calculates standard deviations if you need them. You can enter coefficients for your SPRT and read temperature rather than resistance.

Of course, if you prefer, you can operate the bridge manually. The choice is yours, but either way you'll find this to be a great bridge to use.

Specifications

Bridge	
Range/ Accuracy	–0.001Ω to 0.01Ω: < 5 ppm 0.01Ω to 0.1Ω: < 0.5 ppm 0.1Ω to 1Ω: < 0.1 ppm 0.1Ω to 10 KΩ: < 0.1 ppm 10 KΩ to 10 KΩ: < 0.2 ppm
Linearity	0.01 ppm
Max Ratio	13:1
Test Currents	10 μA to 150 mA, 30-Volt compliance
Current Reversal	Automatic 4 to 1000 seconds
Power	100, 120, 220, and 240 V (±10%), 47–63 Hz, 180 VA
Weight	60 lb. (27.3 kg)
Dimensions	17" W x 11" H x 15" D (432 x 279 x 381 mm)
Scanner	
Inputs	20/10
Operation	Matrix
Thermal EMFs	< 500 nanovolts
Error Contribution	< 20 nanovolts
Contact Ratings	Relay 2-coil latching
Max Carrying Current	2 A (AC/DC) (optional 30 A)
Contact Resistance	<0.007Ω
Insulation Resistance	$>10^{12}\Omega$
Inputs and Outputs	Tellurium Copper (rear panel)
IEEE-488	24-pin IEEE-488
Weight	**5313-001:** 40 lb. (18 kg) **5313-002:** 20 lb. (9 kg)
Dimensions	**5313-001:** 17" W x 11" H x 15" D (432 x 279 x 381 mm) **5313-002:** 5" H (127 mm)

Ordering Information

5581	MI Bridge
5313-001	Scanner, 20 channels
5313-002	Scanner, 10 channels
5313-003	IOTech 488 Interface Card
5313-004	Windows Software

Need a reliable standard resistor? See our selection on pages 28 and 29.

Get the latest product information at www.hartscientific.com

FLUKE DC RESISTANCE STANDARDS — Model 742A

Fluke DC Resistance Standards — Model 742A

- Convenient air resistors don't require oil or air baths
- Calibrate resistance thermometers and other devices
- Includes NIST-traceable calibration data with uncertainty to 1 ppm
- Easily transported for on-site resistance calibration

Do you need high-accuracy working standards for precise, on-site resistance calibrations? If you'd like to avoid maintaining traditional standard resistors in oil baths, Hart has a complete assortment of DC air resistors manufactured by Fluke, with Fluke's proprietary tellurium-copper five-way binding posts.

The Fluke 742A Series covers values from 1 ohm all the way to 100 megohm. These are the finest-quality air resistors you can buy. They're durable, easy to maintain, and easy to use. Their excellent temperature stability allows them to be used from 18°C to 28°C with typically less than 2 ppm degradation. Using the calibration table supplied with the standards, which lists corrections in 0.5°C increments, this uncertainty can be reduced to near zero.

Care has been taken to reduce resistance changes brought about by thermal and mechanical shock. Retrace (shift in resistance) is typically less than 2 ppm after cycling between 0°C and 40°C.

Each of these resistors comes with a NVLAP-accredited report of calibration from Fluke. Accredited recalibrations are available from either Fluke or Hart.

Specifications

Model	Nominal Value Ω	Stability, ppm 6 Months	Stability, ppm 12 Months	Max Change, ppm from 23°C ±5°C (±ppm)	Calibration Uncertainty, ±ppm
742A-1	1	5	8	3.0	1.0
742A-10	10	5	8	3.0	1.0
742A-25	25	5	8	3.0	1.0
742A-100	100	4	6	3.0	1.0
742A-1K	1K	4	6	2.0	1.5
742A-10K	10K	2.5	4	1.5	1.0
742A-100K	100K	4	6	2.0	2.5
742A-1M	1M	6	8	2.0	5.0
742A-10M	10M	6	9	3.0	10.0
742A-7002	Transit Case (holds two units)				

Ordering Information

742A-1	Resistor, DC Standard, 1Ω
742A-10	Resistor, DC Standard, 10Ω
742A-25	Resistor, DC Standard, 25Ω
742A-100	Resistor, DC Standard, 100Ω
742A-1K	Resistor, DC Standard, 1 KΩ
742A-10K	Resistor, DC Standard, 10 KΩ
742A-100K	Resistor, DC Standard, 100 KΩ
742A-1M	Resistor, DC Standard, 1 MΩ
742A-10M	Resistor, DC Standard, 10 MΩ
742A-100M	Resistor, DC Standard, 100 MΩ
742A-7002	Transit Case
1960	Cal, DC Standard Resistor

Xumo (VP Metrology) continues to help set the world pace in primary temperature standards development.

STANDARD AC/DC RESISTORS — Model 5430

Standard AC/DC Resistors — Model 5430

- Long-term stability better than 2 ppm/year (< 1 ppm typical)
- Traceable AC and DC calibrations available
- National lab design proven for more than 25 years

National laboratories around the world have long relied on the standard AC/DC resistors manufactured by Tinsley. Whether they're used in thermometry or electrical applications—with AC or DC bridges—these resistors perform better than any other AC/DC resistors available.

Six resistors in Hart's Model 5430 series cover resistance values from 1 ohm to 10,000 ohms. Each one has an actual resistance within 10 ppm of its nominal value and holds its resistance within 2 ppm per year.

Each resistor comes with a Tinsley certificate on AC performance, traceable to NPL in the UK, including calibration uncertainty of 3 ppm. Additionally, Hart can provide an optional DC certificate, traceable to NIST and NVLAP accredited, with uncertainty below 1 ppm.

Designed originally by a national lab, Tinsley resistors are bifilar wound to minimize reactance and are filled with oil to minimize both time- and temperature-caused instabilities. AC/DC transfer error at 90 Hz is only 0.1 ppm.

For maintaining your oil resistors, Hart provides baths that range from 51- to 167-liter capacity with enough inside shelf space to maintain all your standard resistors. Our 7009 and 7015 models maintain your resistors within 1 mK in the short term (30–60 minutes) and within 5 mK for months at a time (see page 100).

In our lab, we use both AC and DC bridges in addition to Super-Thermometers. We calibrate SPRTs in fixed points, and we calibrate reference resistors. We use standard resistors every day, and we understand the value of being able to rely on resistors that won't drift. Tinsley makes the best AC/DC resistors around, and Hart makes the best maintenance baths. Ask people who know. Then don't compromise.

Specifications

Tolerance	10 ppm
Calibration Uncertainty	AC: 3 ppm (10 KΩ: 4 ppm) DC: 1 ppm (optional)
Long-Term Stability	2 ppm/year
Temperature Coefficient	2 ppm/°C
Recommended Current	1Ω: 100 mA 10Ω: 32 mA 25Ω: 20 mA 100Ω: 10 mA 1 KΩ: 3 mA 10 KΩ: 1 mA
Maximum Current	1Ω: 1 A 10Ω: 320 mA 25Ω: 200 mA 100Ω: 100 mA 1 KΩ: 32 mA 10 KΩ: 10 ma
AC/DC Transfer Error (at 90 hz)	0.1 ppm, typical

Ordering Information

5430-1	Resistor, AC/DC Standard, 1Ω
5430-10	Resistor, AC/DC Standard, 10Ω
5430-25	Resistor, AC/DC Standard, 25Ω
5430-100	Resistor, AC/DC Standard, 100Ω
5430-1K	Resistor, AC/DC Standard, 1 KΩ
5430-10K	Resistor, AC/DC Standard, 10 KΩ
1960	Cal, DC Standard Resistor

See page 100 for standard resistor maintenance bath options.

Read about our calibration training courses on page 153.

MINI FIXED-POINT CELLS

Mini Fixed-Point Cells

- Lower uncertainties than comparison calibrations
- All ITS-90 fixed points from TPW to copper
- Reduced equipment and annual recalibration costs

If cuteness were reason enough to buy a product, Hart's Mini Fixed-Point Cells would win you over easily. But there's a much better reason to buy them: they give you the least expensive, easiest-to-use fixed-point standards for your lab.

Mini cells eliminate the need for comparison calibrations. Temperatures of fixed-point cells are constant and intrinsic, so only the electrical parameters of the sensor under calibration need to be read. If you're calibrating industrial thermometers, thermocouples, or thermistors and want the most accurate calibration possible, these mini cells will give it to you. If you need a wide range of temperatures, mini cells cover the triple point of water (0.01°C) and every ITS-90 point from indium (156.5985°C) to copper (1084.62°C).

With mini cells, realization and maintenance are simple. Mini TPW cells can be automatically realized and maintained in our Model 9210 Maintenance Apparatus (page 32). Realizing the triple point of water takes only five minutes, but the plateaus last all day.

The realization and maintenance of indium, tin, zinc, and aluminum cells are likewise automated through our Model 9260 Mini Fixed-Point Cell Furnace (page 32). Work with them at their designated freeze point, or use them at their melting point to simplify the calibration process even further. We published a paper, "The Comparison Between the Freezing Point and Melting Point of Tin," to help you understand and benefit from the easier procedure of using the melting point of your standard.

These mini cells are made from the same materials and with the same procedures as their full-size counterparts. In fact, they can achieve nearly the same uncertainty levels as Hart's traditional fixed-point cells. Probes as short as nine inches work with these cells. The specifications table (at right) gives you the immersion depth and uncertainty for each cell.

In addition to high-accuracy calibrations of RTDs and PRTs, these cells are perfect for validating the accuracy of SPRTs. If you're doing comparison calibrations with SPRTs, then you know the importance of occasionally checking their accuracy between their own recalibrations. Because these cells are easy to use and maintain, verification checks are simple and convenient.

New in this catalog, you'll find three metal cased mini fixed-point cells. These new metal-cased cells can also be used in the 9260 maintenance furnace. Because they use stainless steel cases, these cells are easier to use and transport without risk of breakage. You'll notice that we have designed the metal cased cells with more immersion depth to give even better uncertainty too!

You'll find these cells easier to use than you expect. You can have a free copy of Xumo Li's paper comparing freeze-point measurements with melting-point measurements, and if you want a high level of training in using metal freeze-point cells, you can attend one of Hart's in-depth training classes held in our lab in Utah.

Ordering Information

5901B	Mini Quartz TPW Cell
5914A	Mini Quartz Indium Cell
5915A	Mini Quartz Tin Cell
5916A	Mini Quartz Zinc Cell
5917A	Mini Quartz Aluminum Cell
5918A	Mini Quartz Silver Cell
5919A	Mini Quartz Copper Cell
5944	Mini Metal Cased Indium Cell
5945	Mini Metal Cased Tin Cell
5946	Mini Metal Cased Zinc Cell
9210	Mini TPW Maintenance Apparatus (see page 32)
9260	Mini Fixed-Point Furnace (for In, Sn, Zn, Al cells—see page 32)
9116	Three-Zone Freeze-Point Furnace (for Ag, Cu cells—see page 24)
1904-X	Accredited Cell Intercomparison
2931-SM	Protective Wood Case, mini cells

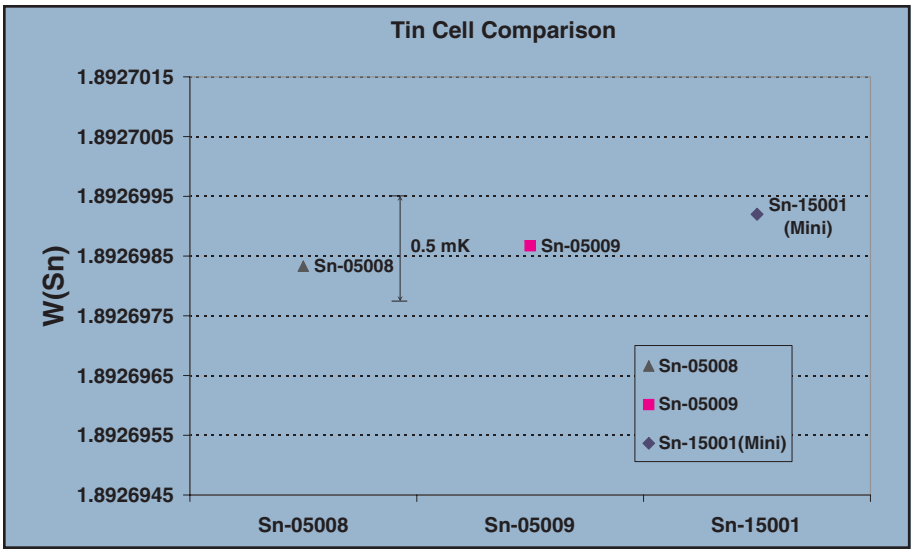
Note: Each Mini Metal Cased Cell includes a 2942-9260 Mini Cell Basket. Indium, tin, zinc, and aluminum Mini Quartz Cells each include a 2940-9260 Mini Cell Basket. Both basket styles adapt the cell to Hart's 9260 Mini Fixed-Point Furnace.

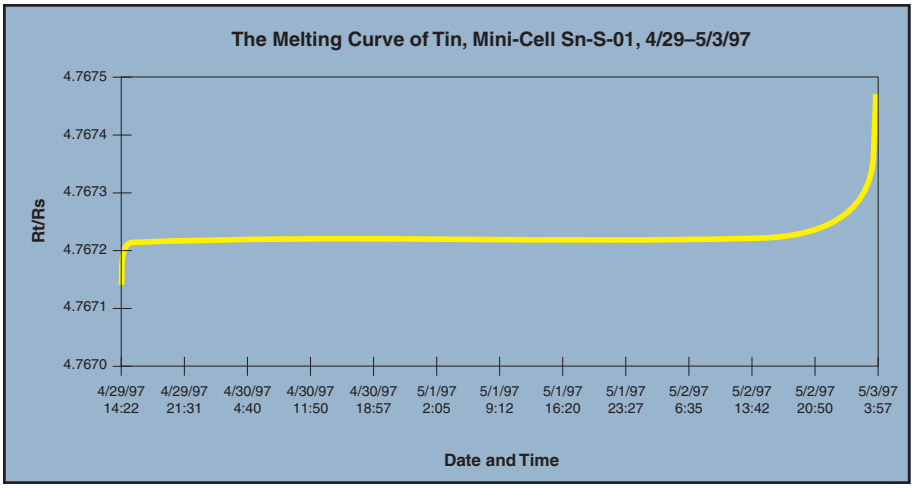
Specifications

Model Number	Fixed-Point	Temperature (°C)	Outside Diameter	Inside Diameter	Total Cell Height	Immersion Depth (mm)[1]	Expanded Uncertainty (mK)	
							Cell Only[2]	Simple Realization[2]
5901B	Water T. P.	0.01	30 mm	9 mm	170 mm	117	0.2	0.5
5914A	Indium M. P.	156.5985	43 mm	8 mm	214 mm	140	1.0	2.0
5915A	Tin M. P.	231.928	43 mm	8 mm	214 mm	140	1.4	3.0
5916A	Zinc M. P.	419.527	43 mm	8 mm	214 mm	140	1.6	4.0
5917A	Aluminum M. P.	660.323	43 mm	8 mm	214 mm	140	4.0	10.0
5918A	Silver M. P.	961.78	43 mm	8 mm	214 mm	140	7.0	n/a
5919A	Copper M. P.	1084.62	43 mm	8 mm	214 mm	140	15.0	n/a
5944	Indium M. P.	156.5985	41.3 mm	7.8 mm	222 mm	156	0.7	1.4
5945	Tin M. P.	231.928	41.3 mm	7.8 mm	222 mm	156	0.8	1.6
5946	Zinc M. P.	419.527	41.3 mm	7.8 mm	222 mm	156	1.0	2.0

[1] Distance from the bottom of the central well to the surface of the pure metal.

[2] "Cell Only" refers to the expanded uncertainty of the cell when realized by traditional methods and maintained using traditional maintenance devices. "Simple Realization" refers to the expanded uncertainty of the cell when realized using practical methods (melting points instead of freezing points or slush ice instead of an ice mantle, for example) and maintained using Hart's models 9210 and 9260 mini cell maintenance apparatus.





Read about our calibration training courses on page 153.

Bill (materials management) shows why we're glad there's a trend toward longer shorts.

MINI FIXED-POINT MAINTENANCE APPARATUS

Mini Fixed-Point Maintenance Apparatus **Model 9210, 9230, and 9260**

- Preprogrammed controller makes realizing fixed points easy
- Half the cost (or less) of traditional fixed-point systems
- Training takes a few hours—not a few years

If the reason you don't use fixed-point cells is because they're too expensive or too difficult to use, you haven't heard of Hart's mini fixed-point apparatus.

9210

The triple point of water (0.01°C) is one of the most important temperatures on the ITS-90. Unfortunately, realizing and maintaining triple point of water cells hasn't always been convenient or cost-effective.

Because ITS-90 calibrations require frequent measurements at the triple point of water, and because the triple point of water is often used as a statistical check against the drift of a temperature standard, it is important to be able to realize and maintain well-constructed triple point of water cells easily.

Hart's 9210 TPW Maintenance Apparatus provides built-in programming for the simple supercool-and-shake realization and maintenance of our Model 5901B Mini TPW Cell. Simply insert the cell, enter the "freeze" mode through the front-panel buttons, have your morning cup of coffee, and when the 9210 audibly alerts you, remove the Mini TPW Cell and give it a shake to initiate freezing a portion of the water. Re-insert the cell, change the program mode to "maintain," and you've got 0.01°C for the rest of the day with uncertainty of only ±0.0005°C.

Precision-machined thermal blocks can also be used to take advantage of the excellent stability and uniformity of the 9210 for performing comparison calibrations. Multi-hole and custom blocks are available with 7-inch depths.

9230

The gallium melting point (29.7646°C) is a critical temperature. Thermometers used in life science, environmental monitoring, and many other applications depend on it for accurate calibrations. Lab standards rely on it as an ITS-90 check standard and as a means of measuring drift between calibrations. Hart Scientific now makes it easy to use.

The new Model 9230 Gallium Maintenance System works with Hart's Model 5943 Stainless Steel Gallium Cell to provide melting plateaus that last a week. Not a day. Not a day-and-a-half. One week.

The Model 5943 Stainless Steel Gallium Cell holds a gallium sample that is 99.99999+% pure. The gallium is sealed in a Teflon envelope in a high purity argon atmosphere, which is itself sealed inside a stainless steel housing. This double-sealing method reduces leaching into the gallium sample and ensures a life of ten years or longer for the cell.

9260

Hart's 9260 Mini Fixed-Point Cell Furnace provides a fixed-point system that cuts in half the financial investment required to do fixed-point calibrations and virtually all the time and training required by traditional systems.

This furnace costs less than half of a large furnace and works with indium, tin, zinc, and aluminum cells to cover all ITS-90 fixed points from 156.5985°C to 660.323°C. The cells themselves, using a smaller volume of 99.9999% pure metal, also cost much less. But cost is only a part of the issue.

The 9260 makes using fixed points easy. Simply insert the cell at the end of the day and let it sit overnight. The next morning, initialize the built-in software routine for your specific cell. Come back in an hour, verify the stability of the cell, and you can take measurements for the rest of the day from a near-perfect temperature source!

The built-in software lets you choose between using melting-point curves or freezing-point curves for each metal. The ITS-90 calls for freezing points, but melting points are easier to realize, and the difference in uncertainty (less than 2 mK for most applications) is generally insignificant. In fact, the difference between using traditional cells at their freezing points and Hart's mini cells at their melting points is not significant for most labs in most applications.

Comparison blocks are also available for the 9260 for high-precision comparison calibrations at high temperatures. Two blocks are available with a variety of pre-drilled wells in addition to blank or custom blocks. Well depth is 9 inches (229 mm).

Models 9210, 9230, and 9260

Specifications	9210	9230	9260
Temperature Range	–10°C to 125°C	15°C to 35°C	50°C to 680°C
Ambient Operating Range	5°C to 45°C	18°C to 28°C	5°C to 45°C
Stability	±0.02°C	±0.02°C	±0.03°C to 300°C ±0.05°C above 300°C
Vertical Gradient	±0.05°C over 100 mm at 0°C	< 0.03°C over six inches during cell maintenance	Top and bottom zones adjustable by offset
Melting/Freezing-Point Duration	6–10 hours, typical	Five days, typical	6–10 hours typical
Resolution	0.01° (0.001° in program mode)	0.01° (0.001° in program mode)	0.01°
Display Scale	°C or °F, switchable		
Immersion Depth	6.75" (171 mm) in optional comparison block	6" (152 mm) in gallium cell	9" (229 mm)
Stabilization Time	15 minutes nominal	Preprogrammed	15 minutes nominal
Preheat Wells	3 wells (for 3.18, 6.35, or 7.01 mm probes)	2	2
Fault Protection	Adjustable software cutout using control probe, separate circuit thermocouple cutout for maximum instrument temperature	Heating/cooling rate cutout	Sensor burnout and short protection, over-temperature thermal cutout
Display Accuracy	±0.25°C	±0.05°C at 29.76°C	±0.2°C to 300°C ±0.3°C to 450°C ±0.5°C to 680°C
Comparison Block	Three multi-hole blocks, blanks, and custom blocks available	Contact Hart	Two multi-hole blocks, blanks, and custom blocks available
Well-to-Well Gradient (in comparison block)	±0.02°C	n/a	±0.02°C
Heating Time	Ambient to 100°C: 45 min.	Preprogrammed	1.25 hrs. from 25°C to 680°C
Cooling Time	Ambient to –5°C: 25 min.	Preprogrammed	10.5 hrs. from 680°C to 100°C
Communications	RS-232 included		
Power Requirements	115 VAC (±10%), 60 Hz, 1.5 A, or 230 VAC (±10%), 50 Hz, 0.75 A, 170 W	115 VAC (±10%), 60 Hz, 1.5 A, or 230 VAC (±10%), 50 Hz, 0.75 A, 175 W	115 VAC (±10%), 60 Hz, 11 A, or 230 VAC (±10%), 50 Hz, 6 A, specify, 1200 W
Exterior Dimensions	8.75" W x 10.25" D x 19.25" H (222 x 260 x 489 mm)		
Weight	15.5 lb. (7 kg) with block	18 lb. (8.2 kg) without cell	45 lb. (20.5 kg) with block

Ordering Information

9210	Mini TPW Maintenance Apparatus
5901B	Mini Quartz Glass TPW Cell
5931	X Cell, Triple Point of Water
1904-Tpw	Accredited Cell Intercomparison
3110-1	Comparison Insert, Blank
3110-2	Comparison Insert A, holes at 1/16", 1/8", 3/16", 1/4", 3/8", and 1/2"
3110-3	Comparison Insert B, 2 holes at 3/16", 2 at 1/4", and 2 at 3/8"
3110-4	Comparison Insert C, 6 holes at 6 1/4"
3110-6	X Cell Adapter Sleeve, 9210
	Call for other comparison insert options.
9230	Gallium Cell Maintenance System
5943	Stainless Steel Gallium Cell
1904-Ga	Accredited Cell Intercomparison
9260	Mini Fixed-Point Furnace
5914A	Mini Quartz Indium Cell
5915A	Mini Quartz Tin Cell
5916A	Mini Quartz Zinc Cell
5917A	Mini Quartz Aluminum Cell
5944	Metal Cased Mini Indium Cell
5945	Metal Cased Mini Tin Cell
5946	Metal Cased Mini Zinc Cell
1904-X	Accredited Cell Intercomparison
3160-1	Comparison Insert, Blank
3160-2	Comparison Insert, 7 holes at 1/4"
3160-3	Comparison Insert, 2 holes at 1/8", 2 at 3/16", 2 at 1/4", 2 at 9/32" (9 mm), and 2 at 3/8"
	Call for other comparison insert options.

See page 18 for triple point of water cells.

Read about our accredited calibration services on page 156.

Doug (shipping) and Travis (customer service) are thinking of starting a mass calibration lab.

X CELLS — Models 5931–5934

X Cells — Models 5931–5934

- Stainless steel casings help protect cells from mishandling
- Accuracies similar to traditional-size quartz cells
- Can be maintained in fluid baths or dry-well calibrators

Have you wanted to use fixed-point cells but couldn't justify the price? Have you been hesitant because of complex realization procedures or the fragile nature of traditional cells?

Hart's X Cells solve all these problems. They provide primary standards performance, are nearly unbreakable, and cost much less than traditional cell systems. The value of the water triple point X Cells is within 0.2 mK of traditional water triple point cells, and the gallium and indium cells include realized uncertainties less than 0.002°C.

Gallium and indium X Cells are constructed using a Teflon crucible containing a sample with purity of at least 99.9999%. The crucible is enclosed within a specially cleaned stainless steel envelope, which is evacuated and back-filled with high-purity argon.

Realizing these reference points could not be easier. Special X Cell maintenance baskets allow the cells to be used in both standard baths and Micro-Baths, and a special sleeve is available for maintaining X Cells in Model 9103 dry-well calibrators.

Simply place the cell in the heat source, select the melt temperature, and within 30 minutes you'll have an ITS-90 reference temperature all day long with stability of ±0.001°C. Once you finish using the cell, just set the freeze temperature and within minutes the cell is again ready for another realization. What could be easier?

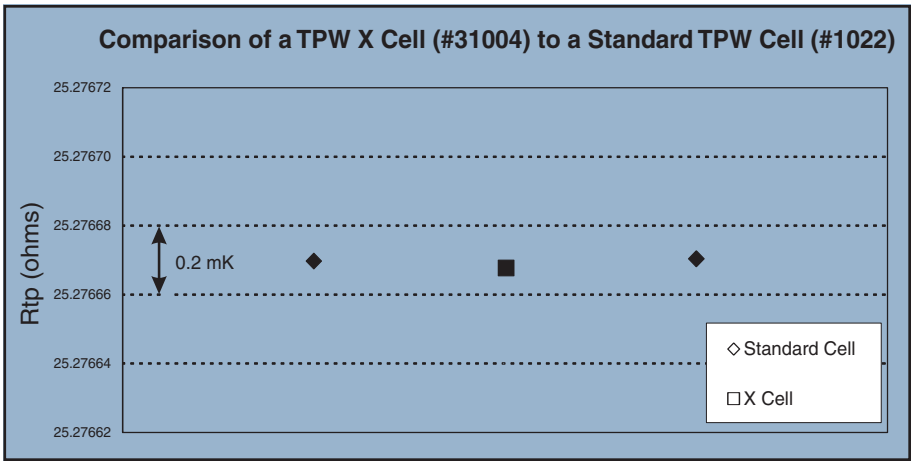
Specifications

Nominal Temperature Values	**Water:** 0.01°C **Gallium:** 29.7646°C **Indium:** 156.5985°C
Expanded Uncertainty (k=2)	**Water:** ±1.0 mK (0.5 typical) **Gallium:** ±1.0 mK (0.5 typical) **Indium:** ±2.0 mK (1.0 typical)
Metal Sample Purity	**Gallium:** 99.99999% **Indium:** 99.9999%
Immersion Depth (in pure sample)	**Water:** 3.4" (86.4 mm) **Gallium:** 3.0" (76.2 mm) **Indium:** 3.0" (76.2 mm)
Casing Material	Stainless Steel
Well I.D.	0.25" (6.35 mm)
Cell Size	5" H x 1" Dia. (127 x 24 mm)

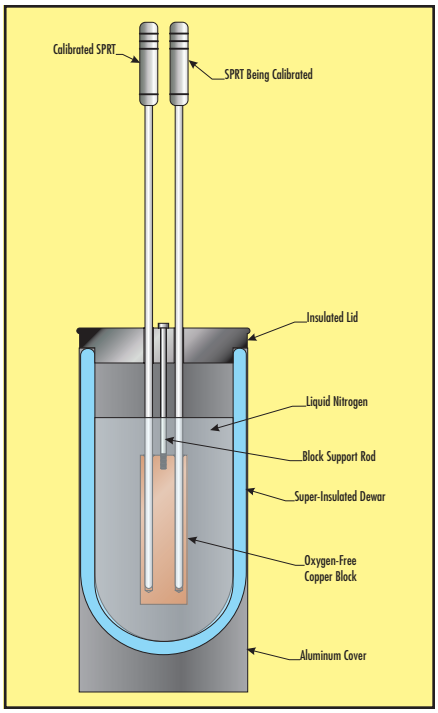
Ordering Information

5931	X Cell, Triple Point of Water
5933	X Cell, Gallium
5934	X Cell, Indium
2025	X Cell Basket, Standard Bath Fill Hole
2025-6102	X Cell Basket, 6102 or 7102
2025-7103	X Cell Basket, 7103
3103-5	X Cell Adapter Sleeve, 9103
3109-5	X Cell Adapter Sleeve, 9011 and 9127
3110-6	X Cell Adapter Sleeve, 9210

Get the latest product information at www.hartscientific.com



LN_2 COMPARISON CALIBRATORS — Model 7196



LN_2 Comparison Calibrators — Model 7196

- Low-cost calibrations to –196°C
- Simple to use
- Uncertainty less than 2 mK

If you need to do calibrations at the triple point of argon but don't want the complexity and cost of using an argon triple point cell, Hart's Model 7196 LN_2 Comparison Calibrators will solve your problems. And they do it for less than half the price of other argon triple point simulators.

The nominal boiling point of nitrogen is –196°C at one atmosphere of pressure. The defining triple point of argon is –189.3442°C. While there is a difference between the nominal boiling point of nitrogen and the argon triple point, the difference can be corrected for mathematically, and an uncertainty of less than 2 mK from the actual argon triple point is achievable.

Hart's LN_2 Comparison Calibrators consist of a super-insulated glass dewar, a high-purity copper block, and a precision-fit lid. The dewar is filled with LN_2 and the copper block is suspended in it; an SPRT is inserted into the block and a calibration is performed against your own calibrated SPRT. The Model 7196-4 includes four 8-mm (0.32") wells. The 7196-13 includes five 8-mm (0.32") wells and eight 6.35-mm (0.25") wells.

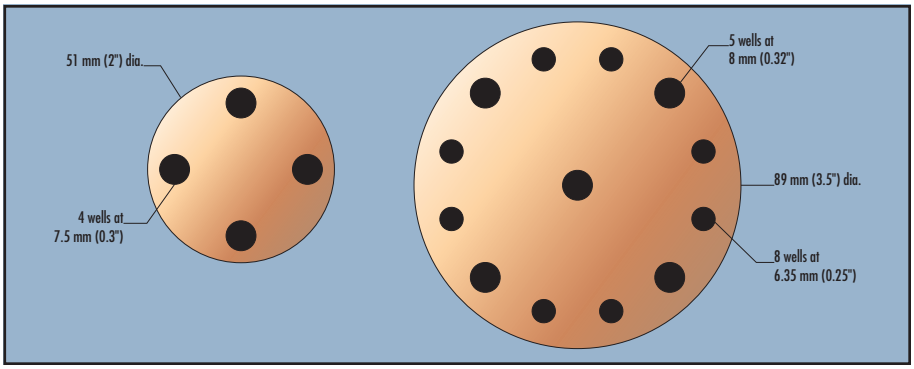
Hart's LN_2 Comparison Calibrators are neither expensive nor complicated to use. If you need supporting data or would like to discuss the theory of operation of an LN_2 Comparison Calibrator, call Hart Scientific today. (Or come to one of our training courses and we'll show you.)

Specifications

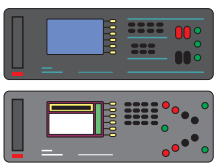
Temperature	Nominal –196°C depending on atmospheric pressure
Thermal Wells	**7196-4**: four 8 mm (0.32") I.D. wells **7196-13**: five 8 mm (0.32") I.D. wells, eight 6.35 mm (0.25") I.D. wells **Both blocks:** 275 mm immersion from top of lid to bottom of well, 150 mm immersion into copper block
Dimensions	180 mm O.D. x 385 mm high
Stability	Typically better than 2 mK
Uniformity	< 0.4 mK between holes
Volume	3.5 liters of liquid nitrogen
Evaporation	Approx. 1" per 45 minutes

Ordering Information

7196-4	LN_2 Comparison Calibrator, 4 holes
7196-13	LN_2 Comparison Calibrator, 13 holes



THERMOMETER READOUT SUMMARY

Readouts	Model	Probe Types	Accuracy at 0°C	Features	Page
	1521	PRTs, Thermistors	±0.025°C	Battery-powered, handheld thermometer; INFO-CON connector reads coefficients without programming.	37
	1522	PRTs, Thermistors	±0.025°C	Stores up to 10,000 readings, plus 100 more on demand; reads PRTs and thermistors (calibrated or uncalibrated) interchangeably.	
	1502A	PRTs	±0.006°C	Resolution of 0.001°C and accuracy to match; uses ITS-90, IPTS-68, CVD, or DIN (IEC 751) conversions.	40
	1504	Thermistors	±0.002°C	Reads thermistors from 0 to 500 KΩ; uses Steinhart-Hart and CVD.	
	1529	PRTs, Thermistors, Thermocouples	±0.006°C (PRT)	Four channels can all be measured simultaneously; battery-powered; logs up to 8,000 readings; flexible display.	42
	1560			Accepts any combination of the modules below; all are easily added to and removed from the 1560 base.	46
	2560	PRTs	±0.005°C	2 channels of 25Ω or 100Ω PRTs.	
	2561	HTPRTs	±0.013°C	2 channels to 1200°C.	
	2562	PRTs	±0.01°C	8 channels of 2-, 3-, or 4-wire RTDs.	
	2563	Thermistors	±0.0013°C	2 channels of resolution to 0.0001°C.	
	2564	Thermistors	±0.0025°C	8 channels for data acquisition.	
	2565	Thermocouples	±0.05°C	Reads most TC types with 0.0001 mV resolution.	
	2566	Thermocouples	±0.1°C	Reads any combination up to 12 channels of virtually any type of TC.	
	2567	1000Ω PRTs	±0.006	2 channels of high-resistance PRTs.	
	2568	1000Ω PRTs	±0.01	8 channels of high-resistance PRTs.	
	1575	SPRTs, Thermistors	±0.001°C	4 ppm accuracy; resolution to 0.0001°C for SPRTs and 0.00001°C for thermistors; 2 channels; add 10 more channels with a mux.	52
	1590	SPRTs, Thermistors	±0.00025°C	1 ppm accuracy; patented DWF connectors; color display; add up to 50 channels with muxes.	

Technical Tip

Readouts and Probes Should Match

Digital thermometer readouts measure resistance, voltage, and sometimes connector temperature (in the case of TCs). The displayed temperature is always a computed result—not a direct measurement! Pretty simple, right? The trouble is that the readout will perform the calculation even if all of the information upon which the calculation is based is wrong or missing. And the error may not always be obvious.

Before making a measurement, check the readout and ensure that the coefficients, excitation current, and reference junction settings are correct. While you're at it, check the sample timing, statistics, and filtering. You'll save yourself a lot of trouble and be much happier with the results.

Phone on belt and laptop in hand, Bernard (VP Sales) comes home to a closely monitored room temperature.

Handheld Thermometers **Models 1521 and 1522**

- Read PRTs/RTDs to ±0.025°C and thermistors to ±0.005°C
- Model 1522 stores multiple data sets totaling 10,000 readings
- INFO-CON connector allows interchangeable use of calibrated probes
- INFO-CON eliminates errors from programming probe data

With the Super-Thermometer, *Black Stack,* and Tweener thermometers, Hart established itself as the clear product leader for thermometer readouts. Our pattern of offering more power and more versatility for less money is indisputable. Another case in point: Hart offers the two most powerful handheld thermometers in the world.

The Models 1521 and 1522 are the first standards thermometers to fit into a battery-powered handheld package. They're as accurate as ±0.005°C! You'll only find this level of accuracy in large desktop units that cost three times more. It's no wonder we call the 1521 the Little Lord Kelvin of thermometry.

Fitting easily into your hand and weighing only 1 pound (0.4 kg), these thermometers can go anywhere. And when they get there, you can have total confidence in the accuracy of your measurements. The 1522 has the power of a full data logger, with memory to hold 10,000 readings.

Probes

The 1521 and 1522 read both Pt-25 and Pt-100 RTDs as well as thermistors.

PRTs and RTDs, with their wide temperature ranges and stabilities, have long been favored as temperature standards. From –200°C to 100°C, the 1521 reads PRTs accurately to ±0.025°C. Even at 800°C these are high-precision readouts, accurate to ±0.1°C.

Ultra-stable thermistors offer excellent stability and even greater accuracies over a more narrow range—typically from about –10°C to 110°C. At temperatures below 50°C, these Handheld Thermometers read thermistors to ±0.005°C. Accuracy at 100°C is ±0.02°C.

While a small number of handheld thermometers on the market offer 0.01° resolution, they fail to provide the accuracy necessary for the last digit to be meaningful. Hart's Handheld Thermometers let you select resolution from 0.1° to 0.001° and offer the accuracy to support even 0.001° resolution.

Of course, the 1521 and 1522 let you match the exact resistance-versus-temperature characteristics of an individually calibrated probe. This is true standards thermometry. Hart's Handheld Thermometers read ITS-90, Callendar-Van Dusen, or Steinhart-Hart coefficients for maximum system accuracy. These are real algorithms, not approximating conversion methods or electronic look-up tables. If you want to use common industrial curves, RTDs can be read using the common DIN 43760 (IEC 751) curve and thermistors can be read using the YSI 400 curve.

INFO-CON Connectors

Probes attach to the 1521 and 1522 using Hart's own "INFO-CON" connector. The INFO-CON (partially based on U.S. Patent 5,857,777) allows you to change the probes you use without requiring you to reprogram your readout. A memory chip in the INFO-CON stores all the critical information about your probe, including its serial number, recall date, and calibration constants.

When you connect your probe, the 1521 automatically recognizes whether you're using an RTD or thermistor and downloads the calibration constants and type of conversion specific to your probe. It also checks the recall date stored in the INFO-CON to verify it has not expired. To dedicate a single probe to your readout, disable the password-protected interchangeability function and your thermometer will read only the probe you specify.

Forget entering calibration constants yourself, and don't worry about the mistakes that can so easily occur during that process. You don't even need to select your sensor type. It's all stored in the INFO-CON. Just plug in your probe and you're ready to take readings. It doesn't get any easier.

Information is loaded into the memory of the INFO-CON by Hart when you purchase a probe or have a probe recalibrated by Hart.

Alternatively, you may load your own information into an INFO-CON through the Handheld Thermometer or through Model 9934 Log*Ware* (see page 79).

If you'd like to use a Hart Handheld Thermometer with probes you already own, no problem! Spare connectors are available. They easily connect to your probes, and you can program them yourself.

Model 1521 LLK

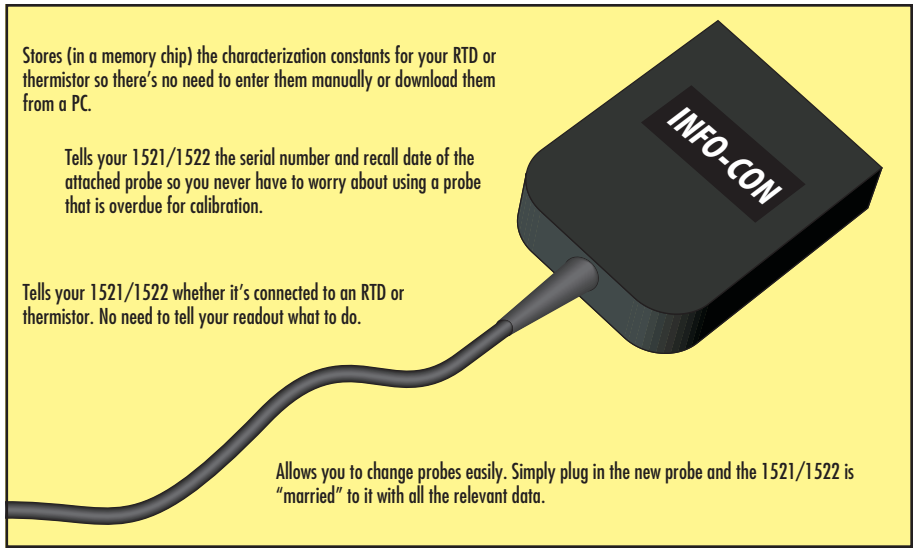
The 1521 Little Lord Kelvin uses a menu system for convenient access to all functions. Calibration and sensor programming functions are password protected to help prevent unauthorized access.

"Min" and "Max" functions store the lowest and highest readings since the last reset. The "Hold" function freezes and stores the current reading (up to six may be stored) for later recall. And the "Delta" function computes the difference between the current reading and a reference value, which may be recorded at any time.

Handheld Thermometers make excellent reference standards for field calibrations.

Each thermometer comes complete with rechargeable nickel-metal-hydride batteries, an AC adapter/charger, an RS-232 cable for connecting to your PC, and a spare INFO-CON connector. Every unit also includes a NIST-traceable calibration with actual resistance measurements for your individual meter at ten points—four representing typical RTD values and six representing typical thermistor values.

A wide variety of standards-quality probes are available from Hart in many different shapes, sizes, and price ranges. On pages 60 to 72 you'll find PRTs as accurate as ±0.010°C and thermistors as accurate as ±0.001°C. The uncertainty of your probe should be added to the uncertainty of the meter to compute total system uncertainty.



Model 1522 LLL

The Model 1522 Little Lord Logger has all the power and great features of the 1521 plus the ability to log data. Two data acquisition modes are included.

In "Auto Logging" mode, the 1522 can store up to 10,000 measurements at user-selected intervals, including the value, unit of measure, date, and time of each measurement. If you need more than one data set, stop recording any time and record as many sets as you like up to a total of 10,000 values. Once the 10,000 value limit is reached, recording stops, so data is never lost unless you tell the 1522 to clear its log.

The 1522 also holds as many as 25 data labels in its memory so that each set of data can be uniquely tagged. Simply select one of the 25 labels you've created before recording data. This label is then recorded with each measurement.

In "Demand Logging" mode, up to 100 individual measurements can be recorded, each one tagged with one of the 25 data labels. Whether you need a lot of measurements from one source or single measurements from many sources, the 1522 is a powerful data recording tool.

With Hart's 9934 Log*Ware* software (see page 79), data management is easy. Data sets gathered remotely through the 1522 can be easily downloaded to a PC either as a single file or as individual files for each data set. Link the LLL to your PC through a serial cable or its IrDA port to send data as ASCII or binary files. View the data, graph it, or apply alarms. With Log*Ware* you can record data in real time either from a 1522 or 1521 Thermometer.

Technical Tip

Calibrate PRTs over Their Useful Range

Most people use their platinum resistance thermometers over a temperature range that is smaller than the total operable range published by the instrument's manufacturer. When recalibrating a PRT, select the calibration range based on the intended use rather than on the manufacturer's maximum range specifications. This will save you money because calibrations over a wider span usually require more temperature points, and therefore cost more. It will also reduce the wear and tear on your probe and result in better measurements since PRTs are generally more stable when used over a narrow range.

One company consistently delivers powerful metrology products that make your life easier. Ask other companies about their handheld thermometers. Ask them about their thermometers that are accurate to within a few millikelvin and that record data at the touch of a button. Then ask them to give it all to you in one package. Hart Scientific does—at a price you'll love. Call us today and get the most powerful handheld thermometers in the world.

LogWare software can be used to graphically and statistically analyze data logged to the Model 1522 LLL. LogWare can also turn either Handheld Thermometer into a real-time datalogger.

The Model 9318 Hard Carrying Case protects your Handheld Thermometer, a probe, and all your accessories.

Don't forget a protective case!

See our calibration and data acquisition software packages on page 74.

Specifications

Sensor Type	Pt 25 to Pt 100	Thermistor
Temperature Range	–200°C to 962°C	–50°C to 150°C
Resistance Range	0Ω to 400Ω	0Ω to 500 KΩ
Characterizations	ITS-90, IEC-751 (DIN "385"), Callendar-Van Dusen	Steinhart-Hart thermistor polynomial, YSI 400 (2252 ohms)
Temperature Accuracy (meter only)	–200°C to 100°C: ±0.025°C 100°C to 400°C: ±0.05°C 400°C to 800°C: ±0.1°C 800°C to 962°C: ±0.15°C	0°C to 50°C: ±0.005°C 50°C to 75°C: ±0.01°C 75°C to 100°C: ±0.02°C
Excitation Current	0.5 mA	5 µA
Operating Range	0°C to 40°C	
Temperature Resolution	0.001°	
Measurement Period	1 second	
Digital Filter	1- to 60-second exponential filter	
Probe Connection	INFO-CON Connector	
Communications	RS-232 (Model 1522 also includes infrared interface)	
Memory	Stores 6 readings in "Hold" mode	Logs 10,000 readings in "Auto Logging" mode; logs 100 readings in "Demand Logging" mode. Memory holds up to 25 data labels that may be attached to Demand Log readings or Auto Log data sets.
Display	6-digit, 7-segment LCD with 16x1 alphanumeric	
Power	Rechargeable nickel-metal-hydride batteries (AC adapter included)	
Size	7.75" H x 4.2" W x 1.5" D (20 x 11 x 4 cm)	
Weight	1 lb. (0.4 kg)	
Probes from Hart	Contact Hart for a wide variety of precision PRTs and thermistors	
Calibration	Accredited 10-point, NIST-traceable resistance calibration provided	

Ordering Information

1521	Handheld Thermometer
1522	Handheld Logging Thermometer
9934-S	Log*Ware*, Single Channel, Single User
9934-M	Log*Ware*, Single Channel, Multi User
2370	Spare RS-232 Cable
2371	Spare INFO-CON Connector
2373	Probe Termination Adapter, INFO-CON to spade lug
2374	Dongle for IR Communications
2375	Mini Thermal Printer, includes power supply, battery pack, paper, adapter, cable
2378	Paper, 2375 Printer
9321	Soft Carrying Case, 1521/1522
9318	Hard Carrying Case, fits 1521/1522 and a 12" probe
2601	Probe Carrying Case
2521	Battery Pack, 1521/1522
2361	Spare AC Adapter, 12 V

Mingjian (primary temperature standards) will go wherever it takes to chase down that last tenth of a milliKelvin.

TWEENERS

Tweeners **Models 1502A and 1504**

- Two Tweeners to choose from—reading PRTs or thermistors
- Battery packs available
- Best price/performance package

One of Hart's best-selling products is the Tweener thermometer, and there's a reason. No other company, not one, has a thermometer that comes close to the performance and features of the Tweener for anywhere near its price.

Model 1502A PRT Readout

The Model 1502A Tweener features accuracy up to ±0.006°C (the Model 1504 is even more accurate, up to ±0.002°C). In addition, it reads both 100-ohm and 25-ohm probes, has a resolution of 0.001°C across its entire range, and is the smallest unit in its class. It also has an optional battery pack for completely portable operation.

Each Tweener is programmable to match a probe's constants for maximum linearity and accuracy. All probe constants and coefficients are programmed through simple, front-panel keystrokes. Temperature is displayed in °C, °F, K, or resistance in ohms.

The 1502A accurately measures the resistance of the probe and then converts the resistance to a temperature value using its built-in algorithms.

For convenience, the 1502A reads the common industrial grade IEC-751 or "385" ALPHA RTD without any programming. Enter the actual R0 and ALPHA of the individual probe for increased accuracy. For maximum accuracy, use the ITS-90 formulas. The Tweener accepts the subranges 4 and 6 through 11.

ITS-90 formulas reside in the Tweener's firmware. If your probe has been calibrated for any of the above subranges of the ITS-90, you simply enter the coefficients directly into your Tweener.

Each thermometer comes complete with an RS-232 interface for automation of temperature data collection, calibrations, or process control functions. An IEEE-488 interface is available as an option.

The 1502A is calibrated digitally using the front-panel buttons. You never have to open the box to calibrate it. This calibration protocol further reduces the cost of the 1502A. It goes where you go and works the way you want it to.

Model 1504 Thermistor Readout

If you need more accuracy in a limited temperature range, the Model 1504 Tweener gives it to you as a thermistor readout. Thermistors are less fragile than PRTs and less likely to be impacted by mechanical shock. Thermistors are more sensitive to temperature, have faster response times, and come in many shapes for different applications.

Typical accuracy of a 1504 is ±0.002°C with a resolution of 0.0001°C.

Software

With our 9934 Log*Ware,* both Tweener models may be used for real-time data acquisition. Collect data and analyze it graphically or statistically. Additionally, Tweeners may be used as reference thermometers with our MET/TEMP II software. (See our software section starting on page 74.)

Battery Option

If you want freedom from AC power in the field or on the plant floor, order Model 2502 and we'll install a DC power board in your Tweener. Then you can connect your own 12-volt DC power or order Hart's 9313 Battery Pack. Our battery gives you three to eight hours between charges. It includes a charger and a nylon pouch with a belt clip.

Calibration Choices

Each Tweener and its accompanying probe (sold separately) have their own individual calibration reports. Overall system error can be calculated from the individual errors, rendering the added cost of system data unnecessary. However, for those requiring it, system data is available at two or more temperatures of your choice. (See calibration options on page 156.)

The thermistor version of the "Tweener" gives you more variety in sensor configurations and even higher accuracy over a limited temperature range.

Specifications	1502A	1504
Temperature Range†	–200°C to 962°C (–328°F to 1764°F)	Any thermistor range
Resistance Range	0Ω to 400Ω, auto-ranging	0Ω to 1 MΩ, auto-ranging
Probe	Nominal R_{TPW}: 25Ω to 100Ω RTD, PRT, or SPRT	Thermistors
Characterizations	ITS-90 subranges 4, 6, 7, 8, 9, 10, and 11 IPTS-68: R_0, α, δ, a_4, and c_4 Callendar-Van Dusen: R_0, α, δ, and β	Steinhart-Hart thermistor polynomial Callendar-Van Dusen: R_0, α, δ, and β
Resistance Accuracy (ppm of reading)	0Ω to 20Ω: 0.0005Ω 20Ω to 400Ω: 25 ppm	0Ω to 5 KΩ: 0.5Ω 5 KΩ to 200 KΩ: 100 ppm 200 KΩ to 1 MΩ: 300 ppm
Temperature Accuracy†, typical (meter only)	±0.004°C at –100°C ±0.006°C at 0°C ±0.009°C at 100°C ±0.012°C at 200°C ±0.018°C at 400°C ±0.024°C at 600°C	±0.002°C at 0°C ±0.002°C at 25°C ±0.004°C at 50°C ±0.010°C at 75°C ±0.020°C at 100°C (Using 10 KΩ thermistor sensor, α=0.04. Does not include probe uncertainty or characterization errors.)
Operating Temperature Range	16°C to 30°C	13°C to 33°C
Resistance Resolution	0Ω to 20Ω: 0.0001Ω 20Ω to 400Ω: 0.001Ω	0Ω to 10 KΩ: 0.01Ω 10 KΩ to 100 KΩ: 0.1Ω 100 KΩ to 1 MΩ: 1Ω
Temperature Resolution	0.001°C	0.0001°C
Excitation Current	0.5 and 1 mA, user selectable, 2 Hz	2 and 10 μA, automatically selected
Measurement Period	1 second	
Digital Filter	Exponential, 0 to 60 seconds time constant (user selectable)	
Probe Connection	4-wire with shield, 5-pin DIN connector	
Communications	RS-232 serial standard IEEE-488 (GPIB) optional	
Display	8-digit, 7-segment, yellow-green LED; 0.5-inch-high characters	
Power	115 VAC (±10%), 50/60 Hz, 1 A, nominal 230 VAC (±10%), 50/60 Hz, 1 A, nominal, specify	
Size	5.6" W x 7.1" D x 2.4" H (143 x 181 x 61 mm)	
Weight	2.2 lb. (1.0 kg)	
Calibration	Accredited NIST-traceable calibration provided	
Probes from Hart	See pages 61 to 66	See pages 68 to 71

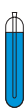
†Temperature ranges and accuracy may be limited by the sensor you use.

Ordering Information

1502A	PRT Thermometer
1504	Thermistor Thermometer
2502	DC Power Option
2505	Spare Connector
2506	IEEE Option
2507	Mini-Printer
2508	Serial Cable Kit
9934-S	Log*Ware*, Single Channel, Single User
9934-M	Log*Ware*, Single Channel, Multi User
9313	Battery Pack
9301	Carrying Case, fits Tweener and 12" probe
9308	Carrying Case, fits Tweener and 6" probe
1930-2	System Cal Report, RTDs (See page 156)
1930-5	System Cal Report, Thermistors (see page 156)

See pages 60 to 72 for a selection of probes to use with Tweeners and other Hart readouts.

Get the latest product information at www.hartscientific.com



See page 18 for triple point of water cells.

CHUB-E4

Chub-E4 **Model 1529**

- Four channels for PRTs, thermistors, and thermocouples
- Displays eight user-selected data fields from any channel
- Logs up to 8,000 readings with date and time stamps
- Battery provides eight hours of continuous operation

So you need multiple channels, battery power, outstanding accuracy, and the ability to read many different sensor types—but you don't need all the power of a 1 ppm Super-Thermometer. We have the answer for you.

Hart's Model 1529 Chub-E4 Thermometer gives you four channels, three major sensor types, lab-quality accuracy, and a ton of great features, all at a price you'll love.

Inputs

The Chub-E4 has four inputs for reading four different sensors simultaneously, and we'll configure those inputs in any of three different ways according to your preference. Choose four channels of thermocouple inputs, four channels of PRT/thermistor inputs, or two channels of each. With this thermometer, reading thermocouples, PRTs, and thermistors accurately from the same device is no problem.

100-ohm or 25-ohm PRTs and RTDs are read using ITS-90, IEC-751 (DIN), or Callendar-Van Dusen conversion methods. Typical accuracies include ±0.004°C at –100°C and ±0.009°C at 100°C. Thermistor readings are converted using the Steinhart-Hart polynomial or standard YSI-400 curve and are as accurate as ±0.0025°C at 25°C with resolution of 0.0001°.

Thermocouple inputs read all the common thermocouple types, including B, E, J, K, N, R, S, T, and Au-Pt, and allow you to choose between internal and external reference junction compensation. Typical accuracy for a type J thermocouple at 600°C is ±0.35°C using internal reference junction compensation and not including the thermocouple.

PRTs and thermistors connect easily to the 1529 using Hart's patented mini DWF connectors, which accept bare wire, spade lug, or mini banana plug terminations. Thermocouples connect using standard or miniature terminations. Measurements are taken each second and can be taken simultaneously or sequentially. A special high-speed mode allows measurements on one channel to be taken at the rate of 10 per second.

Display

If you think three sensor types and four inputs sounds versatile, wait until you see the display panel on the Chub-E4. Displaying measurements in °C, °F, K, ohms, or millivolts and choosing temperature resolution from 0.01 to 0.0001 are just the beginning.

You can also select any eight items from our long list of displayable data fields to view on-screen. Choose statistical functions such as averages, standard deviations, and spreads; choose probe information such as probe type and serial number; choose T1-T2 functions using inputs from any two channels; or choose utility functions such as the date, time, and battery power level. You can even save up to 10 screen configurations for easy recall.

The push of a single front-panel button also brings up a simple menu system to easily guide you through all the internal setup and memory options of the 1529. Probe coefficients, sample intervals, communication settings, password settings, and a host of other functions are all easily accessible.

Communications

The memory and communications capabilities of the Chub-E4 make it perfect for benchtop thermometry, on-site measurements, lab calibration work, and remote data logging. Optional software packages from Hart make this one of the most powerful thermometers on the market.

With battery power and memory to store up to 8,000 measurements (including date and time stamps) at user-selected intervals, the 1529 has plenty of data logging capability. Store 100 individual measurements or any number of automatic log ses-

sions (up to 8,000 readings), each tagged with an identifying session label. Fourteen different logging intervals may be selected, from 0.1 second to 60 minutes.

With Hart's 9935 Log*Ware* II (page 79), data may be quickly downloaded to your PC for complete graphical and statistical analysis. Separate log sessions may even be automatically downloaded to separate files based on session labels. With this software, the 1529 can even be used for real-time data logging. Log four channels at once directly to your PC with virtually no limit to the number of data points you take. You can analyze data, set alarm events, and even set delayed start and stop times.

With MET/TEMP II software, the Chub-E4 may be integrated into a completely automated calibration system. Use one input for your reference thermometer and calibrate up to three other thermometers automatically (see page 75). An RS-232 port is standard on every unit. An IEEE-488 port is optional.

More Great Features

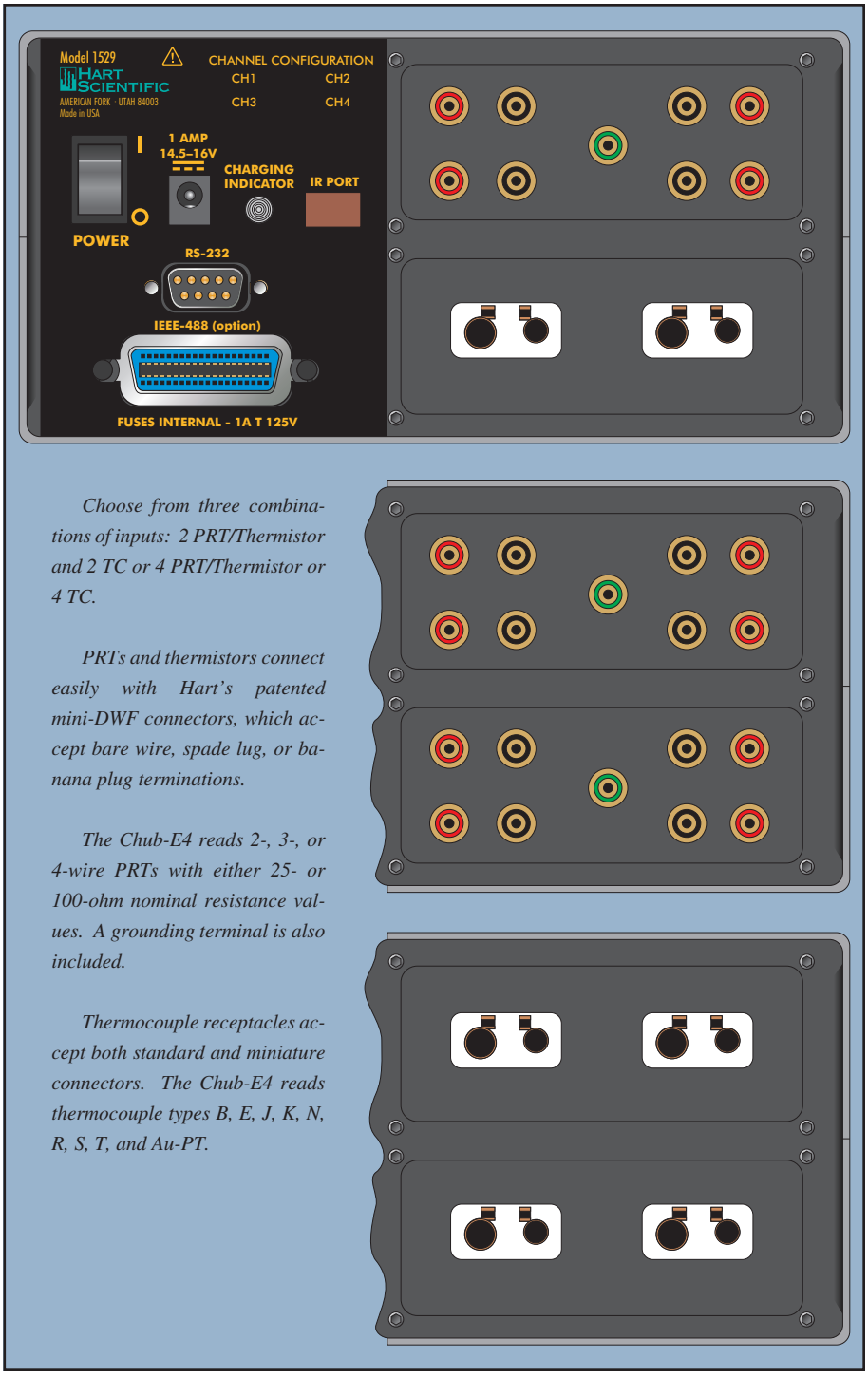
Did we forget some aspect of versatility on this thermometer? No!

The 1529 runs on AC power from 100 to 240 volts, DC power from 12 to 16 volts, or off its internal nickel-metal-hydride battery for eight hours between charging. The standard battery charges in less than three hours and lasts through 500 charge/recharge cycles.

If you want to rack-mount your Chub-E4, we've even got a rack-mount kit for you. This unit fits on your benchtop, in your instrument rack, and even in your hand.

Of course, all the reference thermometers you might need for your 1529 are available from Hart, including secondary standard PRTs, standard thermistors, and noble-metal thermocouples. Carrying cases and even a serial printer for direct printer output are also available.

We've said it before and we'll keep saying it: Hart Scientific simply makes the best thermometer readouts in the world. No one else gives you a comparable combination of accuracy, versatility, productivity-enhancing features, and price. No one. Get a Chub-E4 and just enjoy everything it'll do for you. You'll love it.



Choose from three combinations of inputs: 2 PRT/Thermistor and 2 TC or 4 PRT/Thermistor or 4 TC.

PRTs and thermistors connect easily with Hart's patented mini-DWF connectors, which accept bare wire, spade lug, or banana plug terminations.

The Chub-E4 reads 2-, 3-, or 4-wire PRTs with either 25- or 100-ohm nominal resistance values. A grounding terminal is also included.

Thermocouple receptacles accept both standard and miniature connectors. The Chub-E4 reads thermocouple types B, E, J, K, N, R, S, T, and Au-PT.

Get the latest product information at www.hartscientific.com

Specifications	PRT / RTD	Thermistor	Thermocouple
Inputs	2 channels PRT/thermistor and 2 channels TC, or 4 channels PRT/thermistor, or 4 channels TC, specify when ordering; PRT/thermistor channels accept 2, 3, or 4 wires; TC inputs accept B, E, J, K, N, R, S, T, and Au-Pt TC types		
Temperature Range	–189°C to 960°C	–50°C to 150°C	–270°C to 1800°C
Measurement Range	0 to 400 Ω	0 to 500 KΩ	–10 to 100 mV
Characterizations	ITS-90, IEC-751 (DIN "385"), Callendar-Van Dusen	Steinhart-Hart, YSI-400	NIST Monograph 175, 3-point deviation function applied to NIST 175, 6th-order polynomial
Temperature Accuracy (meter only)	±0.004°C at –100°C ±0.006°C at 0°C ±0.009°C at 100°C ±0.012°C at 200°C ±0.018°C at 400°C ±0.024°C at 600°C	±0.0025°C at 0°C ±0.0025°C at 25°C ±0.004°C at 50°C ±0.010°C at 75°C ±0.025°C at 100°C	Ext. RJC / Int. RJC B at 1000°C: ±0.6°C / ±0.6°C E at 600°C: ±0.07°C / ±0.25°C J at 600°C: ±0.1°C / ±0.35°C K at 600°C: ±0.15°C / ±0.4°C N at 600°C: ±0.15°C / ±0.3°C R at 1000°C: ±0.4°C / ±0.5°C S at 1000°C: ±0.5°C / ±0.6°C T at 200°C: ±0.1°C / ±0.3°C
Temperature Resolution	0.001°	0.0001°	0.01 to 0.001°
Resistance/Voltage Accuracy	0Ω to 20Ω: ±0.0005Ω 20Ω to 400Ω: ±25 ppm of rdg.	0Ω to 5 KΩ: ±0.5Ω 5 KΩ to 200 KΩ: ±100 ppm of rdg. 200 KΩ to 500 KΩ ±300 ppm of rdg.	–10 to 50 mV: ±0.005 mV 50 to 100 mV: ±100 ppm of rdg. (Internal RJC: ±0.25°C)
Operating Range	16°C to 30°C		
Measurement Interval	0.1 second to 1 hour; inputs may be read sequentially or simultaneously at 1 second or greater interval		
Excitation Current	1 mA, reversing	2 and 10 μA, automatically selected	n/a
Display	1.3" x 5" backlit LCD graphical display		
Display Units	°C, °F, K, Ω, KΩ, mV		
Data Logging	Up to 8,000 time- and date-stamped measurements can be logged		
Logging Intervals	0.1, 0.2, 0.5, 1, 2, 5, 10, 30, or 60 seconds; 2, 5, 10, 30, or 60 minutes		
Averaging	Moving average of most recent 2 to 10 readings, user selectable		
Probe Connection	Patented DWF Connectors accept mini spade lug, bare-wire, or mini banana plug terminations		Universal receptacle accepts miniature and standard TC connectors
Communications	RS-232 and IR ports included, IEEE-488 (GPIB) optional		
AC Power	100–240 VAC, 50-60 Hz, 0.4 A		
DC Power	12–16 VDC, 0.5 A (battery charges during operation from 14.5 to 16V DC, 1.0A)		
Battery	NiMH, 8 hours of operation typical without backlight, 3 hours to charge, 500 cycles		
Size	4.0" H x 7.5" W x 8.2" D (102 x 191 x 208 mm)		
Weight	4.5 lbs. (2 kg)		
Probes from Hart	See pages 60 to 72		
Calibration	Accredited NIST-traceable resistance calibration and NIST-traceable voltage calibration provided		

Ordering Information

1529	Chub-E4 Thermometer, 2 TC and 2 PRT/Thermistor inputs
1529-R	Chub-E4 Thermometer, 4 PRT/Thermistor inputs
1529-T	Chub-E4 Thermometer, 4 TC inputs
2506-1529	IEEE Option
9322	Rugged Carrying Case, holds 1529 and four probes up to 12" long
9323	Soft Carrying Case
2513-1529	Rack-Mount Kit
9935-S	Log*Ware* II, Multi Channel, Single User
9935-M	Log*Ware* II, Multi Channel, Multi User
2374	IR Dongle
2375	Thermal Serial Printer, with paper, AC adapter, cable, battery pack
2362	Spare AC Adapter, 15 V

See our calibration and data acquisition software packages on page 74.

CHOOSING THE RIGHT TEMPERATURE READOUT

When you're performing temperature calibrations, the right choice of readout for your reference probe and units under test is critical. Consider the following:

Accuracy

Most readout devices for resistance thermometers provide a specification in parts per million (ppm), ohms, and/or temperature. Converting ohms or ppm to temperature depends on the thermometer being used. For a 100Ω probe, 0.001Ω equals 0.0025°C at 0°C. One ppm would be the same as 0.1 mΩ or 0.25 mK. You should note whether the specification is "of reading" or "of full range." One ppm of reading at 100Ω is 0.1 mΩ. However, 1 ppm of full range, where full range is 400Ω, is 0.4 mΩ.

When reviewing accuracy specifications, remember the readout uncertainty can be a small contribution to total uncertainty and that it may not make economic sense to buy the lowest uncertainty readout. A 0.1 ppm bridge may cost $40,000, whereas a 1 ppm Super-Thermometer costs less than half that. Yet the bridge offers very little improvement—in this case, 0.000006°C (see below).

Measurement Errors

When making high-accuracy resistance measurements, be sure the readout is eliminating thermal EMF errors within the measurement system. A common technique for removing EMF errors uses a switched DC or low-frequency AC current supply.

Resolution

Having 0.001° resolution does not mean the unit is accurate to 0.001°. In general, a readout accurate to 0.01° should have a resolution of at least 0.001°. Display resolution is important when detecting small temperature changes—for example, when monitoring the stability of a calibration bath.

Linearity

Most manufacturers provide an accuracy specification at one temperature (typically 0°C), but it's important to know the accuracy over your working range. The accuracy of the readout will vary depending on the measurement. The uncertainty could be larger at the temperature you're measuring than it is at 0°C. Be sure the manufacturer provides an accuracy specification that covers your working range.

Stability

Stability is important, since you'll be making measurements in a wide variety of ambient conditions and over varying lengths of time. Be sure to review the temperature coefficient and long-term stability specifications. Make sure the variations in your ambient conditions will not affect the readout's accuracy. Be wary of the supplier who quotes "zero drift" specifications. Every readout has at least one drift component.

Calibration

Some readout specifications state "no recalibration necessary." However, ISO guides require the calibration of all measuring equipment. Look for a readout that can be calibrated through its front panel without special software. Also avoid readouts that still use manual potentiometer adjustments or that need to be returned to the factory for recalibration. Most DC readouts are calibrated using high-stability DC standard resistors. Calibration of AC readouts is more complicated, requiring a reference inductive voltage divider and accurate AC standard resistors.

Traceability

Traceability of DC readout measurements is extremely simple through well-established DC resistance standards. Traceability of measurements from AC readouts and bridges is more problematic. Many countries have no established AC resistance traceability. Most countries that have traceable AC measurements rely on AC resistors calibrated with 10 times the uncertainty of the readout or bridge, which significantly increases the system measurement uncertainty.

Convenience Features

Because the push for increased productivity is endless, you'll need a readout with as many time-saving features as possible. Some important ones to look for are direct display in temperature rather than just raw resistance or voltage, acceptance of a wide variety of thermometer types, ease of use for a short learning curve, channel expansion capability through multiplexers, and digital interface (and software) options that allow for automation of measurements and calibrations.

Read about our calibration training courses on page 153.

Sources of Uncertainty - Comparison Calibration of PRTs from –196°C to 420°C		
SPRT	0.001000°C	0.001000°C
1 ppm Super-Thermometer (1 ppm)	0.000250°C	n/a
0.1 ppm Bridge	n/a	0.000025°C
Bath Uniformity / Stability	0.005000°C	0.005000°C
Estimated Total Uncertainty (k=2)*	**0.005105°C**	**0.005099°C**

*RSS, assuming uncertainty components were statistically evaluated.

So, for a mere additional $30,000 you can buy a bridge and improve your system uncertainty by a whopping 0.000006 °C. We suggest you stick with a Super-Thermometer and treat yourself to dinner with the money you save.

THE BLACK STACK

The *Black Stack* **Model 1560**

- Reads SPRTs, RTDs, thermistors, and thermocouples
- Any configuration you like up to eight modules
- High-accuracy reference thermometer (to ±0.0013°C)
- Automates precision data acquisition

Hart's *Black Stack* thermometer has been on the market for seven years and has established itself as one of the most versatile, cost-effective, and accurate readouts in the world.

Nothing about this instrument says ordinary. Traditionally, thermometers were square boxes configured to do one particular job—such as read a calibrated PRT. However, if you also wanted to measure thermistors, you had to buy another instrument that could do this specific task. Some thermometers can do multiple jobs, but they're expensive, complex, and difficult to use. You're paying for functions you don't need and may never use. The *Black Stack* solves these problems and more.

The 1560 *Black Stack* can be any kind of thermometer you want it to be, and it works in three distinctive ways.

It's a reference thermometer with a NIST traceable calibration; it's an automated calibration system reading your reference probe and sensors you're testing; or it's a high-accuracy data acquisition system. And it does these functions better than any other thermometer currently on the market.

The *Stack* consists of up to eight different modules that fit together to do any type of thermometry you choose. You can buy all of them, or any combination of them, and change the *Stack* and its functions anytime you want. Each module stacks behind the preceding one, and when you add a module, the *Stack's* software automatically reconfigures itself to include all of the new functions supplied by that module. There's nothing to take apart. No boards need to be installed. There's no software to load, and nothing has to be calibrated. Just stack a new module onto the back of the previous modules and you're ready to use the *Black Stack* and all of its remarkable features.

Hart's 9935 Log*Ware* II makes the *Black Stack* an even more powerful data acquisition tool. Log*Ware* II provides

graphical and statistical analysis of each channel you're measuring (up to 96 with the *Black Stack*). And with alarms that can be customized, delayed start times, and selectable logging intervals, Log*Ware* II turns the *Black Stack* into the most powerful temperature data acquisition tool on the market. (See page 79.)

Each module connects and disconnects easily from the Black Stack with just two screws.

The Base Unit

The *Stack* starts with a base module. It consists of two parts: a display with the main processor and a power supply. The base module supplies power, communication management, and software coordination for all of the other modules. It has the display, control buttons, and RS-232 port built-in.

Each base module can handle eight thermometer modules stacked behind it with a maximum of 96 sensor inputs. The base module never needs calibration and performs its own diagnostic self-test each time it powers up. The thermometer characteristics of each base module are defined by the thermometry modules stacked behind it.

The Modules

There are nine thermometry modules: an SPRT module, a high-temp PRT module, a PRT scanner module, a standards thermistor module, two 1000-ohm PRT modules, a thermistor scanner module, a precision thermocouple module, and a thermocouple scanner module.

Each module has its own processor and connects to the stack on a proprietary digital bus. Each retains its own calibration data and performs all analog measurement functions within the module.

SPRT Module 2560

The SPRT module reads 25-ohm and 100-ohm four-wire RTDs, PRTs, and SPRTs with very high accuracy. It turns the *Stack* into a first-rate reference thermometer with an accuracy to ±0.005°C.

It has two input channels so you can collect data with two reference sensors, or you can do comparison calibrations of one sensor against a calibrated reference sensor.

Temperature conversion features include direct resistance measurement, ITS-90, W(T90), IPTS-68, Callendar-Van Dusen, or an RTD polynomial conversion. The user-changeable default values for the CVD conversion fit the 100-ohm, 0.00385 ALPHA sensor described by IEC-751.

The SPRT modules can be used one at a time or combined together in any combination for reading up to 16 different reference thermometers. If you stack an SPRT module with a scanner module, you can test multiple sensors against your reference. Unlike other competitive instruments, our PRT Scanner Module operates with or without the two-channel SPRT module. If you can think of a way to use a reference thermometer, you can do it with the *Stack.*

High-Temp PRT Module 2561

This module reads 2.5-ohm and 0.25-ohm four-wire HTPRTs and RTDs. The complete resistance range covers up to 5-ohm sensors with applications as high as 1200°C. The temperature conversion features are the same as for the SPRT module, and like the SPRT module, the connectors are gold plated.

PRT Scanner 2562

This module reads eight channels of two-, three-, or four-wire 100-ohm PRTs or RTDs. The accuracy is ±0.01°C at 0°C for calibration of industrial sensors. The common industrial RTD can be read with the default values in the CVD temperature conversion for fast setup of industrial applications, or you can enter individual probe constants for higher accuracy data acquisition.

Standards Thermistor Module 2563

Special low-drift thermistors are becoming increasingly popular as reference probes in applications with modest temperature ranges up to 100°C. This module has a temperature accuracy of ±0.0013°C at 0°C with a resolution of 0.0001°C.

The 2563 Thermistor Module has two input channels. It displays direct resistance in ohms or converts directly to a temperature readout using either the Steinhart-Hart equation or a higher-order polynomial.

Thermistor Scanner Module 2564

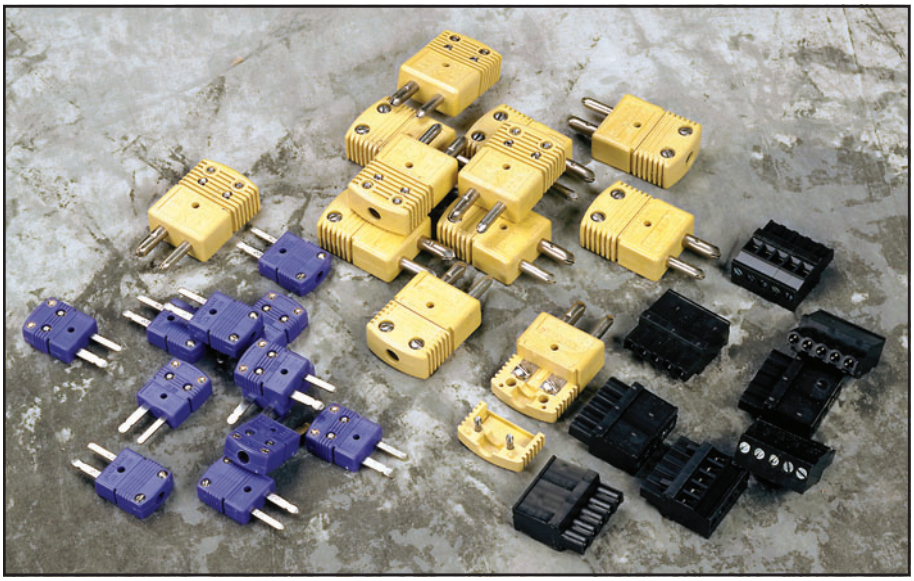
This module is usable with any type of thermistor but has eight channels instead of the two channels found on the Standards Thermistor Module and operates with or without the Standards Thermistor Module. This module's accuracy is ±0.0025°C at 0°C for all eight channels.

The eight channels make the 2564 module an excellent data acquisition tool. It can be used in research work or for verification of biomedical equipment such as DNA sequencing apparatus.

Precision Thermocouple Module 2565

This precision thermocouple module reads any type of thermocouple, including type S platinum thermocouples and the new gold-platinum thermocouples for standards work. This two-channel module has internal reference junction compensa-

The Black Stack is the perfect foundation to build a totally automated calibration system with Hart heat sources and 9938 MET/TEMP II software (see page 75). No programming or system design nightmares.



Convenient connector kits are available so you're ready to connect your sensors to Hart's scanner modules. The PRT and thermistor scanners include one set of eight probe connectors, but you may want spares. The thermocouple scanner does not include probe connectors due to the variety of thermocouple types and the mini versus standard sizes. You can choose just what you want from our list in the ordering information.

tion, or you can use an external source for even greater accuracy.

All the standard ANSI thermocouple types are preprogrammed; however, you can choose a conversion method and then enter the probe characteristics of your sensor, creating a system-calibrated channel. The 2565 module accepts up to three calibration points for error adjustment in the individual sensor. A polynomial interpolation function calculates the points between your measurements.

Type R, type S, and gold-platinum conversions accept complete polynomial calibration coefficients. Additionally, a thermocouple conversion function calculates temperature by interpolating from a table. You enter the temperature in degrees C and the corresponding voltage for your specific sensor from 1 to 10 temperatures. Interpolation is performed between the entered points.

Thermocouple Scanner Module 2566

This module has 12 channels and reads K, J, T, S, R, B, E, and N thermocouples. Each channel can be set to read a different type of thermocouple. All temperature readings are performed in exactly the same manner as with the 2565 module.

The connectors on the scanner module are special dual connectors that accept both the common miniature and standard thermocouple connectors. If you want to use screw terminals, use the appropriately-sized connector with the hood removed.

1000-Ohm PRT Modules 2567 and 2568

For 1000-ohm PRTs, these modules provide all the same great features as the 2560 and 2562 Modules. The two-channel 2567 Module has a resistance range of 0 to 4000 ohms and is accurate to ±0.006°C at 0°C. The 2568 Module reads up to eight 1000-ohm PRTs and at 0°C is accurate to ±0.01°C. Don't use an ohmmeter or multimeter to read your 1000-ohm PRTs when you can use a *Black Stack* loaded with convenient temperature functions.

Extended Communications Module 3560

Need more communications options? The 3560 module adds an IEEE-488 (GPIB) interface, a Centronics printer interface, and analog output via a DC signal (±1.25 VDC).

Features Common to All Modules

The 1560 *Black Stack* is an incredible thermometer. You buy only the modules you need for the work you are doing. If your work changes, simply order the modules with the functions you need and slip them onto the back of the *Stack.* Your thermometer changes its software, display, and method of operation to match the new functions you've added.

Remember, you never have to open the case to add modules. There's no software to load. It's all automatic.

Each module stores its own calibration internally, so you can add or change mod-

ules without recalibrating the whole stack. Module calibration is digital and is performed manually through the base's front panel or over the RS-232 link. If your lab has the capability, you can calibrate modules yourself. If not, send them to us with or without your base unit and we'll recalibrate them. Hart calibrations are accredited.

The LCD screen has multiple methods of displaying data, including a graphical strip chart recorder. The graphical capability of the *Black Stack* makes testing temperature stability easier than ever. Vertical scaling and graph resolution are automatic.

The *Stack* has high-accuracy, two-channel capability or multi-channel functionality if you need it. Its memory stores the most recent 1000 readings, or you can send your data to your PC through the RS-232 port. Each data point is time and date stamped. An IEEE-488 port is optional.

With the *Black Stack* you can read data almost anyway you like—in ohms, millivolts, or temperature, according to your application and preference.

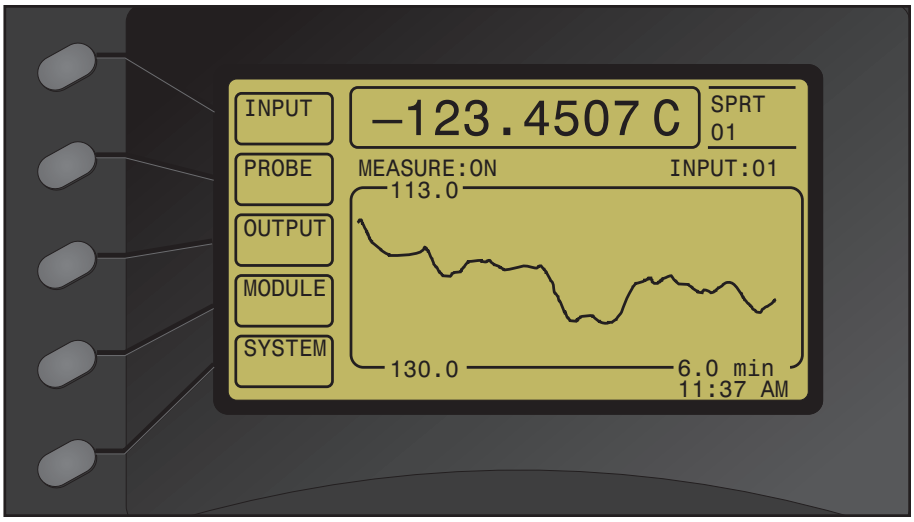
Remember, this thermometer's calibration is traceable to NIST. Its accuracy is as high as ±0.0013°C, depending on the module and sensor you're using.

Hey! Why Did You Make It Look Like That?!

We get asked this question more than any other question. There are several reasons for the shape of the *Black Stack.*

When we started the design process on the *Black Stack,* we wanted a unique instrument that was a true technological leap in thermometry. Incremental improvements are okay sometimes, but if you're going to lead the industry, you might as well go out and lead it.

Here are some of the design criteria we started with. The new thermometer had to be capable of transforming itself into any kind of thermometry instrument the customer wanted, and it had to do this without having to open the box, replace boards, or set up anything. All connections needed to be easily accessible from the front of the instrument, with no connectors on the front panel. The front panel had to be easy to read, with all features including programming done on the front panel, and the programming taking advantage of the graphical capability of the display. The software had to be as creative and as versatile as the instrument. It had to be easy to use and, if at all possible, even fun to use. And finally, it had to be very accurate.



The shape of the *Black Stack* facilitates the function and usability of the instrument. And it is unbelievably functional and fun to use.

The only way you'll truly understand what we're talking about is to get one and try it. Hundreds of customers, including many national standards labs, already have it!

See our calibration and data acquisition software packages on page 74.

Leonard (customer service) tests Hart heat sources at home.

Specifications

Model 1560 Base Unit

Power: 100 to 240 VAC, 50 or 60 Hz, nominal; Attachable Modules: up to 8; Display: 4.25" x 2.25" LCD graphics, LED backlight, adjustable contrast and brightness; Automatic Input Sequencing: 1 to 96 channels; Communications: RS-232; Non-volatile Memory: channel sequence, probe coefficients; Minimum Sample Time: 2 seconds.

Extended Communication Module 3560

The Extended Communication Module adds additional communication interface capability to the system. This module includes a GPIB (IEEE-488) interface, Centronics printer interface, and analog output. The GPIB interface connects the 1560 to a GPIB bus. GPIB can be used to control any function of the 1560 and read measurement data. The printer interface allows the 1560 to send measurement data directly to a printer. The analog output sources a DC signal (±1.25 VDC) corresponding to the value of a measurement.

Resistance Modules

Input Channels	Resistance Range	Basic Resistance Accuracy	Resistance Resolution	Temperature Range	Equivalent Temperature Accuracy†	Temperature Resolution	Excitation Current
SPRT Module 2560							
2	0Ω to 400Ω	±20 ppm of reading (0.0005Ω at 25Ω, 0.002Ω at 100Ω)	0.0001Ω	–260°C to 962°C	±0.005°C at 0°C ±0.007°C at 100°C	0.0001°C	1.0 mA, 1.4 mA
High-Temp PRT Module 2561							
2	0Ω to 25Ω	±50 ppm of reading (0.00013Ω at 2.5Ω)	0.00001Ω	0°C to 1200°C	±0.013°C at 0°C ±0.018°C at 100°C	0.001°C	3.0 mA, 5.0 mA
PRT Scanner 2562							
8	0Ω to 400Ω	±40 ppm of reading (0.004Ω at 100Ω)	0.0001Ω	–200°C to 850°C	±0.01°C at 0°C ±0.014°C at 100°C	0.0001°C	1.0 mA, 1.4 mA
Standards Thermistor Module 2563							
2	0Ω to 1 MΩ	±50 ppm of reading (0.5Ω at 10 KΩ)	0.1Ω	–60°C to 260°C	±0.0013°C at 0°C ±0.0015°C at 75°C	0.0001°C	2 μA, 10 μA
Thermistor Scanner 2564							
8	0Ω to 1 MΩ	±100 ppm of reading (1Ω at 10 KΩ)	0.1Ω	–60°C to 260°C	±0.0025°C at 0°C ±0.003°C at 75°C	0.0001°C	2 μA, 10 μA
1000Ω PRT Module 2567							
2	0Ω to 4 KΩ	±25 ppm of reading (0.025Ω at 1 KΩ)	0.001Ω	–260°C to 962°C	±0.006°C at 0°C ±0.009°C at 100°C	0.0001°C	0.1 mA, 0.05 mA
1000Ω PRT Scanner 2568							
8	0Ω to 4 KΩ	±40 ppm of reading (0.04Ω at 1 KΩ)	0.001Ω	–200°C to 850°C	±0.01°C at 0°C ±0.014°C at 100°C	0.0001°C	0.1 mA, 0.05 mA

Thermocouple Modules

Input Channels	Millivolt Range	Millivolt Accuracy	Millivolt Resolution	Temperature Accuracy,† Ext. CJC	Temperature Accuracy,† Int. CJC	Temperature Resolution
Precision Thermocouple Module 2565						
2	–10 to 100 mV	±0.002 mV	0.0001 mV	±0.05°C	±0.1°C	0.001°C
Thermocouple Scanner 2566						
12	–10 to 100 mV	±0.004 mV	0.0001 mV	±0.1°C	±0.3°C	0.001°C

†Temperature accuracy depends on probe type and temperature.

Ordering Information

1560	Thermometer Base Unit
2560	SPRT Module, 25Ω and 100Ω, 2-channel
2561	High-Temp PRT Module, 0.25Ω to 5Ω, 2-channel
2562	PRT Scanner Module, 8-channel
2563	Standards Thermistor Module, 2-channel
2564	Thermistor Scanner Module, 8-channel
2565	Precision Thermocouple Module, 2-channel
2566	Thermocouple Scanner Module, 12-channel
2567	SPRT Module, 1000Ω, 2-channel
2568	PRT Scanner Module, 8-channel, 1000Ω
3560	Extended Communications Module
9935-S	Log*Ware* II, Mutli Channel, Single User
9935-M	Log*Ware* II, Multi Channel, Multi User
9302	Case (holds 1560 and up to five modules)

Probes

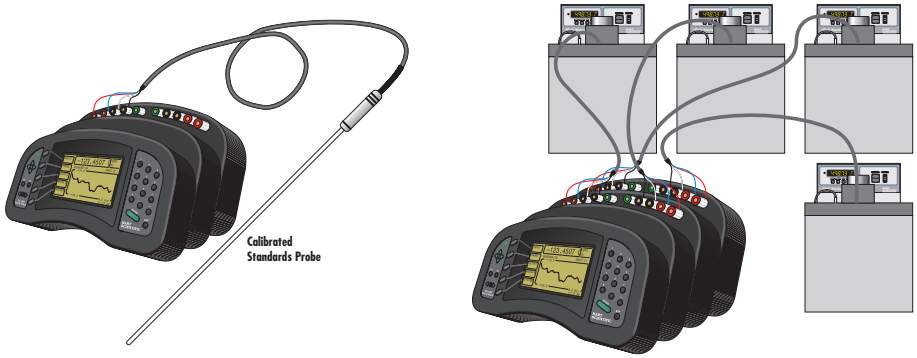
5610-6-X	Thermistor Probe (0.125" dia x 6"), 0°C to 100°C
5610-9-X	Thermistor Probe (0.125" dia x 9"), 0°C to 100°C
5642-X	Standards Thermistor Probe
5612-9-X	Secondary Standard PRT (0.187" dia. x 9"), to 420°C
5613-6-X	Secondary Standard PRT (0.187" dia. x 6"), to 300°C
5614-12-X	Secondary Standard PRT (0.25" dia. x 12"), to 420°C
5626-12-X	Secondary Standard PRT (0.25" dia x 12"), 100Ω, –200°C to 661°C
5626-15-X	Secondary Standard PRT (0.25" dia x 15"), 100Ω, –200°C to 661°C
5628-12-X	Secondary Standard PRT (0.25" dia x 12"), 25Ω, –200°C to 661°C
5628-15-X	Secondary Standard PRT (0.25" dia x 15"), 25Ω, –200°C to 661°C

X = termination. Specify "B" (bare wire), "D" (5-pin DIN for Tweener Thermometers), "G" (gold pins), "I" (INFO-CON for 1521 or 1522 Handheld Thermometers), "J" (banana jacks), "L" (mini spade lugs), "M" (mini banana jacks), or "S" (spade lugs).

See pages 60 to 72 for more probes.

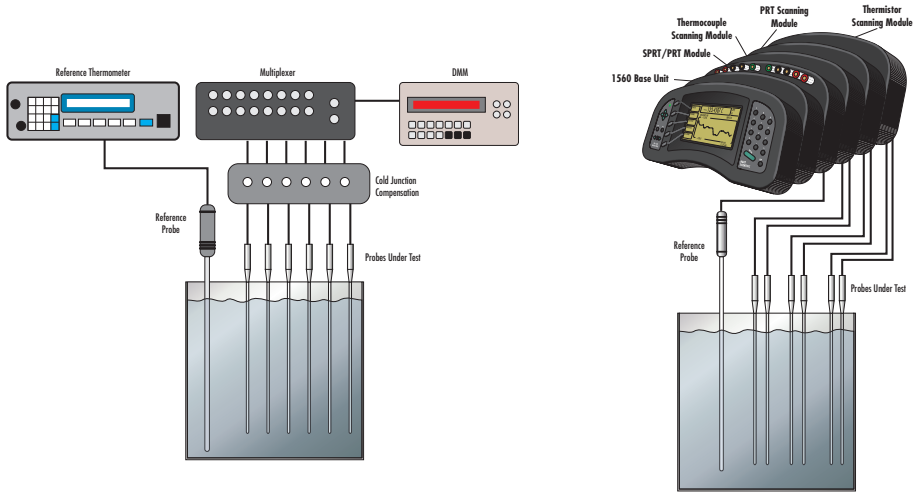
Spare Connector Kits

2380-X	Miniature Thermocouple Connector, 12 pcs. (X = TC type. Choose from K, T, J, E, R, S, N, or U)
2381-X	Standard Thermocouple Connector, 12 pcs. (X = TC type. Choose from K, T, J, E, R, S, N, or U)
2382	RTD/Thermistor Connector, 8 pcs. (Fits 2562, 2564, and 2568 modules)



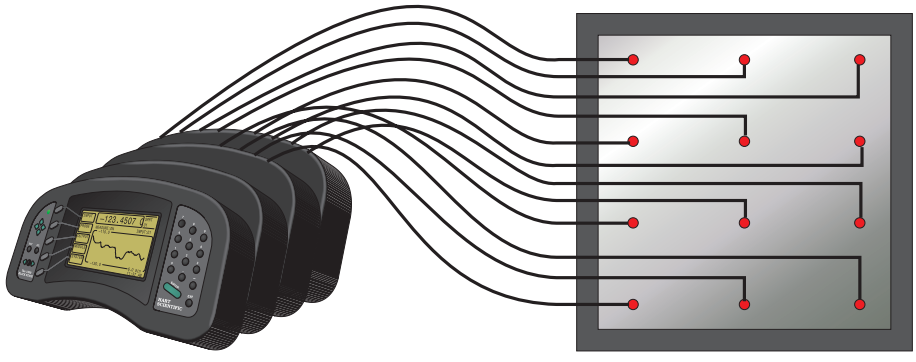
The Black Stack as a High-Accuracy Reference Thermometer

Use the Black Stack with a calibrated standards probe. Using multiple modules, you can have one instrument read a standards probe in each bath or furnace in your lab.



The Black Stack as an Automated Calibration System

The 1560 reads sensors under calibration. Traditional techniques require a reference thermometer, digital multimeter, scanner, and cold junction compensation for thermocouples. With the Black Stack, one instrument does the whole job.



The Black Stack as a High-Accuracy Data Acquisition System

Use the 1560 in research work or critical production roles. With calibrated probes attached, the 1560 calibrates or verifies the performance of ovens, incubators, DNA sequencers, baths, or process equipment.

SUPER-THERMOMETERS

Super-Thermometers **Models 1575A and 1590**

- Accuracy to 4 ppm (0.001°C) or 1 ppm (0.00025°C)
- Bridge-level performance at less than half the cost
- Accepts 0.25-ohm through 100-ohm SPRTs plus thermistors
- Includes all temperature functions and stores setups

Hart's Super-Thermometers are recognized in metrology laboratories around the world for their ease of use and reliable accuracy. The Model 1575A Super-Thermometer is accurate to 0.001°C. The Model 1590 Super-Thermometer II is accurate to 0.00025°C, or 1 ppm.

Both Super-Thermometers are perfectly suited for SPRT calibrations. These are the best lab instruments to take advantage of SPRT accuracy. They're easy to use, they read temperature directly, they have automated data collection, they automatically calculate constants for ITS-90, and both of them are priced at less than half the price of the competitors' resistance bridges.

Of course, there's more.

Bridges

Resistance bridges are one of the most expensive pieces of lab equipment you can buy. Most sell for $30,000 to $50,000. The resistance bridge market is very small, and there's hardly any competition. There's nothing to control the price except your willingness to pay.

Resistance bridges are difficult to use. Their learning curve is long and complex, which means you'll spend plenty of time learning to master one. Time spent learning costs you money, and costs multiply if you have to train other people!

So why buy a bridge if you have a legitimate alternative?

If 1 ppm accuracy gets the job done, the easiest and cheapest way to do it is with one of Hart's Super-Thermometers.

Model 1575A

The Model 1575A Super-Thermometer is a best-selling thermometer because of its ease of use, high accuracy, built-in software, and reasonable price. Temperature is read directly on the display in your choice of scales. There are no manual resistance-to-temperature conversions. Resistance is converted to temperature for you using the ITS-90 algorithm in any one of the instrument's ranges. Up to 16 independent sets of probe characterizations can be stored in the 1575A's memory. Switch SPRTs and simply call up its reference identification number. Forget the extensive, time-consuming setup required by resistance bridges. Read the features common to both units and you'll understand why each is a great buy.

Model 1590

The 1590 Super-Thermometer II has all of the features of the 1575A, plus it has the unbeatable accuracy of 1 ppm and a color screen that tilts to create the best viewing angles. With all of these features, it's still less than half the price of a bridge.

In many labs with standards that require the use of bridges, Super-Thermometers have been accepted as an alternative to bridges because they are a combination of bridge technology and microprocessor-based solid-state electronics—and they're much easier to use.

Both Hart Super-Thermometers come with an accredited calibration.

Accuracy

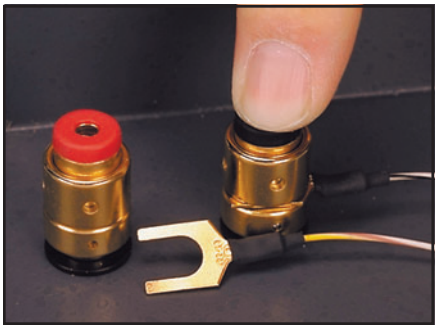
The typical benchtop thermometer has an error level 5 to 10 times larger than the Super-Thermometer, and 20 to 40 times higher than a Super-Thermometer II. With common 25- or 100-ohm SPRTs, the 1575A Super-Thermometer achieves ±0.002°C accuracy and ±0.001°C accuracy with a calibrated external standard resistor. The 1590 Super-Thermometer II is even better with ±0.00025°C accuracy.

ITS-90 specifies the use of 2.5-ohm and 0.25-ohm SPRTs as high-temperature standards up to the silver point (962°C). This very small resistance is difficult to measure and is commonly done only with resistance bridges. The Super-Thermometers address ITS-90 problems directly and are absolutely the most cost-effective solution available.

In addition, resolution with a 25-ohm SPRT is 0.0001°C. Comparison calibrations or calibrations against primary standard fixed points are easily performed. Both instruments have two channels for handling two probes at once. Display and record actual temperatures or choose to read the difference between the two directly from the screen.

Both Super-Thermometers have their own on-board resistors. Each is a high-stability, low thermal coefficient, four-terminal resistor for each of the resistance ranges of the thermometer: 0.25 ohms, 2.5 ohms, 25 ohms, 100 ohms, and thermistor ranges. Resistors are housed in an internal temperature-controlled oven. Can it get any better?

Well, actually it does.



Hart's patented DWF Connectors — so easy to use you'll never want to use anything else.

Add 10 channels to a 1575A Super-Thermometer with a 2575 Mighty-Mux. Or add up to 50 channels to a 1590 Super Thermometer II with 10-channel 2590 Mighty-Mux II multiplexers.

DWF Connectors

Hart's patented Model 2392 DWF Connector is unique in the industry (U.S. Patent 5,964,625). Each one is machined from solid brass and then plated with gold. DWF Connectors accept banana plugs, spade connectors, or bare wires. Banana plugs are inserted in the top. Bare wires go in one of the four side holes and are held in place by a spring-loaded pressure plate. Spade connectors are inserted between the top of the connector and pressure plate and are held in place the same as bare wire. The connections are solid and difficult to dislodge. Bare wire and spade connectors require nothing more than pushing the DWF Connector in. There's nothing to screw down or tighten.

Other Features

Super-Thermometers convert resistance to temperature using your choice of ITS-90 or IPTS-68. ITS-90 requires no conversions; just enter your coefficients directly. For IPTS-68 enter R0, ALPHA, DELTA, A4, and C4. Temperature can be converted from IPTS-68 to ITS-90 automatically at your request. Calendar-Van Dusen equations are also provided in an automated mode.

Thermistor probes are characterized by coefficients of a logarithmic polynomial. Save money and use low-cost, rugged thermistor standards for ±0.001°C accuracy in the low-temperature regions. Other thermometers don't do all this.

Measurements can be displayed as temperatures in °C, K, or °F and as resistance in ohms or a ratio of probe resistance to reference resistance. The current source is controllable between 0.001 mA and 15 mA with a resolution of 0.2%. Integration time and digital filtering are programmable to optimize resolution, stability, and response.

Datalogging and memory functions store measurements, and each thermometer has its own 3.5-inch disc drive for archiving data. The display is a backlit LCD for visual display of information. It has an RS-232, an IEEE-488, and a parallel printer port.

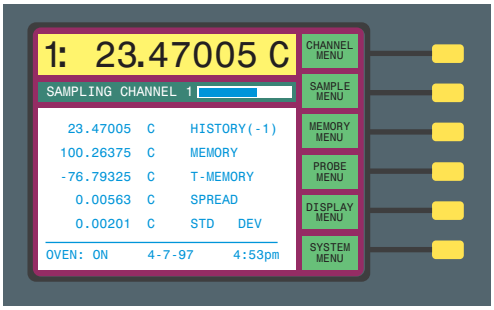
These Super-Thermometers are based on DC electronics, thus eliminating the problems with national lab certification for AC bridges and the removal of quadrature interference from AC-heated fixed-point furnaces.

Multiplexers

If two channels aren't enough, add 10 more with a Mighty-Mux featuring Hart's handy DWF connectors. In fact, add up to 50 more channels to the 1590.

The Model 2575 provides 10 more channels for use with a 1575. For the 1590, the Model 2590 Mighty-Mux II has a cascading ability that lets you have up to 50 channels by chaining more than one Mux together, and you can now set continuous constant current levels on each channel to avoid self-heating effects. Whatever your application, a Mighty-Mux will make it easier and more efficient.

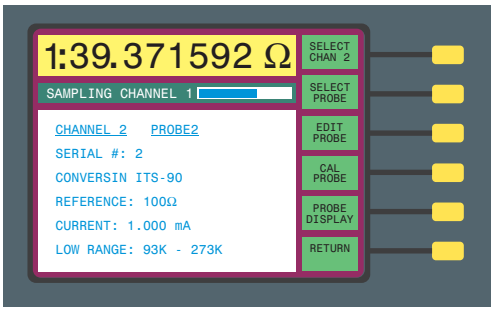
Both units have low thermal EMF relays that are hermetically sealed and magnetically shielded. You're making true four-wire mea-



Customize Your Display

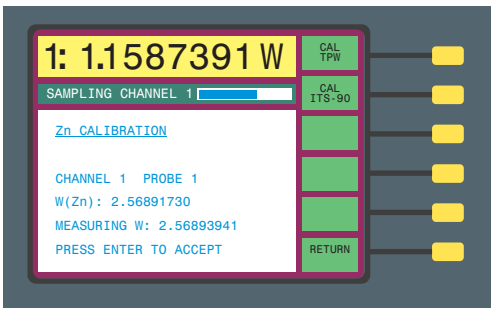
The graphic screen is easily modified to include information that fits your application or preferences. Under the display menu you select up to five lines of on-screen information from 19 different options including:

T-MEMORY	Current value minus the value in memory
T(1) - T(2)	Channel one minus channel two
MAXIMUM	Peak reading since last reset
MINIMUM	Lowest value since last reset
SPREAD	Maximum difference between readings
AVERAGE	Computes average of previous samples
STD DEV	Computes standard deviation of previous samples



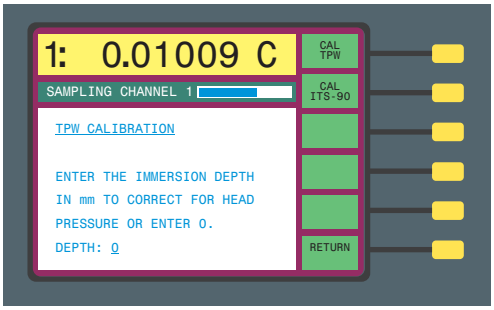
Probe Setup

Each probe's information is identified by its unique serial number for assignment to a specific channel. You select the desired resistance-to-temperature conversion formula, set the probe constants, and select the reference resistor and the drive current. A total of 16 probe setups are stored in internal memory. An unlimited number can be stored to disk and selected when needed. After a probe's information is entered the first time, the Super-Thermometer is immediately set to match that probe by simply selecting the probe's serial number.



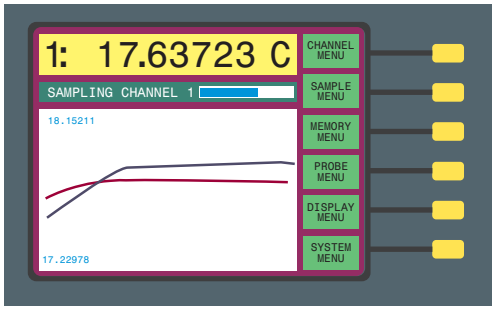
Automatic Calculation of Constants

The Super-Thermometers automatically calculate the required constants for the ITS-90 temperature conversion. Connect your uncalibrated standards probe to the 1590, measure the resistance at the fixed-points or against a calibrated standard, and the 1590 stores the resistance readings and automatically derives the correct constants. You don't need a calculator and a pad of paper. The Super-Thermometers enter the constants directly to the probe setup, saving you time and preventing error in the manual entry of constants.



The Triple Point of Water

Take a reading in the TPW cell just prior to each new measurement. The Super-Thermometers store the current R_{TPW} value and reference it during the conversion from resistance to temperature. This eliminates two sources of measurement error. The drift of R_{TPW} in the SPRT is removed, and the error of the on-board reference resistors is canceled. For convenience and maximum precision, you can even enter the immersion depth of your SPRT in the cell to correct for hydrostatic head.



Graphing Feature

The Super-Thermometers feature real-time, on-scale graphing for monitoring fluid bath stabilization or realizing metal fixed-point plateaus. Simply monitor the graph for stability on one or multiple channels and take your readings in resistance, temperature, or the ratio to the triple point of water. The 3.5-inch disc drive stores readings in an ASCII format for spreadsheet or graphing use. Graphing resolution limits can be manually entered, or maximum resolution is automatically set as the readings stabilize over time. Temperature measurement labs save time by not monitoring or taking data every few seconds.

Specifications	1575A			1590		
	Nominal Resistance	Accuracy (of indicated value)	Equivalent Temp. Value, at 0°C	Nominal Resistance	Accuracy (of indicated value)	Equivalent Temp. Value, at 0°C
Transfer Accuracy (using external reference resistor)	0.25Ω 2.5Ω 25Ω 100Ω 10 KΩ	40 ppm 20 ppm 4 ppm 4 ppm 10 ppm	0.01°C 0.005°C 0.001°C 0.001°C 0.00025°C (thermistor at 25°C)	0.25Ω 2.5Ω 25Ω 100Ω 10 KΩ	20 ppm 5 ppm 1 ppm 1 ppm 5 ppm	0.005°C 0.00125°C 0.00025°C 0.00025°C 0.000125°C (thermistor at 25°C)
Absolute Accuracy (using internal reference resistor)	0.25Ω 2.5Ω 25Ω 100Ω 10 KΩ	100 ppm 40 ppm 8 ppm 8 ppm 20 ppm	0.025°C 0.01°C 0.002°C 0.002°C 0.0005°C (thermistor at 25°C)	0.25Ω 2.5Ω 25Ω 100Ω 10 KΩ	40 ppm 20 ppm 6 ppm 6 ppm 10 ppm	0.01°C 0.005°C 0.0015°C 0.0015°C 0.00025°C (thermistor at 25°C)
Typical Resolution	0.25Ω 2.5Ω 25Ω 100Ω 10 KΩ	10 ppm 5 ppm 1 ppm 1 ppm 3 ppm	0.0025°C 0.00125°C 0.00025°C 0.00025°C 0.000075°C (thermistor at 25°C)	0.25Ω 2.5Ω 25Ω 100Ω 10 KΩ	10 ppm 2 ppm 0.5 ppm 0.5 ppm 2 ppm	0.0025°C 0.0005°C 0.000125°C 0.000125°C 0.00005°C (thermistor at 25°C)
Resistance Range	0Ω to 500 KΩ					
Internal Reference Resistors	1Ω, 10Ω, 100Ω, 10 KΩ					
Minimum Measurement Period	2 seconds					
Current Source	0.001 mA to 15 mA, programmable					
Analog Output	–5 to +5 V					
Display	Monochrome LCD with CCFT backlight			Color LCD with CCFT backlight		
Power	100–125/200–250 V AC (user switchable), 50/60 Hz, 1 A					

surements with a floating guard and support for up to 20 mA of drive current.

Super-Thermometers vs. Digital Multimeters

Good eight-and-a-half-digit multimeters might give you accuracy to ±0.005°C in the resistance measurement. However, DMMs require separate high-stability current sources, and you have to make EMF offsets, worry about a scheme to switch between forward and reverse current during the measurement, and devise a switch to get a second channel for an external standard resistor.

Once you've done all of this, you still have to convert resistance to temperature with tedious manual calculations.

Super-Thermometers do all of this automatically.

Super-Thermometers vs. Everything Else

There really isn't anything else to compare to the 1590 and 1575A. No other readout is this easy to use. You'll be doing calibrations with it the first day you receive it, not the first day after the training program is over.

Specifications - Muxes	
Channels	**2575:** 10 **2590:** 10 per unit, cascade up to 5 units for 50 channels
Connector	4-wire plug, floating guard
Terminals	Gold-plated Hart DWF Connectors
Relays	Low thermal EMF, hermetically sealed, magnetically shielded
Contact Resistance	< 0.1Ω
Isolation	1 x 10^{12} between relay legs
Channel Selection	Manual or auto
Current Capability	20 mA
Current Levels	**1575A:** Current on active channel only **1590:** Standby current 1 mA, 0.5 mA, or 10 μA on all channels
Power	Via connection to 1575A or 1590
Size	20.3" W x 12.6" D x 7" H (516 x 320 x 178 mm)

Ordering Information

1575A	Super-Thermometer
2575	Multiplexer, 1575
1590	Super-Thermometer II
2590	Multiplexer, 1590
742A-25	Standard DC Resistor, 25Ω
742A-100	Standard DC Resistor, 100Ω

Debbie (information systems) sometimes works at home so she can "actually get something done." We caught this picture of her in action on one of those days.

Need a reliable standard resistor? See our selection on pages 28 and 29.

SUPER-THERMOMETER: THEORY OF OPERATION

Hart's "Super-Thermometer" readouts (Models 1575A and 1590) require a unique electronic design to achieve the necessary accuracy while meeting size, weight, cost, and speed constraints. This article explains the measurement technique used by these instruments and discusses issues related to performance.

Measurement Technique

Fundamentally, Super-Thermometers measure the resistance ratio between two resistors by comparing their voltages when equal currents are applied. The simplified schematic in Figure 1 shows the basic components of the measurement circuitry. The reference resistor and sensor are connected in series, and the current flows through both simultaneously. The current produces a voltage on each that is proportional to their respective resistances. The voltages are measured with the amplifier and ADC. Since only one of the voltages can be measured at a time, the relay must be used to switch between them.

The voltage on each resistor is measured twice: once with the current in one direction, and again with the current in the opposite direction. Subtracting the two voltage measurements eliminates offset voltages (including those arising from thermoelectric EMF) since these offsets are constant. In summary, one ratio measurement requires four voltage samples:

1. Sensor, forward current (V_{X1})
2. Sensor, reverse current (V_{X2})
3. Reference, forward current (V_{R1})
4. Reference, reverse current (V_{R2})

The voltage samples are subtracted and divided to produce a ratio of sensor resistance to reference resistance:

$$r = \frac{V_{X1} - V_{X2}}{V_{R1} - V_{R2}} = \frac{R_X}{R_R}$$

Using this approach, errors from driving current imprecision, voltage offsets, and amplifier and ADC inaccuracies are avoided because these all affect the voltage samples equally.

Each voltage sample requires 0.5 seconds. (It takes 0.15 seconds to set the current and relay and allow time for the voltages to settle and 0.35 seconds for the ADC to make a measurement and send it to the CPU.) Since four samples are required, the entire ratio measurement takes two seconds.

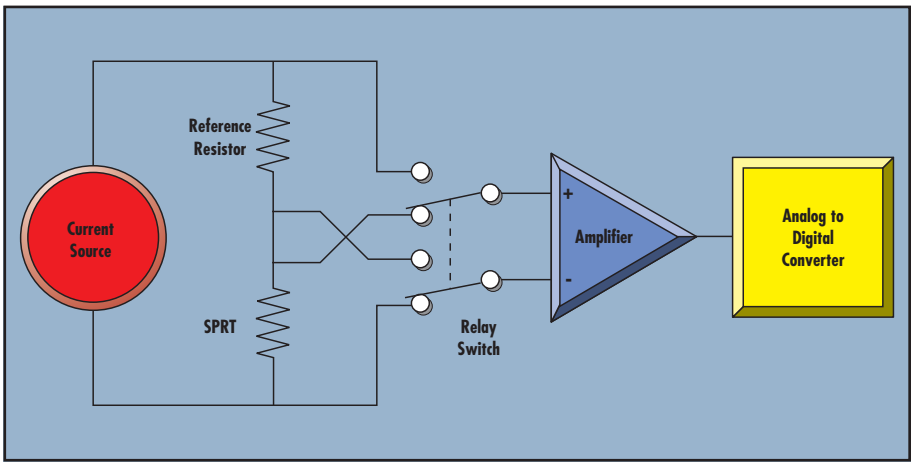


Figure 1. Simplified schematic diagram of the measurement circuit.

Depending on how the measurement timing is set up, more than one raw ratio sample may be integrated into one measurement. Digital filtering is applied to reduce noise in the measurements. The CPU then calculates the resistance of the sensor by multiplying the measured resistance ratio by the known resistance of the reference resistor. Temperature is calculated from resistance using one of the built-in conversion algorithms. Finally, statistical values are recalculated to incorporate the latest measurement. Figure 2 at right shows this sequence of operations.

Performance Issues

Measurement of temperature with uncertainty approaching 1 mK or better presents some significant challenges. Various sources of error inherent in resistance thermometry make it difficult to achieve this level of accuracy. For instance, lead resistance in some cases can cause errors of several tenths of a degree. Problems also arise from sources such as thermoelectric EMF, reactance, and leakage. The accuracy achieved by the Super-Thermometers is only possible because these effects have been carefully studied and dealt with. Consider the following issues:

Lead Resistance

Measurements using an electrical sensor can be affected by the resistance in the connecting wires, or leads. Resistance also exists in the connectors and the junctions between the wires and connectors. In commonly used two- or three-wire measurement circuits, these resistances and their variability cause errors from 0.1°C to 1.0°C.

Super-Thermometers use a four-wire circuit that completely eliminates the effects of lead resistance. In this scheme, often referred to as a Kelvin circuit, the sensor is driven with current from one set of wires and the resulting EMF is sensed with a different set of wires. The signal is passed to an amplifier with a very high input impedance that draws negligible current from the sensor. As a result, no measurable voltage develops along the EMF sensing wires. Super-Thermometers accurately measure the resistance of sensors even in the presence of lead resistance that can be as high as 10Ω.

Thermoelectric EMF

A resistance sensor such as a PRT contains several junctions between wires of different metals. These act like thermocouples generating small voltages called thermoelectric EMFs. Unless rejected in some way, these thermoelectric EMFs can interfere with the sensor EMF and degrade the accuracy of the measurement. There are three different techniques

that can be used to cancel thermoelectric EMF.

Some resistance bridges apply AC driving current and use sensing circuits that detect only the AC signal, rejecting the DC EMFs. This technique is very effective at eliminating thermoelectric EMF errors but can lead to other errors. Reactance, leakage, and eddy currents become much more significant with AC current. A different technique, sometimes used in DMMs, periodically switches off current to the sensor and measures the thermoelectric EMF directly. The problem with this is it leads to self-heating errors as the sensor warms and cools from the varying current.

Super-Thermometers use a third technique. Two separate measurements are made and the driving current is simply reversed for the second measurement. Thermoelectric EMF causes errors that are opposite in the two measurements. In essence, averaging the two measurements cancels the errors. This technique is very effective at eliminating errors from thermoelectric EMF while avoiding the AC-related errors and self-heating problems of the other methods. In fact, it's so effective that no observable error caused by thermoelectric EMF is found in the Super-Thermometers.

Reactance

The use of AC driving current often causes errors in resistance thermometry because sensors and their lead wires have inductance and capacitance that cannot be entirely eliminated. To get accurate temperature measurements, AC instruments must be used with sensors and wiring that have limited inductance and capacitance. They must also use quadrature balancing techniques to cancel the reactance as much as possible.

Super-Thermometers use DC circuitry that makes all of this unnecessary. Virtually any type of sensor may be used with a Super-Thermometer, even if the sensor has very large amounts of capacitance and inductance. Super-Thermometers allow plenty of time for currents and voltages to settle before beginning a sample. If necessary, the delay time can be increased even more.

Leakage

Resistance sensors can be susceptible to electrical leakage through the insulation material surrounding the lead wires and sensing element. Leakage is often significant at low temperatures where the insulation absorbs moisture from the air or at high temperatures where the electrical conductivity of the insulating material is relatively high. Leakage and some other effects, such as dielectric absorption and eddy currents, are much more significant with AC than with DC. By operating with DC driving current, Super-Thermometers achieve excellent accuracy over a wide range of conditions.

Self-Heating

"Self-heating" results from power being dissipated in the sensor by the driving current. It causes the temperature of the sensor to be higher than it should be. Super-Thermometers achieve full accuracy with small currents that minimize self-heating (1 mA for PRTs and 10 µA for thermistors). The current can be set within a wide range and with excellent resolution. Being able to set the current to precise values allows self-heating errors to be controlled, measured, and eliminated.

Component Drift

The accuracy of a typical resistance measuring instrument is seriously limited by the stability, or lack thereof, of its electrical components. The design of the Super-Thermometers eliminates sensitivity to variations in the components due to aging or temperature by, in effect, recalibrating itself during every measurement. Drift of the driving current, amplifier bias current, amplifier offset voltage, amplifier gain, ADC offset, and ADC scale have no effect on the measurement.

The accuracy to which Super-Thermometers measure resistance is affected by the drift of only one component: the reference resistor. The four built-in resistors are high-quality, hermetically sealed, low temperature coefficient, metal film resistors that are temperature controlled for excellent stability. Even better stability can be achieved if external standard resistors are used and they are immersed in a precisely controlled oil bath.

Noise and Resolution

Electrical noise is present in any measurement circuit—it's unavoidable. Excessive noise appears in measurements as random variations over time. This makes it impossible to detect small real changes in the parameter being measured. In other words, it limits the effective resolution of the measuring instrument.

Electrical noise in the Super-Thermometers comes from a variety of sources. A small amount of noise is generated by the resistors and semiconductor devices in the measurement circuitry. Some noise (quantization noise) results from the limited resolution of the ADC. Electrical interference or EMI from internal or external sources can also introduce noise. Although it is impossible to completely eliminate all

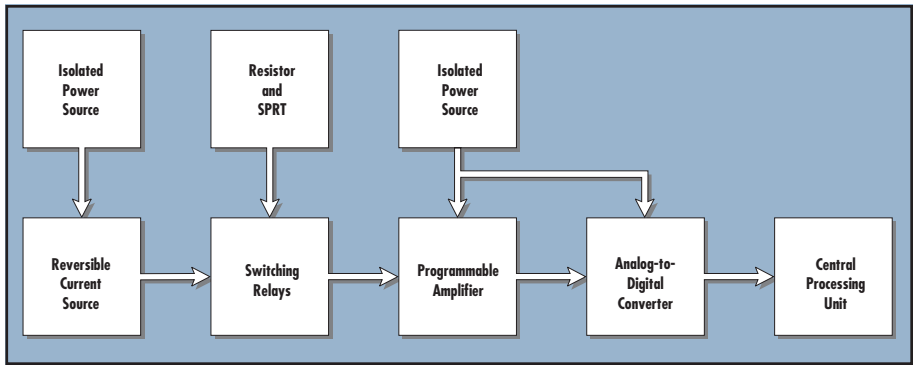


Figure 2. Measurement processing operations.

noise, some steps can be and are taken to reduce it.

Components were selected for the Super-Thermometers that produce minimal noise. The ADC was chosen, in part, for its excellent resolution (24 bits). Shielding is used to block EMI from reaching the sensitive circuits. To further reduce noise, the Super-Thermometers use filtering and EMI suppression devices throughout the circuit. (Since DC driving current is used, interference coming from the 50/60 Hz mains supply is effectively rejected. AC instruments are more susceptible to this interference.) Finally, the CPU applies digital filtering to remove much of the remaining noise. The end result is the capability of making measurements with effective resolution of 0.25 ppm.

One possible drawback of digital filtering is that it makes the instrument react more slowly to changes in the resistance or temperature being measured. Super-Thermometers allow the user to adjust the digital filter to achieve the right balance between resolution and response.

Nonlinearity

With all other sources of error under control, all that's left is nonlinearity. Consider nonlinearity to be curvature in the graph of the relationship between the actual resistance ratio and the resistance ratio measured by the Super-Thermometers. It is a result of imperfections in the analog-to-digital converter and also, to a smaller degree, the power supply and amplifier.

To minimize nonlinearity in the Super-Thermometers, three steps have been taken. First, the best available components have been selected. For instance, the ADC is a dual-slope integrating type that has linearity at least 10 times better than other precision integrating or sigma-delta ADCs.

Second, the employed measurement technique inherently rejects much of the nonlinearity. Because samples of opposite polarity are subtracted, zeroth-order errors (offsets), second-order errors, and all higher even-order components of nonlinearity are canceled. What's left are third-order and higher odd-order components that diminish greatly in magnitude the higher the order.

The third step is to mathematically correct for the third-order nonlinearity. This is the purpose of the "ADC" calibration parameter. This parameter is adjusted during calibration to achieve the best possible linearity.

Measurement Speed

The measurement technique used by the Super-Thermometers gives these instruments valuable attributes that others in its class don't have. One of these is speed. Super-Thermometers are capable of completing a new measurement in about two seconds. Even if multiple sensors are being measured in turn, the measurement time per sensor is still only two seconds. Compare this to a typical resistance bridge that takes 30 to 60 seconds to make the first measurement after a sensor is connected.

The speed of the Super-Thermometers gives it the advantage of allowing greater efficiency as well as better accuracy during a batch calibration process involving a large number of sensors. Integrating a Super-Thermometer with its multiplexer (Model 2575 or 2590) enhances its capability even more, giving it 10 input channels (or up to 50 for the 1590). The measurement speed of the Super-Thermometers makes other applications possible such as tracking fast-changing temperatures, measuring temperature differences, or evaluating thermal response times.

Solid-State Design

Other advantages result from the solid-state approach used by the Super-Thermometers. Unlike a bridge that requires a large, heavy precision ratio transformer and dozens of relays, this instrument uses semiconductor circuits. This gives it better reliability, smaller size, lighter weight, and lower cost. By keeping the size and cost of the measuring circuit small, more resources can be dedicated to other important features such as intelligent user interface and system control electronics, a graphic display, and a built-in disk drive, all contributing to making Super-Thermometers the versatile, useful tools so many metrologists have come to rely on.

When putting, some people consider the slope of the green and the cut of the grass. Hart employees check the ambient temperature. (Jill, sales; Jon, sales; Chris, welding; Brad, bath production)

EVALUATING CALIBRATION SYSTEM ACCURACY

Is your calibration system accurate enough?

Obviously, a measurement device such as a PRT can be no more accurate than the system used to calibrate it. You wouldn't use a dry-well and a hand-held multimeter to calibrate an SPRT, right? After listing the factors that contribute error to a PRT (which might include drift, hysteresis, repeatability, resistance shunting, and others in addition to the calibration uncertainty), it is clear that the accuracy of the calibration system must be much better than the desired accuracy of the PRT. But exactly how accurate does it need to be?

Test Uncertainty Ratio

Ideally, metrologists evaluate all the sources of uncertainty, including uncertainty in calibration, and make sure the combined uncertainty is within the limits required for the application. However, this approach might require too much effort, and in many cases some of the sources of error, or values for their uncertainties, cannot be known.

For an alternative, we might assume that the calibration uncertainty should be less than some particular fraction of the specification—below an established *test uncertainty ratio* (TUR). This approach is quite simple and is widely used. A commonly used TUR, as given by the ANSI/NCSL Z540 standard, is 4 to 1, meaning the uncertainty of the system used to calibrate a measurement device should be no greater than 25% of the desired accuracy of the device. So, if we want a PRT to be accurate to ±0.1°C, its calibration should have an uncertainty of ±0.025°C or better.

Uncertainty Components

Once we've established a required uncertainty for our calibration system, how do we determine if our system meets this requirement? What we first need to do is list all the sources of uncertainty, and then assign reasonable values to them. Some of the uncertainties that might apply in a PRT calibration system would be those associated with the reference thermometer calibration, reference thermometer stability, thermometer readouts, bath uniformity, immersion effects, electrical and thermal noise (including bath stability), and day-to-day process variations.

Some of these can be evaluated statistically, by making repeated measurements and calculating the standard deviation of the measurements. This is often designated as a *type A* evaluation. Others might just be assumed from the best information available, such as manufacturer's specifications. This is a *type B* evaluation.

Readout Uncertainty

Readout uncertainty is often simply obtained from the manufacturer's specifications. But what do we do if the readout's specs are in resistance and we need an uncertainty in terms of temperature? We have to do a little conversion by dividing the resistance spec by the slope of the PRT's resistance-temperature curve.

Suppose we are using a readout that has a spec of 6 ppm (of reading) and we are measuring a temperature near 420°C with a 100Ω PRT. The resistance at this temperature would be about 257Ω, and from the T vs. R table for the PRT we see that the resistance changes about 0.35Ω/°C near 420°C. So, the spec of the readout converted to temperature for this measurement is

$$u(readout) = \frac{(6 \cdot 10^{-6})(257\Omega)}{0.35\,\Omega/°C} = 0.0044°C$$

The same type of calculation can be used for thermocouples, using a readout's voltage accuracy spec and the thermocouple's T vs. mV slope at the measured temperature. However, with a thermocouple we also need to consider the uncertainty of the reference junction temperature, along with the T vs. mV slopes at the measured temperature and the reference junction temperature.

Now, with no information that indicates otherwise, we should assume that the error from the readout is equally likely to be anywhere within the specification—that is, it follows a uniform distribution. To be able to compare and combine uncertainty components, they must all be stated as standard deviations. To convert the spec of the readout (now in terms of temperature) to an equivalent standard deviation, we divide by $\sqrt{3}$, which makes 0.0025°C for the PRT readout example above.

Combining Uncertainties

With a list of uncertainties, we can now combine them to get the uncertainty of our calibration system. The easiest way to combine them would be to simply add them up. However, this would give us a number that is probably much larger than the actual uncertainty. If our uncertainty components are independent, the correct way to combine them is using the root-sum-squares formula:

$$u(system) = \sqrt{u_a^2 + u_b^2 + u_c^2 + \ldots}$$

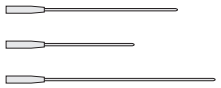
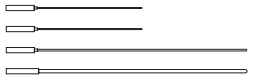
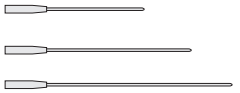
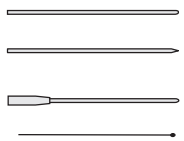
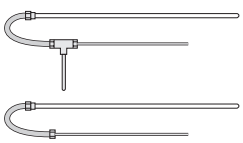
This will give us the best estimate of the standard deviation of the total error in our calibration system. But then we'll want to apply a *coverage factor*. We don't want the error in our system to be within our limits just *some* of the time, but we'd rather it be within the limits *most* of the time. So we would multiply the standard uncertainty by a coverage factor k, such as k=2, to give an *expanded uncertainty*. The components of uncertainty and the resulting expanded uncertainty for a typical PRT calibration system are shown in the table below.

Uncertainties for a PRT Calibration System, at 420°C

Reference SPRT calibration	0.0030°C
Reference SPRT stability	0.0005°C
Thermometer readout, SPRT	0.0025°C
Thermometer readout, PRT	0.0025°C
Bath uniformity	0.0025°C
Immersion effects	0.0015°C
Thermal (bath stability) and electrical noise	0.0006°C
Process variability	0.0030°C
Combined and expanded uncertainty, k=2	0.0126°C

For further information on evaluating uncertainty, recommended sources are ISO *Guide to the Expression of Uncertainty in Measurement* or ANSI/NCSLI *U.S. Guide to the Expression of Uncertainty in Measurement* and ISO/IEC 17025. You might also consider attending one of our seminars, where we spend time discussing uncertainty in measurements and allow you to have all your questions answered.

THERMOMETER PROBE SUMMARY

Reference Probes	Model	Range	Size	Basic Accuracy†	Page
PRTs					
	Secondary Standards PRTs				
	5626	–200°C to 661°C	12" or 15" x 0.25"	±0.007°C at 0°C	61
	5628	–200°C to 661°C	12" or 15" x 0.25"	±0.006°C at 0°C	
	Secondary Reference PRTs				
	5612	–200°C to 420°C	9" x 0.187"	±0.018°C at 0°C	62
	5613	–200°C to 300°C	6" x 0.187"	±0.018°C at 0°C	
	5614	–200°C to 420°C	12" x 0.25"	±0.018°C at 0°C	
	Precision Industrial PRTs				
	5627-6	–200°C to 300°C	6" x 0.187"	±0.05°C at 0°C	64
	5627-9	–200°C to 420°C	9" x 0.187"	±0.05°C at 0°C	
	5627-12	–200°C to 420°C	12" x 0.25"	±0.05°C at 0°C	
	Fast Response PRTs				
	5622-05	–200°C to 350°C	100 x 0.5 mm	±0.04°C at 0°C	65
	5622-10	–200°C to 350°C	100 x 1.0 mm	±0.04°C at 0°C	
	5622-16	–200°C to 350°C	200 x 1.6 mm	±0.04°C at 0°C	
	5622-32	–200°C to 350°C	200 x 3.2 mm	±0.04°C at 0°C	
	Small Diameter Industrial PRTs				
	5618A-6	–200°C to 300°C	6" x 0.125"	±0.05°C	66
	5618A-9	–200°C to 500°C	9" x 0.125"	±0.05°C	
	5618A-12	–200°C to 500°C	12" x 0.125"	±0.05°C	
Thermistors					
	Thermistor Standards				
	5640	0°C to 60°C	9" x 0.25"	±0.0015°C	68
	5641	0°C to 60°C	4.5" x 0.125"	±0.001°C	
	5642	0°C to 60°C	9" x 0.125"	±0.001°C	
	5643	0°C to 100°C	4.5" x 0.125"	±0.0025°C	
	5644	0°C to 100°C	9" x 0.125"	±0.0025°C	
	Secondary Thermistor Probes				
	5665	0°C to 100°C	3" x 0.110"	±0.015°C	70
	5610	0°C to 100°C	6" or 9" x 0.125"	±0.015°C	
	5611	0°C to 100°C	.110" or .070" dia.	±0.015°C	
	5674	0°C to 70°C	9" x 0.188"	±0.07°C	
Thermocouples					
	Type S Thermocouple Standards				
	5650-20	0°C to 1450°C	20" x 0.25"	±0.7°C at 1100°C	72
	5650-20C	0°C to 1450°C	20" x 0.25"	±0.7°C at 1100°C	
	5650-25	0°C to 1450°C	25" x 0.25"	±0.7°C at 1100°C	
	5650-25C	0°C to 1450°C	25" x 0.25"	±0.7°C at 1100°C	
Other					
	Glass Thermometers	–38°C to 405°C –36°F to 761°F	15" length	0.1°C Divisions 0.2°F Divisions	73

†"Basic Accuracy" includes calibration uncertainty and short-term repeatability. It does not include long-term drift.

Probes

Secondary Standard PRTs — Models 5626 and 5628

- Range to 661°C
- Meets all ITS-90 requirements for resistance ratios
- R_{TPW} drift < 20mK after 500 hours at 661°C

Hart's high-temp secondary standards fill the gap between affordable, but temperature-limited secondary PRTs and more expensive, highly accurate SPRTs.

If you're using block calibrators, furnaces, or temperature points above normal PRT temperatures (420°C), then these two PRTs are for you. The 5626 is nominally 100Ω and the 5628 is nominally 25.5Ω. Both instruments have a temperature range of –200°C to 661°C. They make great working or check standards for calibration work up to the aluminum point.

Using a regular PRT at temperatures above 500°C exposes the platinum to contamination. If the PRT is used as a reference or calibration standard, contamination is a major problem. SPRTs, which are more expensive and delicate, can handle the higher temperatures, but with greater risk to the instrument due to shock, contamination, or mishandling. The 5626 and 5628 are designed to reduce the contamination risk through the use of internal protection while not impairing performance.

In addition to the right measurement performance and durability, a PRT for secondary applications should be priced affordably. Hart's new PRTs are inexpensive and come with an accredited calibration. The calibration comes complete with ITS-90 constants and a resistance-versus-temperature table.

Check the temperature range, check the stability, check the price! Who else gives you this much quality, performance, and value for your money? No one!

Specifications

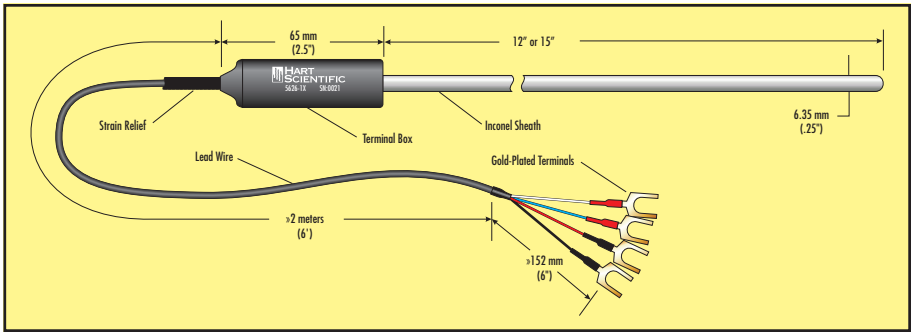
Temperature Range	–200°C to 661°C
Handle Temp.	0°C to 80°C
R_{TPW}	**5626:** 100Ω (±1Ω) **5628:** 25.5Ω (±0.5Ω)
W(Ga)	≥ 1.11807
Calibration Uncertainty (k=2)	±0.006°C at –200°C ±0.004°C at 0°C ±0.009°C at 420°C ±0.014°C at 661°C
Stability	**5626:** ±0.003°C **5628:** ±0.002°C
Long-Term Drift	**5626:** < 0.03°C/500 hours at 661°C **5628:** < 0.02°C/500 hours at 661°C
Immersion	At least 5" recommended
Sheath	Inconel™ 600
Lead Wires	4-wire Super-Flex PVC, 22 AGW
Termination	Gold-plated spade lugs, or specify
Size	0.25" dia. x 12" or 15" standard, custom lengths available

Ordering Information

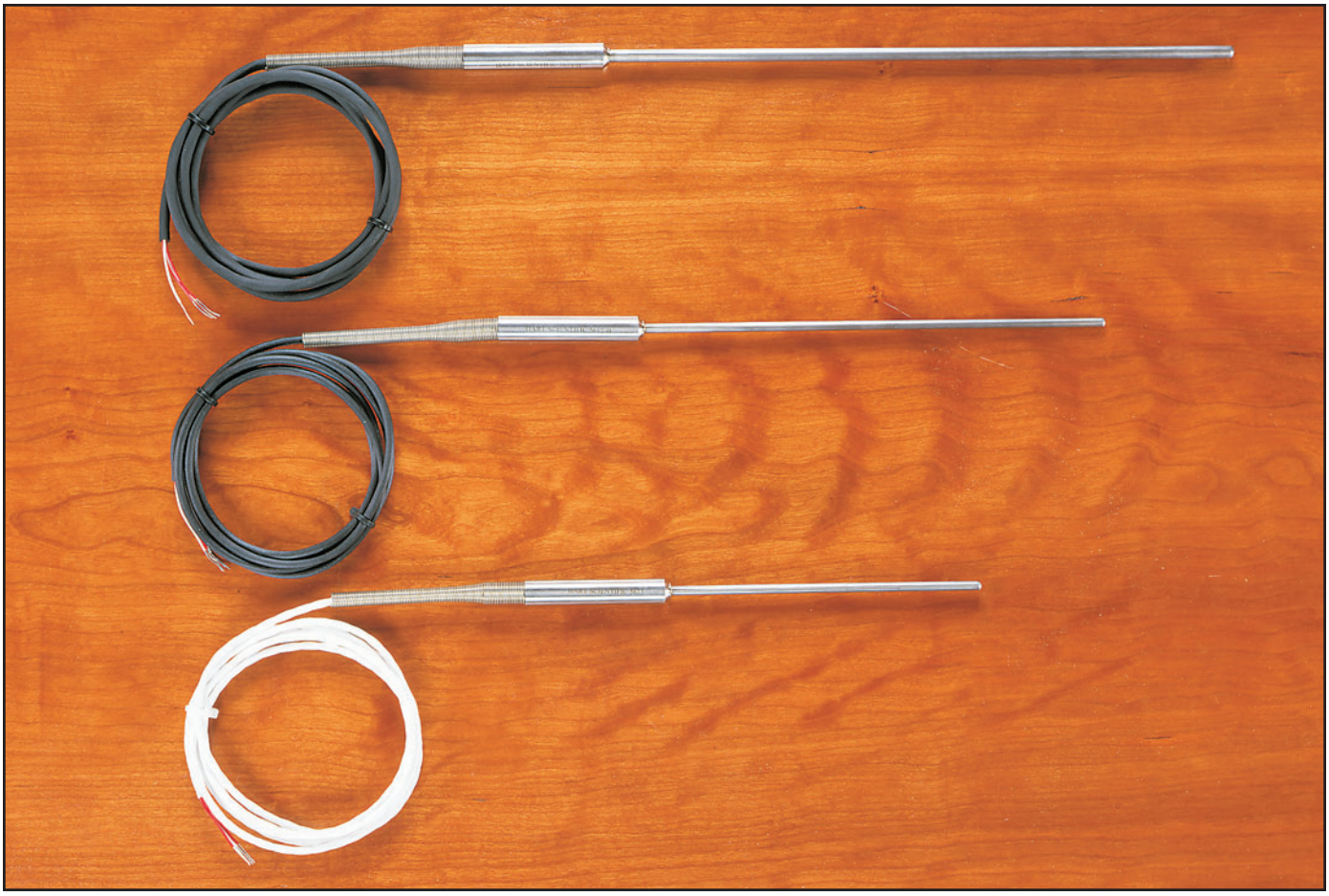
5626-12-X	High-temp PRT, 100Ω, 12"
5626-15-X	High-temp PRT, 100Ω, 15"
5628-12-X	High-temp PRT, 25.5Ω, 12"
5628-15-X	High-temp PRT, 25.5Ω, 15"
2601	Spare Case, 12" PRT
2602	Spare Case, 15" PRT

Case included with purchase of Model 5626 or 5628 PRT.
X = termination. Specify "B" (bare wire), "D" (5-pin DIN for Tweener Thermometers), "G" (gold pins), "I" (INFO-CON for 1521 or 1522 Handheld Thermometers), "J" (banana plugs), "L" (mini spade lugs), "M" (mini banana plugs), or "S" (spade lugs).

See page 18 for triple point of water cells.



SECONDARY REFERENCE TEMPERATURE STANDARDS



Secondary Reference Temperature Standards **Models 5612, 5613, and 5614**

- Affordable wide-range accuracy
- Excellent stability
- Reference-grade platinum sensing element

Need a durable but accurate sensor for use in the factory, field, or lab? The Model 5614 Secondary Temperature Standard is the answer.

The 5614 is a Platinum Resistance Thermometer (PRT) that's 12 inches long with an Inconel 600 sheath and a 1/4" outside diameter. It is designed to be used as a transfer device from the highest laboratory standards to industrial or second-tier lab locations. It has short-term accuracy of ±0.02°C at 200°C.

The element is constructed of reference-grade platinum wire (99.999% pure) for excellent stability. The wire is wound in a coil and placed in a mandrel where it's uniformly supported in a manner to virtually eliminate hysteresis. The electrical configuration is a four-wire current-potential hookup to eliminate effects of lead-wire resistance.

These Inconel-sheathed probes have a partially supported sensing element, making them more durable than SPRTs. The element is protected in an ultrahigh-purity ceramic case with a hermetic glass seal to improve output stability by locking out moisture and contaminants.

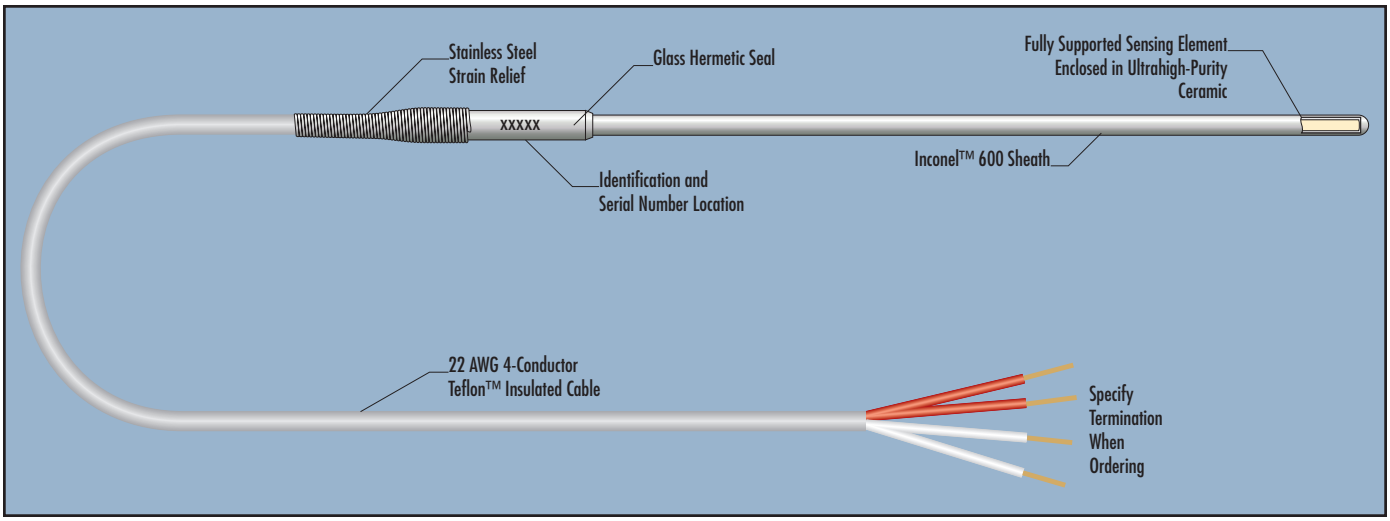
This probe comes calibrated in accordance with ITS-90, which makes it compatible with many excellent readout devices, including Hart's 1529 Chub-E4, 1560 *Black Stack,* and 1502A Tweener. It bridges the gap between a 100-ohm industrial RTD and an SPRT.

For those needing faster thermal response, or where diameter and immersion depth are problems, order the 6-inch 5613 or the 9-inch 5612. These probes are excellent reference probes for comparison calibrations in a Hart dry-well.

A printout of sensor resistance is provided in 1°C increments for each probe. The 5614 and 5612 are calibrated from –196°C to 420°C. The 5613 is calibrated to 300°C.

We've tested many of the probes on the market. We've used them in our manufacturing facility and tested them in the lab, and this is an excellent secondary standards PRT. Other instruments on the market are priced much higher, have lower stability, or have lower quality.

Remember, these instruments are inexpensive and have excellent durability. Each



Terminations are available as spade lugs, mini spade lugs, DIN connectors, banana plugs, INFO-CON, bare wire, or gold pins.

probe is individually calibrated and includes a report of calibration from the manufacturer. Contact Hart for optional calibration in Hart's NVLAP accredited lab.

Ordering Information

5612-9-X	Secondary Standard PRT, 3/16" x 9", –200 to 420°C
5613-6-X	Secondary Standard PRT, 3/16" x 6", –200 to 300°C
5614-12-X	Secondary Standard PRT, 1/4" x 12", –200 to 420°C
2601	Probe Carrying Case

X = termination. Specify "B" (bare wire), "D" (5-pin DIN for Tweener Thermometers), "G" (gold pins), "I" (INFO-CON for 1521 or 1522 Handheld Thermometers), "J" (banana plugs), "L" (mini spade lugs), "M" (mini banana plugs), or "S" (spade lugs).

Specifications

Resistance	Nominal 100Ω (±0.1Ω)
Temperature Coefficient	0.003925 ohms/ohm/°C nominal
Temperature Range	–200°C to 420°C (5613 to 300°C; transition and cable temperature 150°C maximum)
Transition Temperature	5°C to 200°C
Drift Rate	±0.01°C at 0°C per year maximum, when used periodically to 400°C
Sheath Material	Inconel™ 600
Leads	Teflon™-insulated, silver-plated stranded copper, 22 AWG
Termination	Specify. See Ordering Information.
Hysteresis	< 0.01°C at 0°C using –196°C and 420°C as the end points
Immersion Effects	Reading will not vary more than 0.005°C when the probe immersion is varied between 4 inches and 10 inches in an ice bath (5614).
Calibration	Includes manufacturer's NIST-traceable calibration and table with R vs. T values in 1°C increments from –183°C to 500°C. The 5614 and 5612 are calibrated to 420°C and the 5613 to 300°C. ITS-90 coefficients included. *Optional accredited calibration available from Hart.*
Probe Accuracy (includes calibration uncertainty and short-term stability)	±0.018°C at –196°C ±0.018°C at 0°C ±0.019°C at 200°C ±0.023°C at 420°C
Time Constant	Nine seconds typical for 63.2% response to step change in temperature in water flowing at 3 feet per second
Size: 5612	0.187" dia. x 9"
5613	0.187" dia. x 6"
5614	0 . 25" dia. x 12"

Read about our accredited calibration services on page 156.

Precision Industrial PRTs — Model 5627

- Vibration and shock resistant
- 3/4-inch bend radius for increased durability
- NIST-traceable calibration included

When buying a PRT, performance isn't the only criterion you need to look at. The real issues are price-to-accuracy and price-to-durability ratios.

The Model 5627 probes have a temperature range up to 420°C and an accuracy as good as ±0.05°C. They come in three different lengths. (The six-inch model covers –200°C to 300°C.) Each instrument is shipped with its ITS-90 coefficients and a calibration table in 1°C increments.

One of the best features of this sensor is that it conforms to the standard 385 curve, letting you use your DIN/IEC RTD meters fully. Why use a probe that's less accurate than your meter?

The 5627 is manufactured using a coil suspension element design for increased shock and vibration resistance. It has a mineral-insulated sheath with a minimum bend radius of 3/4-inch for flexibility and durability. (Bend, if any, should be specified at time of order.)

Six-inch 5627s are calibrated at –196°C, –38°C, 0°C, 200°C, and 300°C. For 9-inch and 12-inch versions, an additional point is added at 420°C.

Each probe is individually calibrated and includes a report of calibration from the manufacturer. Contact Hart for calibration in Hart's NVLAP-accredited lab.

This probe is an excellent value. It has the price-to-accuracy and price-to-durability ratios you should demand in every PRT you buy!

Specifications

Resistance	Nominal 100Ω
Temperature Coefficient	0.00385Ω/Ω/°C nominal
Temperature Range	–200°C to 420°C (5627-6 to 300°C; transition and cable temperature: 0°C to 150°C)
Drift Rate	±0.13°C at 0°C after 1000 hours at 400°C
Sheath Material	316 Stainless Steel
Leads	Teflon™-insulated, nickel-plated stranded copper, 22 AWG
Termination	Specify. See Ordering Information.
Time Constant	Four seconds maximum for 63.2% response to step change in water moving at 3 fps.
Bending Radius	Sheath may be ordered with a bend on a minimum radius of 3/4" except for 2" area of sheath near tip. (Hart lab requires 8" [20 cm] of unbent sheath to re-calibrate.)
Calibration	Includes manufacturer's NIST-traceable calibration and table with R vs. T values in 1°C increments from –196°C to 500°C (to 300°C for Model 5627-6). ITS-90 coefficients included. *Optional accredited calibration available from Hart.*
Immersion	At least 4" recommended
Accuracy (includes calibration uncertainty and short-term stability)	±0.050°C at –196°C ±0.050°C at 0°C ±0.051°C at 200°C ±0.055°C at 420°C
Size	**5627-12:** 12" L x 1/4" Dia. **5627-9:** 9" L x 3/16" Dia. **5627-6:** 6" L x 3/16" Dia.

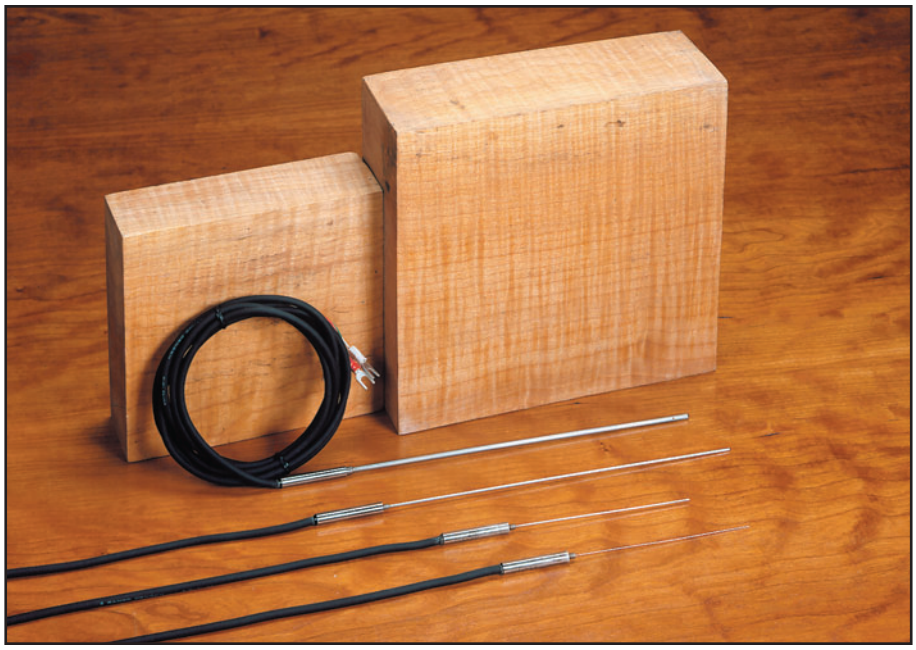
Ordering Information

5627-6-X	Secondary PRT, 6" x 3/16", –200°C to 300°C
5627-9-X	Secondary PRT, 9" x 3/16", –200°C to 420°C
5627-12-X	Secondary PRT, 12" x 1/4", –200°C to 420°C
2601	Protective Case

X = termination. Specify "B" (bare wire), "D" (5-pin DIN for Tweener Thermometers), "G" (gold pins), "I" (INFO-CON for 1521 or 1522 Handheld Thermometers), "J" (banana plugs), "L" (mini spade lugs), "M" (mini banana plugs), or "S" (spade lugs).

Get the latest product information at www.hartscientific.com

FAST RESPONSE PRTs — Model 5622



Fast Response PRTs — Model 5622

- Time constants as fast as 0.4 seconds
- Available as DIN/IEC Class A PRTs or with ITS-90 calibration
- Small probe diameters ranging from 0.5 mm to 3.2 mm

For special temperature measurement applications requiring fast response or short immersion over a wide temperature range, Hart's new 5622 series PRTs are the perfect solution.

Made by Netsushin, one of the world's leading PRT manufacturers, this series includes four models with stainless steel sheaths ranging from 0.5 to 3.2 mm (0.02" to 0.125") in diameter. Because these high-quality wire-wound sensors come in small packages, heat transfer to the sensors occurs quickly. Time constants from 0°C to 100°C are as fast as 0.4 seconds.

Immersion requirements for these probes is also a plus, ranging from just 10 mm to 64 mm (0.4" to 2.5"), depending on the model. Getting into shallow or tight places is not a problem. And because these probes can handle temperatures from –200°C to 350°C, they're more versatile than most thermistors.

Model 5622 PRTs come with two calibration options. Uncalibrated, each of these probes conforms to DIN/IEC Class A requirements with accuracy of ±0.15°C at 0°C and ±0.55°C at 200°C and –200°C. Alternatively, any Model 5622 PRT may be purchased with a Model 1922-4-N ITS-90 Comparison Calibration, which includes seven points from –197°C to 300°C. With calibration, short-term accuracies are achieved as good as ±0.04°C at 0°C.

Readout options for the Model 5622 PRTs include Hart's Little Lord Kelvin and Little Lord Logger Handheld Thermometers (page 37) as well as the 1502A Tweener Thermometer (page 40). Each of these readouts will read your PRT as a standard DIN/IEC probe or as an individually calibrated PRT.

Whatever your thermometry requirements are, come to Hart. No one else offers a wider range of standards-quality reference thermometers than Hart.

Specifications

Temperature Range	–200°C to 350°C
Nominal R_{TPW}	100Ω
Sensor	Four "385" platinum wires
Calibrated Probe Accuracy (includes calibration uncertainty and short-term stability)	**5622-05 and 5622-10:** ±0.04°C at –200°C ±0.04°C at 0°C ±0.09°C at 200°C ±0.09°C at 300°C **5622-16 and 5622-32:** ±0.04°C at –200°C ±0.04°C at 0°C ±0.045°C at 200°C ±0.055°C at 300°C
Uncalibrated DIN/IEC Conformity	DIN/IEC Class A; ±0.15°C at 0°C
Time Constant (63.2%)	From 0°C to 100°C: **5622-05:** 0.4 seconds **5622-10:** 1.5 seconds **5622-16:** 3.0 seconds **5622-32:** 10 seconds (90%)
Immersion Depth	**5622-05:** 10 mm (0.4") **5622-10:** 20 mm (0.8") **5622-16:** 32 mm (1.25") **5622-32:** 64 mm (2.5")
Thermal EMF	20 mV at 350°C
Sheath	316 SST **5622-05:** 100 x 0.5 mm (4" x 0.02") **5622-10:** 100 x 1.0 mm (4" x 0.04") **5622-16:** 200 x 1.6 mm (8" x 0.06") **5622-32:** 200 x 3.2 mm (8" x 0.13")
Cable	PVC, 4-wire cable, 2 meters long, 90°C max temp

Ordering Information

5622-05-X	Fast Response PRT, 0.5 mm (0.02")
5622-10-X	Fast Response PRT, 1.0 mm (0.04")
5622-16-X	Fast Response PRT, 1.6 mm (0.06")
5622-32-X	Fast Response PRT, 3.2 mm (0.13")

All models come without calibration unless calibration purchased separately.

1923-4-N	Calibration, PRT Comparison, –196°C to 300°C
2601	Protective Case

X = termination. Specify "B" (bare wire), "D" (5-pin DIN for Tweener Thermometers), "G" (gold pins), "I" (INFO-CON for 1521 or 1522 Handheld Thermometers), "J" (banana plugs), "L" (mini spade lugs), "M" (mini banana plugs), or "S" (spade lugs).

See our calibration and data acquisition software packages on page 74.

SMALL DIAMETER INDUSTRIAL PRT 5618A

Small Diameter Industrial PRT 5618A

- Small diameter sheath, 0.125" (3.2mm)
- Excellent stability
- Includes ITS-90 coefficients
- Calibrated from –200°C to 500°C

For secondary level performance with full ITS-90 calibration, Hart's new 5618A series PRTs are an excellent choice for critical temperature measurements. Featuring a 1/8-inch diameter (3.2 mm) sheath, these industrial standards probes have reduced response time without compromising precision. This small diameter 5618A probe works well in many applications where immersion depth is limited. Larger diameter probes give more measurement error in short immersion depth applications because they radiate more heat to or from ambient air.

With each probe you will receive a full calibration report traceable to NIST and compliant to ANSI/NCSL Z540. On the report you'll get the test data and the ITS-90 calibration coefficients that you can easily input into your Hart thermometer. If you are using a 1521 Handheld Thermometer readout, we'll program the coefficients directly into your INFO-CON connector.

The 5618A is also a great probe to use for calibrating your Hart 9132 or 9133 infrared calibrators. In fact, these IR black body heat sources were designed to be calibrated with this type of probe. Now you can calibrate these targets in your own lab!

For use from –200°C to 500°C (the six-inch model goes to 300°C), you won't find a better industrial standard in this configuration than our 5618A. We recommend using the 5618A PRTs with the 1521, 1522, 1502A, 1529, or 1560 thermometer readouts.

Technical Tip

Interim Checks Save Trouble Later

You spend good money getting your reference standards calibrated. How can you be sure that they continue to measure accurately prior to their next calibration? One way is to periodically compare them to other reference standards with higher accuracy. Such a test is called an interim check.

An interim check that most of us are familiar with is the use of a water triple point cell to check the stability of a PRT. The ISO 17025 suggests the use of interim checks as a quality safeguard. Do this regularly and keep good records. Your customers and your auditors will thank you. And if you find a problem, you'll be glad you found it sooner rather than later!

Specifications

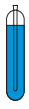
Resistance	Nominal 100Ω at 0°C
Temperature Coefficient	0.003923Ω/Ω/°C nominal
Temperature Range	–200°C to 500°C (–200°C to 300°C for 5618A-6-X)
Drift Rate	±0.1°C when used periodically to 500°C
Sheath Material	316 SST
Leads	22 AWG Teflon, 6'
Termination	Specify
Hysteresis	Less than 0.01°C at 0°C when using –196°C and 420°C as the end points.
Time Constant	9 seconds max for 63.2%
Thermal EMF	Less than 25 mV at 420°C
Calibration	Includes manufacturer's NIST-Traceable (Z540) calibration w/ITS-90 coefficients, R vs. T values in 1°C increments
Size	**5618A-12:** 12"L x 1/8" diameter **5618A-9:** 9"L x 1/8" diameter **5618A-6:** 6"L x 1/8" diameter
Probe Accuracy (includes calibration uncertainty and short-term stability)	±0.05°C over entire range

Ordering Information

5618A-12X	12" Small Diameter Probe
5618A-9-X	9" Small Diameter Probe
5618A-6-X	6" Small Diameter Probe
2601	Protective Case

X = termination. Specify "B" (bare wire), "D" (5-pin DIN for Tweener Thermometers), "G" (gold pins), "I" (INFO-CON for 1521 or 1522 Handheld Thermometers), "J" (banana plugs), "L" (mini spade lugs), "M" (mini banana plugs), or "S" (spade lugs).

Don't forget a protective case!



See page 18 for triple point of water cells.

HOW ACCURATE IS THAT PROBE?

At Hart, we field inquiries every day about reference thermometers. Inevitably, as a particular thermometer is discussed, the same bottom-line question is asked: "How accurate is it?"

The purest metrology answer to this question is, at best, disconcerting: "Nobody knows until you re-calibrate it—*after* you've used it."

While this is probably the best answer that can be given, it's not very helpful when you're trying to select the right thermometer. So if you'd like an idea of accuracy *before* you buy a thermometer, here are five things to consider.

Calibration

One of the most important contributors to the accuracy of your reference thermometer is the way it was calibrated. All calibrations are not equal.

Calibrations by fixed points are generally better than calibrations by comparison. Calibrations limited to a narrow temperature range are better than calibrations done over a needlessly wide range. Calibrations by people who know what they're doing are better than calibrations by people who don't.

Your calibration should describe the method used, state the uncertainty or test-uncertainty-ratio of the calibration, include a calibration report that meets your quality standards and demonstrates traceability to a national laboratory, and be done by an accredited lab or company you trust. The uncertainty of your probe's own calibration is the first element of accuracy to consider.

Short-Term Stability (Repeatability)

Just because your thermometer has been well calibrated doesn't mean it repeats each identical measurement perfectly. Limitations on the abilities and physical purity of the sensing element and other materials used in the construction of the thermometer prohibit perfect repeatability.

Different types of thermometers made by different manufacturers have varying susceptibilities to errors from hysteresis, oxidation, and other sources of instability. Thermocouples, for example, are inherently less repeatable than reference-grade thermistors. Strain-free SPRTs are more repeatable than industrial RTDs. The point is that short-term instabilities cannot be "calibrated out" and must be considered as an additional source of uncertainty.

Long-Term Stability (Drift)

Long-term stability, or "drift," is a critical specification for any reference thermometer. Many causes of short-term instability grow worse as a thermometer's thermal history increases. Normal wear and tear takes its toll on even the best sensing elements and affects their output. It's important to note that "normal wear and tear," in this case, should be defined in the specification.

For example, a drift specification may be stated as "less than 2 mK after 100 hours at 661°C" (such as on page 9) or as "±0.01°C at 0°C per year maximum, when used periodically to 400°C" (such as on page 63). If your intended use of the thermometer is more or less strenuous than what the manufacturer states, you may anticipate correspondingly more or less drift.

Many causes of long-term drift can be periodically addressed and, to some extent, removed. The effects of oxidation, for example, can be largely removed by occasional annealing at high temperatures. Annealing, itself, however, adds more high-temperature history to the sensor and should not be done needlessly. One of the reasons the drift specification is so important is that it helps identify how long you can use your thermometer between recalibrations. Be wary of suppliers who don't provide a drift specification.

Usage

You won't find a specification to account for all the ways a reference thermometer can be misused (or even abused), but in evaluating specifications it must be understood that the manufacturer has made assumptions regarding how its instrument will be used. At Hart, we tend to write "looser" specifications to allow for instruments being used in less ideal conditions than those under which we use them. Not every manufacturer is so generous.

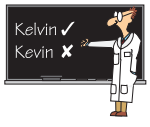
Typical examples of misuse include inadequate immersion depth, subjection to mechanical or thermal shock, inadequate thermal contact against the subject being measured, use outside the specified temperature range, and extended use at extreme ends of the temperature range. Before assuming your thermometer will perform the way the manufacturer says it will, satisfy yourself that it will be used within the manufacturer's intended parameters.

Display Accuracy

The uncertainty of the thermometer's readout device (bridge, DMM, *Black Stack,* etc.) must be added to the uncertainty of the actual thermometer when considering total accuracy. No electrical thermometer (PRT, thermistor, thermocouple, etc.) generates a direct temperature reading. The resistance or voltage must always be interpreted (and usually fitted to an equation), and there are always errors inherent in this process.

In the Final Analysis...

In the end, the fact remains that the metrologist is right. You won't know how accurately your thermometer has performed until you recalibrate it. The moral is simple: consider all the appropriate performance specifications, use the thermometer correctly and carefully, and recalibrate it soon to verify its performance. As recalibrations yield positive results and confidence in an instrument grows, calibration intervals can be extended and maintenance costs decreased. If you're buying from the right manufacturer and handling your thermometer correctly, you'll find it not uncommon to experience much better results than what the manufacturer has specified.



Read about our calibration training courses on page 153.

Read about our accredited calibration services on page 156.

THERMISTOR STANDARDS PROBES

Thermistor Standards Probes **Models 5640–5644**

- Accuracy to ±0.001°C
- Affordable system accuracy to ±0.004°C or better
- NIST-traceable calibration included from manufacturer; accredited Hart calibration optional

If you want a high-accuracy probe with excellent stability at a great price, the Model 5640-series Thermistor Standards Probes give you all three in a great package. Why pay for an SPRT when you can get ±0.001°C accuracy from 0°C to 60°C in a calibrated thermistor probe for about one-third the cost of an uncalibrated SPRT alone?

Each probe uses an ultra-stable glass thermistor enclosed in a thin-wall stainless steel tube. The basic semiconductor element is a bead of manganese, nickel, and cobalt oxides mounted on 0.1 mm platinum wires. For long-term stability, the thermistor is aged at various temperatures for 16 weeks. During the aging process, verification of the probe's stability is done to ensure performance to published specs.

The 5640, 5641, and 5642 thermistor probes are designed for the temperature range of 0°C to 60°C. The 5643 and 5644 probes span the 0°C to 100°C temperature range. They offer stability of either ±0.002°C or ±0.005°C. These stability levels are guaranteed for one full year.

Precision calibration, traceable to NIST, is provided with each probe. A computer-generated table in increments of 0.01°C is furnished with each calibration based on the formula:

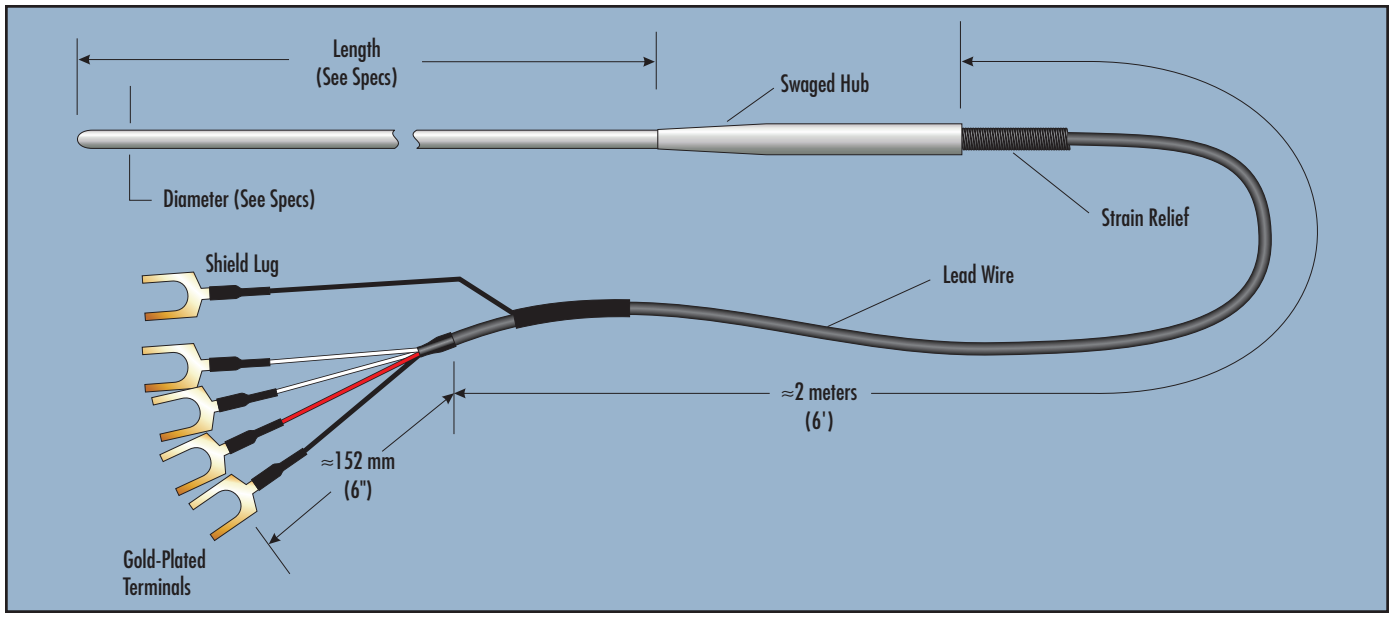
$$R = \exp\left(A + \frac{B}{T} + \frac{C}{T^2} + \frac{D}{T^3}\right)$$

The constants for the formula are obtained from a polynomial regression performed on the calibration data obtained. Over the range of 0°C to 60°C, calibration is performed at the triple point of water (0.01°C) and 15°C, 25°C, 30°C, 37°C, 50°C and 60°C. For the 0°C to 100°C temperature range, the additional calibration points of 80°C and 100°C are used.

Each probe is individually calibrated and includes a report of calibration from the manufacturer. Contact Hart for calibration in Hart's NVLAP accredited lab.

Thermistor standards are rugged, precision sensors suitable for use as secondary or working temperature standards for laboratory metrology applications. Because they generally are not affected by shock and vibration, you can use them in the most difficult field environments without worrying about calibration integrity.

Combine these probes with Hart's Model 1560 *Black Stack* thermometer to read directly in °C, °F, or K. This combina-



Specifications

Model	Dia x Length	Range	Drift °C/Year	Accuracy (Mfr.)† 0–60°C	Accuracy (Mfr.)† 60–100°C	Wires	Nominal Resistance at 25°C
5640	0.25" x 9" (6.35 x 229 mm)	0°C–60°C	±0.005°C	±0.0015°C	n/a	4	4 kΩ
5641	0.125" x 4.5" (3.18 x 114 mm)	0°C–60°C	±0.002°C	±0.001°C	n/a	4	5 kΩ
5642	0.125" x 9" (3.18 x 229 mm)	0°C–60°C	±0.002°C	±0.001°C	n/a	4	5 kΩ
5643	0.125" x 4.5" (3.18 x 114 mm)	0°C–100°C	±0.005°C	±0.0015°C	±0.0025°C	4	10 kΩ
5644	0.125" x 9" (3.18 x 229 mm)	0°C–100°C	±0.005°C	±0.0015°C	±0.0025°C	4	10 kΩ

†Does not include long-term drift.

tion gives you resolution of 0.0001 degrees and total system accuracy is better than ±0.004°C.

Compare the cost of a 5640 calibrated probe and a *Black Stack* thermometer to the cost of one uncalibrated SPRT. Between 0°C and 100°C, nothing beats the value of the 5640 Series Thermistors.

Ordering Information

5640-X	Standards Thermistor Probe
5641-X	Standards Thermistor Probe
5642-X	Standards Thermistor Probe
5643-X	Standards Thermistor Probe
5644-X	Standards Thermistor Probe
2601	Protective Case

X = termination. Specify "B" (bare wire), "D" (5-pin DIN for Tweener Thermometers), "G" (gold pins), "I" (INFO-CON for 1521 or 1522 Handheld Thermometers), "J" (banana plugs), "L" (mini spade lugs), "M" (mini banana plugs), or "S" (spade lugs).

Technical Tip

Thermistors Make Great Reference Thermometers!

Contrary to some traditional belief, reference-grade thermistors do indeed make great temperature standards. Consider:

- Stability. Today's glass-encapsulated thermistors are well sealed to prevent sensor oxidation and drift. In fact, standards-level thermistors usually won't drift more than a few millidegrees in a year.
- Accuracy. Thermistors are easier (than PRTs) to read accurately because of their larger base resistance and large change in resistance-per-degree. It's common to get meaningful and repeatable readings from a thermistor with resolution of 0.0001°C.
- Durability. While a bare thermistor bead can be fairly delicate, a properly constructed stainless steel-sheathed thermistor probe can be more rugged than a PRT or SPRT.

For about the same cost of a secondary level PRT, you can buy a well-calibrated standards thermistor probe with accuracy and stability that rivals an SPRT. You can also save wear and tear on your SPRT by using a thermistor over the 0°C to 100°C temperature range.

SECONDARY REFERENCE THERMISTOR PROBES

Secondary Reference Thermistor Probes

- Range 0°C to 100°C
- Short-term accuracy to ±0.015°C; one year drift < ±0.01°C
- Includes NIST-traceable calibration from manufacturer; accredited Hart calibration optional

Hundreds of thousands of thermistors are sold every year, but only a few have the stability necessary for use as high-accuracy thermometry standards. If you're looking for economical lab-grade thermistor probes for accurate work across a narrow temperature range, Hart's Secondary Reference Series thermistor probes are the best you can buy.

A thermistor offers several advantages over a PRT as a reference thermometer in some applications. First, there's size. A thermistor is much smaller than a PRT element, and so it can be built into a much larger variety of probe shapes and sizes. The smaller element contributes to much faster response times, too.

If your application involves frequent handling, a thermistor is less susceptible to mechanical shock than a PRT. The bottom line may be better accuracy in fieldwork.

Higher base resistance and larger resistance coefficients make it easier to achieve precision readings. Better resolution and accuracy are possible for a lower cost.

These probes come in a complete assembly ready for use, and they make an excellent match with the uncertainties of our thermometer readouts: the 1504 Tweener, the 1521 and 1522 Handheld Thermometers, the 1529 Chub-E4, the 1560 *Black Stack,* and the 1575A and 1590 Super-Thermometers.

These probes are accurate to ±0.015°C, and each comes with a NIST-traceable calibration and a resistance versus temperature table printed in 0.1°C increments.

The Secondary Reference Series Thermistors cover the temperature range of 0°C to 100°C. No other sensors can match the accuracy and price combination of these high-accuracy thermistor probes. Try one and you'll agree.

Specifications - 5610, 5611, 5665	
Resistance	Nominal 10,000Ω at 25°C
Range	0°C to 100°C
Calibration	R vs. T table with 0.1°C increments, interpolation equation furnished
Calibration Uncertainty	Table and equation are accurate to ±0.01°C
Drift	Better than ±0.01°C per year
Repeatability	Better than ±0.005°C
Size and Construction	See table on opposite page.
Termination	Specify when ordering.

Specifications - 5674	
Resistance	Nominal 10,000Ω at 25°C
Range	0°C to 70°C
Calibration	Optionally available from Hart. See page 156.
Drift	Better than ±0.02°C per year
Repeatability	Better than ±0.07°C
Size and Construction	See table on opposite page.
Termination	Specify when ordering.

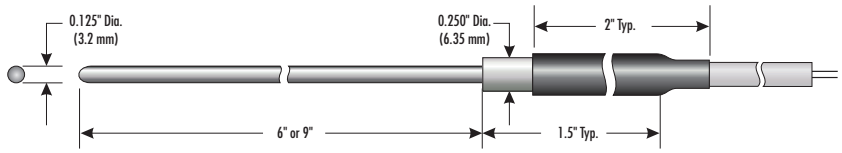
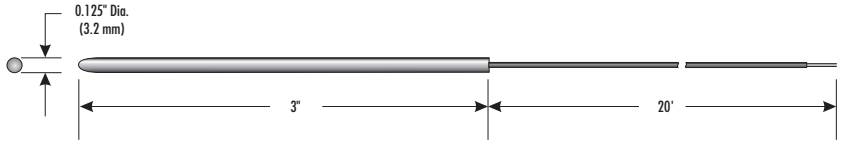
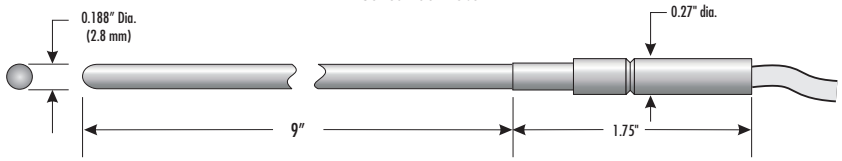
Ordering Information

5610-6-X	6" Immersion Probe
5610-9-X	9" Immersion Probe
5611-X	Silicone-Bead Probe
5665-X	Miniature Immersion Probe
5674-X	Series 400 Thermistor
2601	Protective Case

X = termination. Specify "B" (bare wire), "D" (5-pin DIN for Tweener Thermometers), "G" (gold pins), "I" (INFO-CON for 1521 or 1522 Handheld Thermometers), "J" (banana plugs), "L" (mini spade lugs), "M" (mini banana plugs), or "S" (spade lugs).

Get the latest product information at www.hartscientific.com

SECONDARY REFERENCE THERMISTOR PROBES

Model		Applications	Construction
5610-6	**Immersion Probe** 	Immersion, calibration standards	Stainless Steel Diameter: 0.125" Sheath Length: 6" Lead Length: 6'
5610-9			Stainless Steel Diameter: 0.125" Sheath Length: 9" Lead Length: 6'
5611	**Silicone-Bead Probe** 	Immersion in most liquids (except silicone oils), pharmaceutical, faster response	2-Wire Silicone Coated Diameter: 0.070" Sheath Length: 0.55" Lead Length: 6'
5665	**Miniature Immersion Probe** 	Liquid and soil immersion	Stainless Steel Diameter: 0.125" Sheath Length: 3" Lead Length: 20'
5674	**Series 400 Probe** 	Immersion, calibration standards	Stainless Steel Diameter: 0.188" Sheath Length: 9" Lead Length: 4'

Technical Tip

Handle Your Probe Correctly

Good thermometer handling procedures help maintain calibration accuracy. Here are a few pointers.

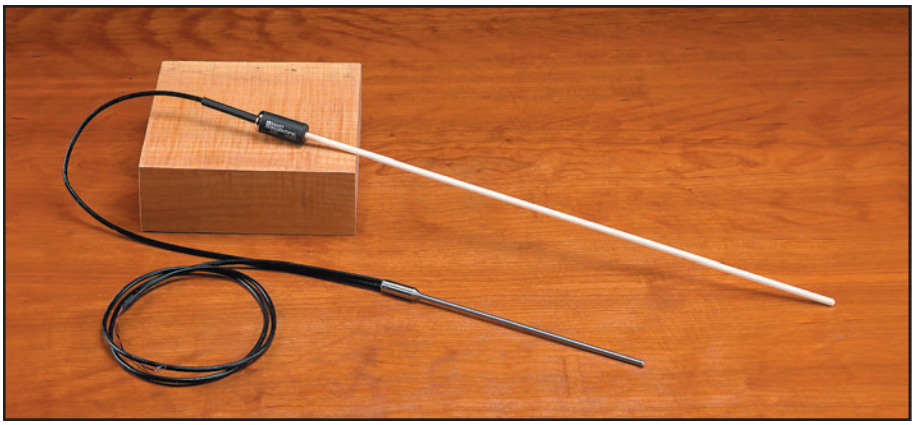
Don't

- Don't subject a PRT to physical shock or vibration.
- Don't bend a probe that is not designed for bending.
- Don't subject a thermometer to sudden extreme temperature changes.
- Don't install compression fittings on a probe sheath.
- Don't subject a thermometer to temperatures outside its range.
- Don't subject a thermometer's transition junction, handle, or lead wires to temperatures outside their ranges (which likely differ from the thermometer's range).
- Don't immerse the probe past the bottom of its handle.

Do

- Do immerse a probe to at least its minimum immersion depth.
- Do allow the thermometer time to stabilize before taking readings.
- Do use the proper current to prevent self-heating errors.
- Do check your probe's R_{TPW} value frequently.
- Do test the shunt resistance of your probe periodically. (Shunt resistance is the resistance between the probe sensor and the probe sheath.)

Steve (customer service) knows lighting and apertures nearly as well as he knows self-heating and immersion effects.



Type S Thermocouple Standards — Model 5650

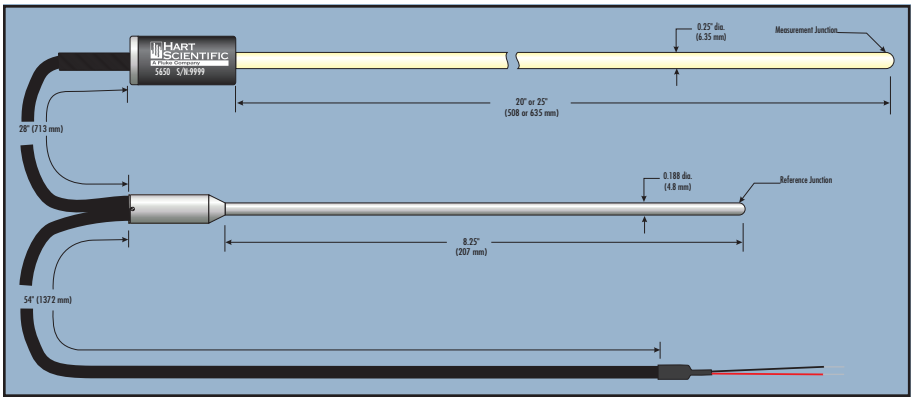
- Designed by Hart's primary standards design team
- Two sizes available, each with or without reference junction
- Calibration uncertainty of ±0.5°C to 1100°C, ±3°C to 1450°C

Made from the finest platinum and platinum-rhodium alloy, the 5650 Type S covers 0°C to 1450°C with uncertainties less than 0.5°C over most of that range. With four different models to choose from, we have a type S thermocouple to fit your application.

The measuring junction of the 5650 is encased in a 0.25-inch (6.35 mm) alumina sheath that can be ordered in lengths of 20 or 25 inches (50.8 or 63.5 cm) to fit the specific requirements of your application. A reference, or "cold," junction may also be ordered. The reference junction uses a stainless steel sheath and is 8.25 inches long (21 cm) by 0.188 inches in diameter (4.8 mm). The thin diameter minimizes the immersion depth needed, but the extra length ensures you can get all the immersion you like.

Special tin-plated, solid-copper connecting wires with ultra-low EMF properties are used to help retain the integrity of your measurement junction as the probe attaches to your micro voltmeter or Hart *Black Stack*.

Each 5650 comes from a spool of wire that has been sample tested using fixed-point standards to ensure uncertainties less than 0.5°C up to 1100°C. From 1100°C to 1450°C, the uncertainty increases linearly to 3.0°C. If you need greater accuracy, order an individual calibration with fixed-point standards to reduce uncertainties to ±0.15°C below 962°C and increasing linearly to ±2.0°C at 1450°C.



The probe assembly can be easily disassembled for performing your own bare-wire calibrations.

Specifications

Range	0°C to 1450°C
Type	Platinum/10% rhodium vs. platinum (type S)
Calibration	Wire spool sampling method by fixed point (optionally available by fixed point for individual thermocouples)
Calibration Uncertainty	±0.5°C to 1100°C ±3.0°C to 1450°C
Hot Junction Sheath Dimensions	0.25" (6.35 mm) diameter; see Ordering Information for lengths
Reference Junction Sheath Dimensions	0.188" diameter x 8.25" length (4.8 x 210 mm)
Long-Term Stability	±0.5°C to 1100°C ±2.0°C to 1450°C (over one year depending on usage)
Short-Term Stabilities	±0.2°C to 1100°C ±0.6°C to 1450°C
Immersion	At least 6" recommended
Copper/Copper Wires to Readout	60" L, tin-plated, Teflon-insulated, low EMF solid copper
Protective Case	Model 2602 case included
Weight	2 lb. (1 kg)

Ordering Information

5650-20-X	Type S TC, 20" x 1/4"
5650-20CX	Type S TC, 20" x 1/4", with reference junction
5650-25-X	Type S TC, 25" x 1/4"
5650-25CX	Type S TC, 25" x 1/4", with reference junction

X = termination. Specify "B" (bare wire), "W" (generic copper-to-copper TC connector), or "R" (standard Type R/S TC connector). Models with reference junctions should not specify "R" and models without reference junctions should not specify "W".

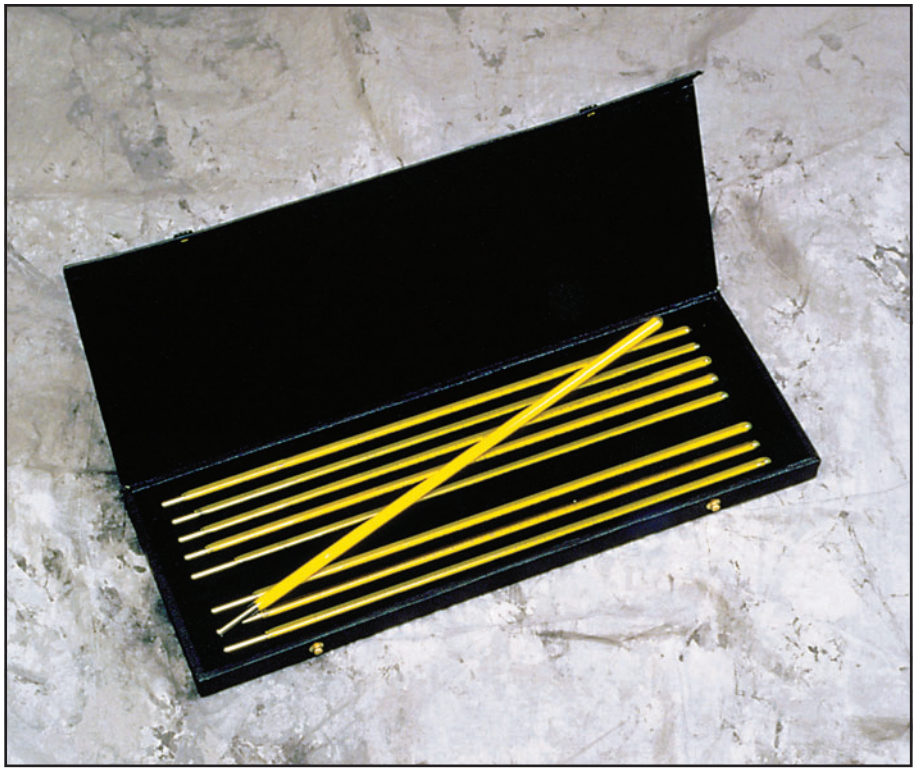
1918-B	Four-point calibration by fixed point (Sn, Zn, Al, Ag). Extrapolated to 1450°C.

Note: Calibration uncertainty for individually calibrated 5650s by fixed point is ±0.25°C below 1100°C and ±2.0°C above 1100°C. 2602 case included with new models.

2602	Spare Case

Read about our calibration training courses on page 153.

ERTCO LIG THERMOMETER SETS



Complete Sets of ASTM Precision Factory-Calibrated (Certified) Thermometers

Cat. No	No. of Thermometers	ASTM Nos.	Ranges Covered
62-70C-FC	9	62C–70C	–38°C to 405°C
62-70F-FC	9	62F–70F	–36°F to 761°F

Need LIG thermometers? These ERTCO models are manufactured in accordance with ASTM precision specifications and provide accurate and reproducible measurements. These total-immersion-thermometers are perfect for critical temperature measurements or as calibration standards.

When used properly, these instruments typically have errors of less than ±0.01% of scale. Each one is accurate to ±1 scale division, and stem diameters vary from 7 mm to 8 mm. These thermometers are 379 mm (14.9") long. Individual serial numbers are given to each unit.

Every LIG thermometer is given a NIST-traceable calibration. Data includes the ice-point reading, five calibration points, tabulated corrections (to one-tenth of the smallest scale division) for each calibration point, the serial and test number of the NIST standard, and test notes.

Choose a set of total-immersion thermometers from ERTCO and put them on the same order as your other Hart instruments. Like always, we'll take care of your customer service needs.

Each set contains nine thermometers. Here are the individual ranges:

Temperature Ranges for Celsius Set 62-70C-FC		Temperature Ranges for Farenheit Set 62-70F-FC	
62C	–38°C to 2°C	62F	–36°F to 35°F
63C	–8°C to 32°C	63F	18°F to 89°F
64C	25°C to 55°C	64F	77°F to 131°F
65C	50°C to 80°C	65F	122°F to 176°F
66C	75°C to 105°C	66F	167°F to 221°F
67C	95°C to 155°C	67F	203°F to 311°F
68C	145°C to 205°C	68F	293°F to 401°F
69C	195°C to 305°C	69F	383°F to 581°F
70C	295°C to 405°C	70F	563°F to 761°F

Specifications

Type	Mercury-in-glass, total immersion	
Length	179 mm	
Diameter	7–8 mm	
Accuracy	± 1 scale division	
Calibration	NIST traceable with data & corrections	
Scale Divisions	62C-66C	0.1°C
	67C, 68C	0.2°C
	69C, 70C	0.5°C
	62F-66F	0.2°F
	67F, 68F	0.5°F
	69F, 70F	1.0°F

Technical Tip

What Is a Total-Immersion Thermometer?

A total immersion thermometer is one that is designed to be immersed to the point of reading. When measuring a temperature toward the top of the thermometer's range, the thermometer will be almost completely immersed. When calibrating a total-immersion thermometer, deep baths are required (see page 84). We also recommend a fluid level adapter. This will bring the fluid level of your bath up to your eye level for more accurate reading of the LIG thermometer (see page 84 or 106).

A "partial-immersion" thermometer only requires immersion part way no matter where the mercury level is. The manufacturer usually marks this immersion point on the thermometer.

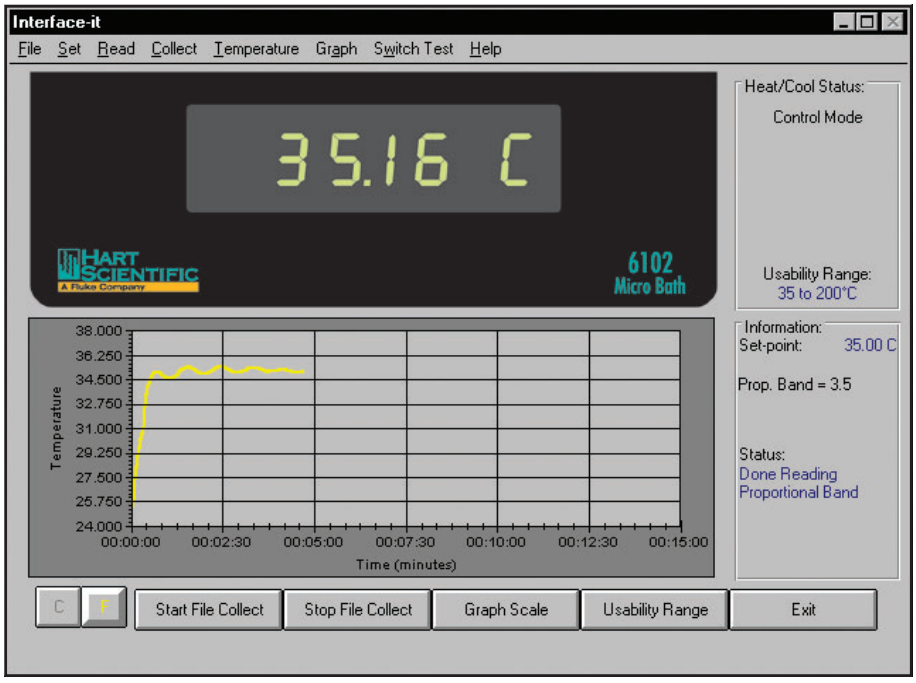
For "complete-immersion" thermometers, the entire thermometer must always be immersed. This can be rather tricky to read if the mercury level is several inches below the level of the fluid you are measuring. If you use complete-immersion thermometers often, you may wish to get a Hart bath with a built-in window. Call us for details.

Get the latest product information at www.hartscientific.com

SOFTWARE SUMMARY

Model	Name	Description	Page
9930	Interface-*it*	Windows-based interface to all Hart dry-wells and baths that include an RS-232 port (virtually all units). Provides access to all controller functions and the ability to graphically monitor the temperature displayed on the heat source.	74
9938	MET/TEMP II	Complete calibration system software. Communicates with Hart thermometers & heat sources to control & take readings. Generates calibration constants and reference tables. Now works with Fluke MET/TRACK!	75
9933	Table*Ware*	Generates calibration constants and reference tables based on calibration data entered by the user.	78
9934	Log*Ware*	Turns any 1-channel Hart thermometer readout (1521, 1502, 1504, etc.) into a real-time datalogger. Includes flexible graphing functions as well as statistics for logged data. Also provides programming, downloading, and data analysis tool for Hart logging thermometers.	79
9935	Log*Ware* II	Graphical data analysis software for multi-channel thermometers (1529, 1560, 1575A, 1590). Works in real-time or from downloaded data sets.	

INTERFACE-it Model 9930



Interface-*it* **Model 9930**

- Free with nearly every Hart heat source
- Provides PC access to Hart controller functions
- Graphically displays heat source temperatures

The Hart Scientific 9930 Interface-*it* software package is included with every Hart dry-well and bath that has an RS-232 interface. The 9930 lets you use your own PC to control the function of that Hart bath or dry-well. You can view the temperature, program the ramp and soak routine, change the set point, see the power usage, or check the proportional band setting. Interface-*it* will let you do this and more, all from your PC!

The 9930 software also has basic data collection features, though it is not a full automation package. You have probably seen so-called automation software packages from other companies with fewer features than you get with our free Interface-*it* software.

If you need more features, check out our entire list of functional calibration software.

Norman (European sales) debates whether to cook up his rutabaga or use it for lawn bowling.

MET/TEMP II **Model 9938**

- Fully automated calibration of RTDs, TCs, thermistors, and many heat sources
- Calibrates up to 100 sensors at up to 40 points
- Performs coefficient calculations and generates tables and reports
- Includes optional integration with Fluke's MET/TRACK® database

Few things matter in your work more than productivity. And few things can help make you more productive than well-written automation software. We've got the world's best temperature calibration automation software—exactly what you need to be productive. It's Windows® based and it's easy to use.

You may be familiar with the Hart automation software duo Calibrate-*it* and Generate-*it*. Now both come in a single package. We call it MET/TEMP II! Written by the same Hart Scientific temperature experts that brought you the original Calibrate-*it* and Generate-*it* software, this new package interfaces with Fluke's MET/TRACK— the industry standard for asset management.

Calibrating sensors manually is expensive because of labor costs. It takes roughly four hours to calibrate a sensor at three points, then another hour on top of that for paperwork to document the temperature data and to create the certificate. This is much too time-consuming. Now there's a better way.

With MET/TEMP II software, you simply place your test sensors in a heat source, connect them to a readout, and enter your setup data into your PC. Sometime later, hit your print button, take the reports out of your printer, sign them, and ship the sensors back to your customer. Your customers will love the fast turnaround.

It's your choice. Spend four hours the old way and handle everything manually, or fifteen minutes with our software and have plenty of time to read your e-mail.

This software package tests thermocouples (all types), RTDs, SPRTs, thermistors, and even liquid-in-glass thermometers (LIGs). Virtually any sensor with a resistance or voltage output can be tested, up to 100 sensors at a time. They don't even have to be the same type. You can select as few as 1 or as many as 40 temperatures at which to test your sensors. Nobody makes more ultra-stable heat sources and thermometer readouts for temperature calibration work than Hart Scientific. MET/TEMP II can use virtually every one of them. You don't need to worry about special software drivers for each different piece of equipment. Just plug and play.

Use MET/TEMP II with these instruments:

Thermometer Readouts

- 1590 Super-Thermometer II (2590 Mighty-Mux II optional)
- 1575A Super-Thermometer (2575 Mighty-Mux optional)
- 1560 *Black Stac*k (with any combination of modules)
- 1529 Chub-E4
- 1502, 1504 Tweener Thermometers
- 1521, 1522 Handheld Thermometers
- Fluke Hydra series dataloggers

Heat Sources

- All Hart baths with RS-232
- All Hart dry-blocks with RS-232, including 9112 & 9114 furnaces
- Fluke dry-block models 514, 515, 517, 518
- Any other heat source (temperatures must be set manually)

Did we mention that MET/TEMP II also works with the Fluke Hydra Series II data loggers?

You can even calibrate heat sources such as Hart dry-wells and Micro-Baths with this software.

MET/TEMP II also lets you perform semi-automated fixed-point calibrations. The software allows you to program soak times in the cell before taking readings. You may even mix fixed points with comparison points in the same calibration. Of course, we also include fixed-point information on the new report layout.

If you use the 1560 *Black Stack*, you can simultaneously calibrate up to 64 RTDs, 64 thermistors, 96 thermocouples, or any combination. That's a lot of sensors.

MET/TEMP II allows you to track the serial numbers, model numbers, calibration dates, and recall dates of all test equipment

and sensors under test. Optionally, this data may be synchronized with information in your MET/TRACK database. MET/TEMP II also stores customer names and addresses for printing on reports.

With MET/TEMP II, you make your own choices regarding precision and throughput. When setting up tests, you specify the required stability level at each set-point to ensure that readings are taken only under the conditions you require. You'll get the exact level of precision you want based on the equipment you have and the calibration time you set.

MET/TEMP II will interface with MET/TRACK to record calibration and maintenance history, traceability information, and even the location of your thermometers and heat sources. Use it with MET/TRACK and watch your productivity take a big step up.

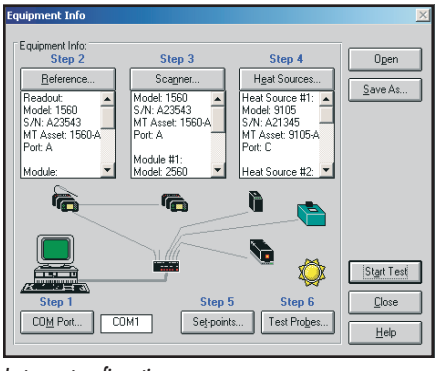
Calibration reports are automatically created from your setup data and test results. Each report conforms completely to the requirements of ANSI/NCSL Z540-1. It's fast, it's accurate, and it's complete.

This is true Windows software. It runs on Windows 9x/ME/2000/NT/XP and includes a context-sensitive online help system. Just click the help button (or press F1) from any screen and you'll get the information you need. When you experience the interface of this software, you'll agree nothing could be easier.

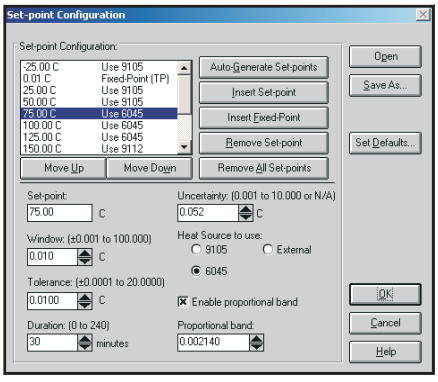
The MET/TEMP II Coefficients and Tables application contains utilities for data analysis. It calculates ITS-90 coefficients and residuals for each sensor tested. Tables can be generated with temperature-versus-resistance, temperature-versus-ratio, or temperature-versus-EMF data. Each report can be generated in °C, °F, or K and in selectable increments from 0.01 to 100.

For PRTs, MET/TEMP II calculates coefficients for ITS-90, IPTS-68, Callendar-Van Dusen, and polynomial functions. For thermistors, it calculates coefficients for polynomial functions, includ-

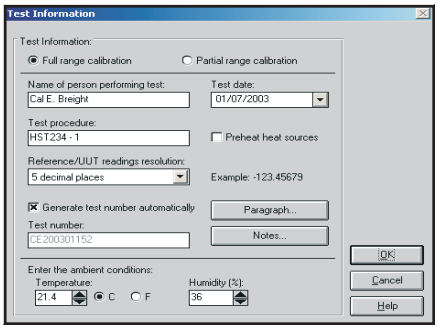
MET/TEMP II software can be used with any Hart thermometer readout, and it controls any combination of Hart dry-wells and baths. Choose from more than 9 readouts and 40 heat sources to calibrate up to 100 sensors automatically. Whether you need 1 mK accuracy for advanced metrology work or 1 °C accuracy for industrial sensors, Hart has the equipment to fit your application. It also provides quick and accurate generation of sensor coefficients and tables.



Instrument configuration screen.



Set-point configuration screen.



Test information screen.

ing Steinhart-Hart. Thermocouple coefficients can be calculated for types B, E, J, K, N, R, S, T, and AuPt. This software even allows you to verify that the appropriate temperatures are used to calculate coefficients.

Need subranges in ITS-90? No problem. Want to print tables for any temperature range and in any incremental amounts? No problem. Need to generate formatted reports that conform to ANSI/NCSL Z540-1? No problem.

Data can also be exported to spreadsheets or other statistical analysis software as comma-delimited or tab-delimited text. MET/TEMP II does all of that and more, but best of all it does it automatically.

There's not much you could ever want to do that this package won't do. This is real calibration software, not merely a data acquisition package with a fancy name!

Other software packages work with one or two instruments; they won't control the wide variety of heat sources our software does. Other software doesn't fully automate the calibration process.

Control dry-wells, baths, readouts, and the entire calibration process. Store data on test equipment and on sensors under test. There's absolutely nothing even close to this software on the market.

When you've got more work to do than you can do in a 12-hour day, and you still need some time to visit accounting to straighten out a few things, MET/TEMP II will take care of business for you. Go home. Spend some time with your kids. Play a game of golf. It's your choice how you spend your time! Download a demo from our Web site today.

Ordering Information

9938	MET/TEMP II Software (package includes CD-ROM, RS-232 multiplexer box, adapter, and PC cable)
LIC-9938	MET/TRACK License

Report of Calibration

Report No: CE200206126-002
Page 1 of 1

Temp Tech Co.
105 Celcius Drive
Out Town, USA
34567-8998

Model:	5614	Customer:	Our Customer
Serial:	365232		One Customer Way
Description:	Probe, Secondary Standard		Technology Drive
			Any Town, USA 23456
Calibration Range:	Full		
Received Condition:	New		
Current:	1.0 mA		
Procedure:	HST000 - 0		

The above referenced instrument was calibrated by direct measurement of generated temperatures using the reference standards listed in the "Test Equipment" table at the bottom of this report. The internal calibration coefficients and the data abtained are shown on page 2. A Test Uncertainty Ratio (TUR) of at least 4:1 was maintained unless otherwise indicated. This calibration is traceable to NIST or natural physical constants and is in compliance with ANSI/NCSL Z540-1 and MIL-STD 45662A.

Nominal (Set-point) (C)	Actual Value (Reference) (C)	UUT (Test Sensor) (Ohms)	Measurement Uncertainty (C)	Method of Realization
-25.00	-24.9697	89.2564	0.050	COMP
0.01	0.0100	100.0235	0.010	TP
25.00	25.0155	110.2354	0.050	COMP
50.00	49.9895	123.5642	0.050	COMP
75.00	75.0045	132.2514	0.050	COMP
100.00	99.9692	138.2563	0.050	COMP
125.00	124.9835	145.0251	0.050	COMP

Test Equipment

Manufacturer	Model	Description	Serial Number	Recall Date
Hart Scientific, Inc.	1529	"Chub-E4" Thermometer 2-RTD/2-TC	A23564	6/30/2002
Hart Scientific, Inc.	5614	Secondary Reference Temperature Std., 1/4" x 12"	360984	1/17/2003
Hart Scientific, Inc.	5901	TPW	123456	2/1/2003
Hart Scientific, Inc.	9105	Drywell, Low-Temperature	A23765	NCR

Notes: This test was performed in accordance with the test procedure indicated above.

Calibration Date: 6/3/2002
Recall Date: 6/3/2003
Temperature: 21 C
Humidity: 25%
Customer Order: 54543-544S

Technician: _____
Cal E. Breight

Approved By: _____

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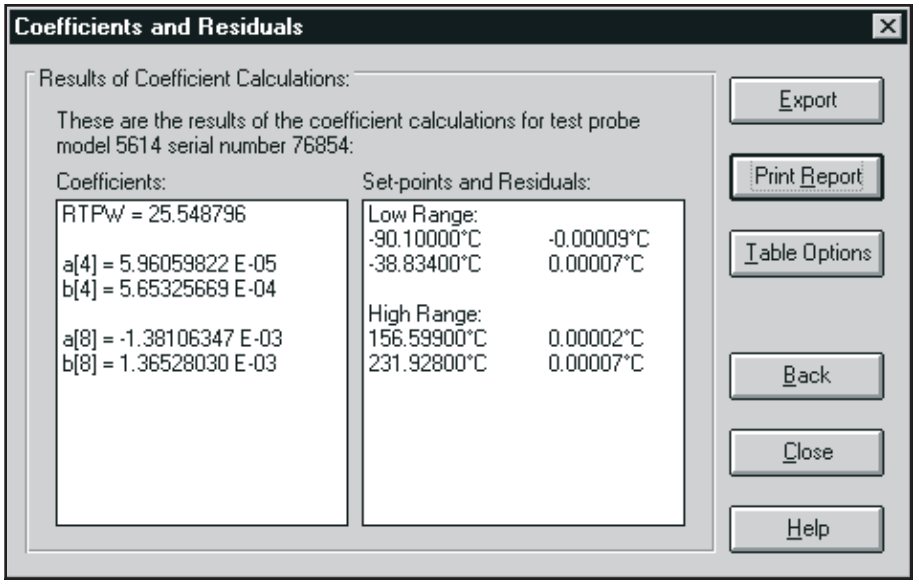
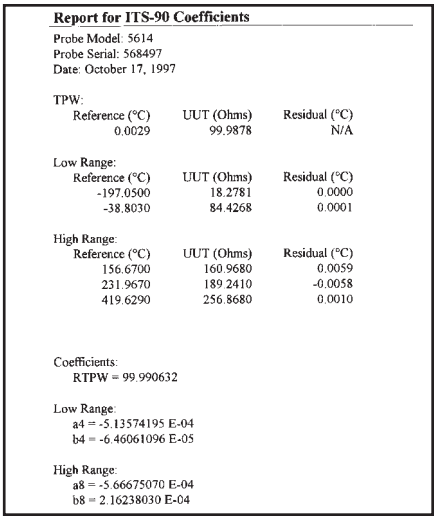
MET/TEMP II software creates test reports that fully comply with ANSI/NCSL Z540-1 requirements. Among the features included in each report are report numbers, pagination, test procedure numbers, test data, stated uncertainties, and test results shown as tolerances. Two locations are also available on the report for special notes.

Get the latest product information at www.hartscientific.com

Read about our calibration training courses on page 153.





Report for ITS-90 Coefficients

Probe Model: 5614
Probe Serial: 568497
Date: October 17, 1997

TPW:

Reference (°C)	UUT (Ohms)	Residual (°C)
0.0029	99.9878	N/A

Low Range:

Reference (°C)	UUT (Ohms)	Residual (°C)
-197.0500	18.2781	0.0000
-38.8030	84.4268	0.0001

High Range:

Reference (°C)	UUT (Ohms)	Residual (°C)
156.6700	160.9680	0.0059
231.9670	189.2410	-0.0058
419.6290	256.8680	0.0010

Coefficients:
RTPW = 99.990632

Low Range:
a4 = -5.13574195 E-04
b4 = -6.46061096 E-05

High Range:
a8 = -5.66675070 E-04
b8 = 2.16238030 E-04

TableWare Model 9933

- Calculates coefficients for RTDs, thermistors, and thermocouples
- Generates three types of temperature tables
- Easy-to-use, time-saving interface
- Outputs to ASCII text file or printed report

Ordering Information

9933	TableWare Software

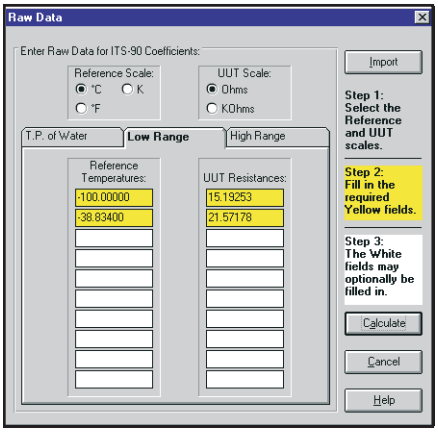
Okay, you know about the benefits of our MET/TEMP II software, but you didn't order your Hart instruments with RS-232 ports, or maybe you've made the mistake of buying less capable competitor products.

Well, you don't need to worry, because we've got something for you, too! Our 9933 Table*Ware* software package does everything that MET/TEMP II's Coefficients and Tables Application does except automatically collect data. Table*Ware* is a calculate-and-generate data software package that uses manually entered data. It still saves you time and money on your calculations, so it's a great buy.

Table*Ware* calculates coefficients for RTDs, thermistors, and thermocouples. It uses ITS-90, IPTS-68, Callendar-Van Dusen, and polynomial equations. Table*Ware* also generates temperature-versus-resistance, temperature-versus-ratio, and temperature-versus-EMF tables. And it includes functions for importing and exporting data for use with other data analysis programs.

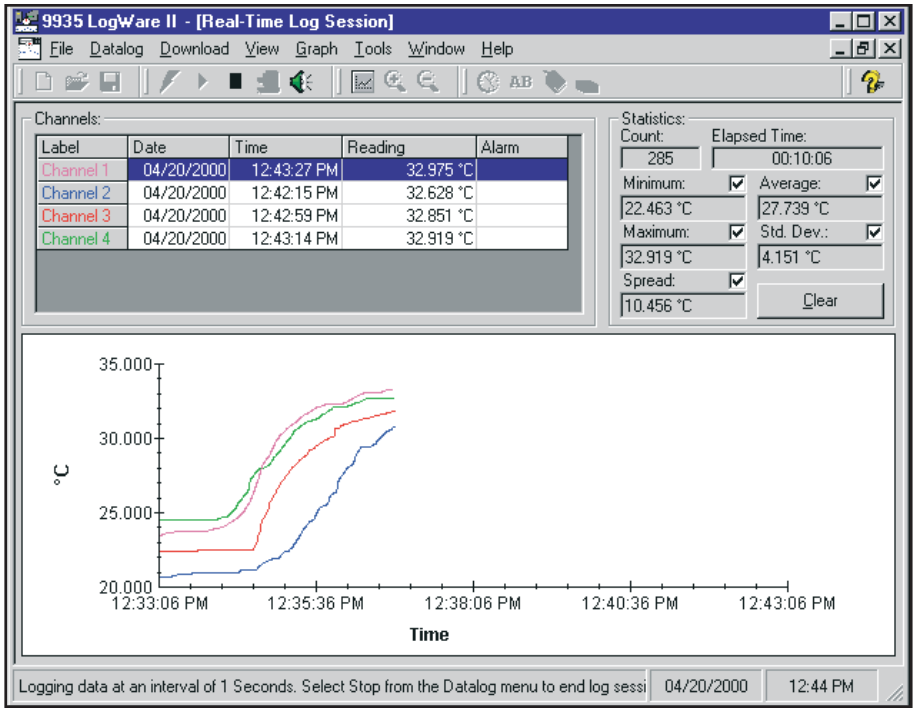
You simply enter or import the raw resistance or voltage data from your calibrations. Table*Ware* generates coefficients, calculates residual values, and generates useful tables.

Hart's Table*Ware* is reasonably priced and works the way you do.



Input screen.

Need a quick turnaround on a service issue? Brad (customer service) is always ready to do whatever it takes.



LogWare — Models 9934 and 9935

- Turns any Hart thermometer readout into a real-time datalogger
- Calculates statistics and displays customized graphs
- User-selectable alarms, delayed start times, and sample intervals
- Two versions for single-channel or multi-channel thermometer readouts

Turn any Hart thermometer readout into a real-time datalogger with one of Hart's Log*Ware* software packages. Whether you use our 9934 Log*Ware* with a single-channel thermometer readout or 9935 Log*Ware* II with one of Hart's multi-channel readouts, you'll agree that this is the easiest data acquisition program you've ever used.

Log*Ware* lets you acquire data to your PC graphically and store it to a text file. It also performs statistical functions automatically on each data set.

Log*Ware* was designed specifically for temperature data acquisition. Set high and low alarm conditions, program a delayed start time, store a data log for a fixed number of readings or length of time, program the acquisition interval from 1 second to 24 hours, and let the software record the data you need the way you need it.

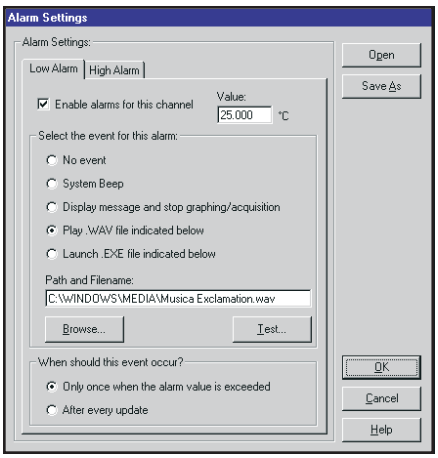
During a log session you can view the data in a time/temperature trend graph while the data points are stored to a file on your PC. Output the graph to your printer, view the test points from a spreadsheet, or review the pertinent log statistics once your log is completed. With Log*Ware* II you can collect and view data from up to 96 probes.

With Hart's 1522 LLL and 1529 Chub-E4 thermometer readouts, there's even more you can do. Both readouts store thousands of data points in multiple log sessions. Log*Ware* lets you download your data into individual log sessions and view each one separately.

Store readings from your freezers, ovens, chambers, and anywhere else you need to record temperature, bring it back to your PC (through a standard serial cable or infrared dongle), and Log*Ware* will separate each log session into individual data sets. You don't have to load the text file into your spreadsheet and try to figure out which data points went with which log session. Log*Ware* does all that for you.

Log*Ware* also gives you the ability to make configuration changes to your thermometer readout. Program your probe coefficients, write calibration data to your meter, set password-protected parameters, and access other tools specific to your thermometer readout all from your PC.

Get the most out of your readout with Log*Ware*. If you don't agree this is the best temperature acquisition system for your application, send it back and we'll refund your money. Buy it today and try it out at no risk.



Alarm settings screen.

Ordering Information

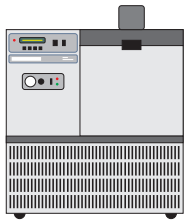
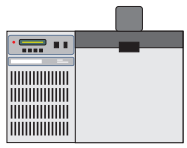
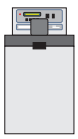
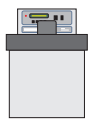
9934-S	Log*Ware*, Single Channel, Single User
9934-M	Log*Ware*, Single Channel, Multi User
9935-S	Log*Ware* II, Multi Channel, Single User
9935-M	Log*Ware* II, Multi Channel, Multi User

Get the latest product information at www.hartscientific.com

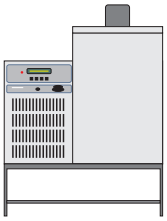
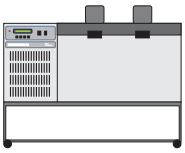
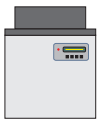
Software

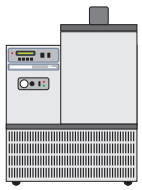
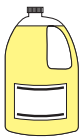
BATH SUMMARY

Compact Series	Model	Range	Stability	Depth	Features	Page
	6330	35°C to 300°C	±0.005°C at 100°C ±0.015°C at 300°C	9.25" 234 mm	Small benchtop footprint. Optional cart includes storage space.	82
	7320	–20°C to 150°C	±0.005°C at –20°C ±0.005°C at 25°C	9.25" 234 mm	Small 2.4-gallon (9.2-liter) tank. Uniformity ±0.005°C.	
	7340	–40°C to 150°C	±0.005°C at –40°C ±0.005°C at 25°C	9.25" 234 mm	Low temperature calibrations. Metrology-level performance.	
	7380	–80°C to 100°C	±0.006°C at –80°C ±0.010°C at 0°C	7" 178 mm	Achieves –80°C in less than 130 minutes. Quiet operation.	
	7312	–5°C to 110°C	±0.001°C at 0°C	19.5" 496 mm	Maintains two TPW cells. Compact, quiet.	20
	6331	40°C to 300°C	±0.007°C at 100°C ±0.015°C at 300°C	18" 457 mm	18" of depth with just 16 liters of fluid. RS-232 included.	84
	7321	–20°C to 150°C	±0.005°C at –20°C ±0.005°C at 25°C	18" 457 mm	Perfect for LIG thermometers with optional kit. Quiet operation.	
	7341	–40°C to 150°C	±0.005°C at –40°C ±0.005°C at 25°C	18" 457 mm	Fast temperature changes. Access opening accommodates many thermometers.	
	7381	–80°C to 110°C	±0.006°C at –80°C ±0.005°C at 0°C	18" 457 mm	Stability of ±0.006°C or better over full range. Compatible with MET/TEMP II software.	

Standard Baths	Model	Range	Stability	Depth	Features	Page
	7060	–60°C to 110°C	±0.0025°C at –60°C ±0.0015°C at 25°C	12" 305 mm	Reaches –60°C with standard refrigeration.	88
	7080	–80°C to 110°C	±0.0025°C at –80°C ±0.0015°C at 25°C	12" 305 mm	Best combination of stability and ultralow temperatures.	
	7100	–100°C to 110°C	±0.003°C at –100°C	13.25" 337 mm	No external cooling for –100°C.	
	7008	–5°C to 110°C	±0.0007°C at 25°C	13" 331 mm	Large tank for larger mass immersion. Maintains standard resistors.	90
	7011	–10°C to 110°C	±0.0008°C at 0°C ±0.0008°C at 25°C	12" 305 mm	Self-contained refrigeration. Best-priced ultrastable, cooled bath.	
	7012	–10°C to 110°C	±0.0008°C at 0°C ±0.0008°C at 25°C	18" 457 mm	Maintains up to 4 WTP cells for weeks. Large access: 6.3" x 11.5" (162 x 292 mm).	
	7030	–30°C to 150°C	±0.006°C	11" 279 mm	Fast heating and cooling. Optional fluid level adapter for LIGs.	
	7037	–40°C to 110°C	±0.002°C at –40°C ±0.0015°C at 25°C	18" 457 mm	Lowest-temperature deep-well bath. Mercury cell maintenance bath.	
	7040	–40°C to 110°C	±0.002°C at –40°C ±0.0015°C at 25°C	12" 305 mm	Self-contained single-stage refrigeration. Digital controller.	
	6020	40°C to 300°C	±0.001°C at 40°C ±0.005°C at 300°C	12" 305 mm	Broad range to 300°C. Optional RS-232 and IEEE-488 interface.	94
	6022	40°C to 300°C	±0.001°C at 40°C ±0.005°C at 300°C	18.25" 464 mm	Deep tank for SPRT or LIG thermometers. Optional fluid level adapter.	
	6024	40°C to 300°C	±0.001°C at 40°C ±0.005°C at 300°C	13.25" 337 mm	Larger access opening and tank size for higher throughput.	
	6045	40°C to 400°C	±0.002°C at 100°C ±0.004°C at 400°C	12" 305 mm	Designed for use with oil or salt. High-resolution set-point to 0.00018°C.	96
	6050H	40°C to 550°C	±0.002°C at 200°C ±0.007°C at 500°C	12" 305 mm	Better stability than sand baths. High temperatures, low gradients.	

BATH SUMMARY

Special Application	Model	Range	Stability	Depth	Features	Page
	6054	50°C to 300°C	±0.003°C at 100°C ±0.005°C at 300°C	24" 610 mm	Maintains constant fluid level.	98
	6055	200°C to 550°C	±0.003°C at 200°C ±0.01°C at 550°C	17" 432 mm	Includes LIG sighting channel.	
	7007	–5°C to 110°C	±0.001°C at 0°C ±0.003°C at 100°C	24" 610 mm	Large, 7-inch-diameter working space.	
	7009	0°C to 110°C	±0.0007°C at 25°C	13" 331 mm	Largest capacity with 4.8-cubic foot (167-liter) working area and 0.7 mK stability.	100
	7015	0°C to 110°C	±0.0007°C at 25°C	13" 331 mm	Ultrastable for maintaining resistors. Large access and workspace. Splash- and spill-resistant lid.	
	7108	20°C to 30°C	±0.004°C	8" 203 mm	Peltier cooling means no compressor and quieter performance. Maintains standard resistors.	
	7911A2	0°C	±0.002°C	8" 203 mm	Easy and affordable zero-point source for calibrating temperature sensors	102

Other	Item	Description	Page
	Custom Baths	Hart Scientific offers a wide variety of customized temperature baths including: ■ oceanography baths with titanium tanks ■ windowed baths for LIG and viscometry applications ■ baths with built-in low-temperature blackbody cones ■ baths with extended or shortened depths and widths ■ much more—just tell us what you need	103
	Bath Fluids	Silicone oils, salt, and cold fluids in convenient, small quantities.	104
	Bath Accessories	Fluid level adapters, LIG magnifier, probe holding stands, brackets, and clamps.	106
	Rosemount Bath Controllers	Model 7900 controller designed by Hart integrates the features of Hart's 2100 controller and can be used in place of the Rosemount 915 controller with Rosemount-designed baths.	108
	Hart Bath Controllers	Model 2100 and 2200 controllers can be integrated with homemade baths or other heat sources to achieve performance levels approaching Hart baths.	109

Note: See page 112 for portable Micro-Baths.

COMPACT BATHS

Compact Baths **6330, 7320, 7340, and 7380**

- Stability and uniformity each better than ±0.008°C
- Metrology-level performance in lab-friendly sizes
- Convenient use on benchtops or on matching carts

When you only need a circulator or utility bath to control a process within a few degrees or to maintain biological test samples, talk to a utility bath manufacturer. But when you're doing precision thermometer testing, and stability and uniformity are critical to the success of your work, talk to us.

Hart Scientific has been making the world's best-performing temperature baths for almost two decades. With our proven heating/cooling designs and hybrid analog-digital controller, Hart baths apply the most effective technologies that are commercially feasible. These four compact baths are no exception.

Model 6330

This bath delivers all the high temperatures you need up to 300°C (572°F). With stability and uniformity at 300°C better than ±0.015°C and ±0.020°C respectively, calibrations can easily be performed at this high temperature with total uncertainty better than ±0.05°C. At lower temperatures, stability and uniformity are even better.

The 6330 is only 12 inches wide and less than 19 inches tall, so it fits easily onto a benchtop without consuming precious space. An optional cart with casters and a storage area raises the 6330 to a convenient height when used on a floor and provides an extra cabinet for lab supplies. With built-in handles, it even lifts easily onto and off of its cart or benchtop. No matter where you want to use this bath—or even if you want to move it around—the 6330 gets there hassle-free.

Models 7320 and 7340

Also featuring large work areas, our Model 7320 and 7340 baths cover your needs for low temperature calibrations. The 7320 covers a range from –20°C to 150°C and the 7340 reaches even colder temperatures to –40°C. Below 0°C, these baths maintain an impressive stability of ±0.005°C with uniformities better than ±0.006°C. No utility bath performs as well as Hart's compact baths below 0°C or at critical room and body temperatures—or even at important higher temperatures such at 100°C and 122°C.

Model 7380

For ultracold temperatures, the 7380 reaches –80°C quickly and maintains a two-sigma stability of ±0.006°C when it gets there. The 7380 is a true metrology bath, not a chiller or circulator. With uniformity to ±0.008°C, comparison calibration of temperature devices can be performed with high precision.

Each bath includes an RS-232 serial interface and our Model 9930 Interface-*it* software for controlling your bath from a PC. With a Hart Scientific thermometer readout, such as a *Black Stack,* and our MET/TEMP II software, automated calibrations can run unattended.

Hart Scientific doesn't make chillers, circulators, or so-called utility baths, and utility bath manufacturers don't make metrology baths. Use the right tools for your work and reap the best possible results. Baths from Hart Scientific are the most stable and uniform of any you'll find. They'll give you results no other bath can.

With an optional floor cart (including locking casters), your bath can easily be moved to any place you need it. (Available for the 6330, 7320, or 7340. Casters included on the 7380.)

Specifications	6330	7320	7340	7380
Range	35°C to 300°C	–20°C to 150°C	–40°C to 150°C	–80°C to 100°C
Stability	±0.005°C at 100°C (oil 5012) ±0.010°C at 200°C (oil 5017) ±0.015°C at 300°C (oil 5017)	±0.005°C at –20°C (ethanol) ±0.005°C at 25°C (water) ±0.007°C at 150°C (oil 5012)	±0.005°C at –40°C (ethanol) ±0.005°C at 25°C (water) ±0.007°C at 150°C (oil 5012)	±0.006°C at –80°C (ethanol) ±0.010°C at 0°C (ethanol) ±0.010°C at 100°C (oil 5012)
Uniformity	±0.007°C at 100°C (oil 5012) ±0.015°C at 200°C (oil 5017) ±0.020°C at 300°C (oil 5017)	±0.005°C at –20°C (ethanol) ±0.005°C at 25°C (water) ±0.010°C at 150°C (oil 5012)	±0.006°C at –40°C (ethanol) ±0.005°C at 25°C (water) ±0.010°C at 150°C (oil 5012)	±0.008°C at –80°C (ethanol) ±0.012°C at 0°C (ethanol) ±0.012°C at 100°C (oil 5012)
Heating Time†	250 minutes, from 35°C to 300°C (oil 5017)	80 minutes, from 25°C to 150°C (oil 5012)	60 minutes, from 25°C to 150°C (oil 5012)	25 minutes, from 25°C to 100°C (oil 5010)
Cooling Time	n/a	100 minutes, from 25°C to –20°C (oil 5012)	110 minutes, from 25°C to –40°C (ethanol)	130 minutes, from 25°C to –80°C (ethanol)
Stabilization Time	15–20 minutes			
Temperature Setting	Digital display with push-button data entry			
Set-Point Resolution	0.01°; 0.00018° in high-resolution mode			0.01°
Display Resolution	0.01°			
Digital Setting Accuracy	±0.5°C			
Digital Setting Repeatability	±0.01°C			
Access Opening	3.7" x 6.8" (94 x 172 mm)			3.25" x 4.5" (86 x 114 mm)
Working Area	3.2" x 5.25" (81 x 133 mm)			3" x 4" (86 x 114 mm)
Depth	9.25" (234 mm)			7" (178 mm)
Wetted Parts	304 stainless steel			
Power	115 VAC (±10%), 50/60 Hz, 7 A or 230 VAC (±10%), 50/60 Hz, 3.5 A, specify	115 VAC (±10%), 60 Hz, 15 A or 230 VAC (±10%), 50 Hz, 8 A, specify, 1400 VA		115 VAC (±10%) 60 Hz, 16 A or 230 VAC (±10%), 50 Hz, 8 A, specify
Volume	2.4 gal (9.2 liters)			1 gal (4 liters)
Size	12" W x 21.5" D x 18.5" H (305 x 546 x 470 mm) off cart; 12" W x 21.5" D x 32.25" H (305 x 546 x 819 mm) on cart	12" W x 24.5" D x 23" H (305 x 622 x 584 mm) off cart; 12" W x 24.5" D x 32.25" H (305 x 622 x 819 mm) on cart		12" W x 24" D x 30" H (305 x 610 x 762 mm)
Weight	42 lb. (19 kg)	78 lb. (35.4 kg)		115 lb. (52 kg)
Automation Package	Interface-*it* software and RS-232 included (IEEE-488 optional)			

†Rated at nominal 115 V (or optional 230 V)

Technical Tip

Bath Fluid Affects Performance

Hart determines its bath specifications by using selected fluids for particular temperatures. Your application, however, may require different fluids over different temperatures. Considering that fluid characteristics change with temperature, some care must be taken to apply general specifications to your own application.

For example, Hart often uses water to spec baths at 25°C. The properties of viscosity, thermal conductivity, and heat capacity make water an ideal fluid at 25°C. However, if you want to cover a range from –5°C to 110°C, water just won't work. Hart's 5010 silicone oil fluid will more than adequately cover that range, but it may not perform as well as water at 25°C. Carefully testing the fluid you use over the range you use can tell you what you need to know for your uncertainty budget.

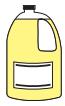
Ordering Information

6330	Compact Bath, 35°C to 300°C
2020-6330	Spare Access Cover, SST, 6330
2076-6330	Floor Cart, 6330 (13.5" H)
2001-IEEE	IEEE-488 Interface

7320	Compact Bath, –20°C to 150°C
2020-7320	Spare Access Cover, SST, 7320/7340
2076-7320	Floor Cart, 7320/7340 (9" H)
2001-IEEE	IEEE-488 Interface

7340	Compact Bath, –40°C to 150°C
2020-7320	Spare Access Cover, SST, 7320/7340
2076-7320	Floor Cart, 7320/7340 (9"H)
2001-IEEE	IEEE-488 Interface

7380	Compact Bath, –80°C to 100°C
2020-7380	Spare Access Cover, SST, 7380
2125-C	IEEE-488 Interface (RS-232 to IEEE-488 converter box)



See our selection of bath fluids on page 104.

See our calibration and data acquisition software packages on page 74.

DEEP-WELL COMPACT BATHS

Deep-Well Compact Baths **Models 6331, 7321, 7341, and 7381**

- 18" of depth with just 4.2 gallons of fluid
- Perfect for liquid-in-glass thermometer calibrations with optional LIG kit
- Fast, quiet, compact (yet deep!), and economical

Need a bath with a lot of immersion depth, great stability, and a low price tag? How about one that minimizes fluid costs, changes temperatures quickly, and runs quietly? (Did we mention these new baths look fantastic?)

Hart's new Deep-Well Compact Bath series features four models covering temperatures from –80°C to 300°C.

Each model includes an 18-inch (457 mm) deep tank to accommodate long-stem PRTs, SPRTs, and liquid-in-glass (LIG) thermometers. Access openings are 4.7" by 6.8" (120 by 172 mm) so you can calibrate many thermometers simultaneously. Yet only 4.2 gallons (15.9 liters) of fluid are needed to get all the benefits Deep-Well Compact Baths offer.

Using Hart's own best-in-class temperature controller, these baths deliver the performance you need for confidence in your calibrations. The Model 7381 (–80°C to 110°C) features both stability and uniformity better than ±0.007°C over its entire range. The Models 7341 and 7321 (–40°C to 150°C and –20°C to 150°C, respectively) are stable to ±0.005°C and uniform to ±0.007°C at temperatures below ambient. And the Model 6331 provides stability and uniformity from ±0.007°C to ±0.025°C over its range from 40°C to 300°C.

Be sure to understand the performance of the temperature calibration equipment you buy. Some manufacturers offer only limited (and often difficult to interpret) specifications. The table at right includes stability and uniformity values for the entire range of each bath—and tells you what fluid we used in the measurements. If that's still not enough, give us a call and we'll be happy to explain anything—and share data with you.

Hart's control system automatically adds refrigeration when you need to cool down quickly, and shuts down refrigeration when you need to heat up quickly. For maximum stability, refrigeration levels are automatically balanced to match the set-point temperature you're working at.

Connect any of these baths to a Hart thermometer readout and Hart's industry-leading MET/TEMP II temperature calibration software, and you'll be performing automated probe calibrations within minutes from switch-on.

Want to optimize your bath for calibrating liquid-in-glass thermometers? Simple. With the optional LIG Thermometer Calibration Kit, you get an easy-to-install fluid level adapter tube that raises the meniscus of the bath fluid to within about 0.5" of the top surface of the bath itself. The kit also includes a thermometer carousel that fits onto the top of the fluid level adapter tube and holds up to ten LIG thermometers in place. A magnifying scope (8X) is also available that mounts to the front of any Deep-Well Compact Bath so you can clearly see the liquid level of your thermometer against its temperature scale (see page 106).

Like all Hart baths, these units come with a report of test that includes one hour of stability data and a verification of set-point accuracy. A convenient overflow reservoir captures any excess fluid resulting from fluid expansion, allowing the trapped fluid to be reused following subsequent fluid contraction. A drain is also provided for easily emptying the bath's tank when needed.

The 2019-DCB Liquid-in-Glass Thermometer Calibration Kit includes a carousel which holds up to 10 thermometers and an adapter tube which raises the bath fluid level to within 5–15 mm of the thermometers' readings. The 2069 Magnifier Scope mounts easily to the front of any Deep-Well Compact Bath to provide magnification of 8X or greater.

Ranges from –80°C to 300°C

Specifications	6331	7321	7341	7381‡
Range	40°C to 300°C	–20°C to 150°C	–40°C to 150°C	–80°C to 110°C
Stability	±0.007°C at 100°C (oil 5012) ±0.010°C at 200°C (oil 5017) ±0.015°C at 300°C (oil 5017)	±0.005°C at –20°C (ethanol) ±0.005°C at 25°C (water) ±0.007°C at 150°C (oil 5012)	±0.005°C at –40°C (ethanol) ±0.005°C at 25°C (water) ±0.007°C at 150°C (oil 5012)	±0.006°C at –80°C (ethanol) ±0.005°C at 0°C (ethanol) ±0.005°C at 100°C (oil 5012)
Uniformity	±0.007°C at 100°C (oil 5012) ±0.017°C at 200°C (oil 5017) ±0.025°C at 300°C (oil 5017)	±0.007°C at –20°C (ethanol) ±0.007°C at 25°C (water) ±0.010°C at 150°C (oil 5012)	±0.007°C at –40°C (ethanol) ±0.007°C at 25°C (water) ±0.010°C at 150°C (oil 5012)	±0.007°C at –80°C (ethanol) ±0.007°C at 0°C (ethanol) ±0.007°C at 100°C (oil 5012)
Heating Time†	130 minutes, from 40°C to 300°C (oil 5017)	120 minutes, from 25°C to 150°C (oil 5012)	120 minutes, from 25°C to 150°C (oil 5012)	60 minutes, from 25°C to 100°C (oil 5012)
Cooling Time†	14 hours, from 300°C to 100°C (oil 5017)	110 minutes, from 25°C to –20°C (ethanol)	120 minutes, from 25°C to –40°C (ethanol)	6 hours, from 25°C to –80°C (ethanol)
Stabilization Time	15–20 minutes			
Temperature Setting	Digital display with push-button data entry			
Set-Point Resolution	0.01°; 0.00018° in high-resolution mode			
Display Resolution	0.01°			
Digital Setting Accuracy	±1°C			
Digital Setting Repeatability	±0.01°C			
Access Opening	4.7" x 6.8" (120 x 172 mm)			
Depth	18" (457 mm) without Liquid-in-Glass Thermometer Cal Kit 19" (482 mm) with Liquid-in-Glass Thermometer Cal Kit			
Wetted Parts	304 stainless steel			
Power†	115 VAC (±10%), 50/60 Hz, 15 A or 230 VAC (±10%), 50/60 Hz, 8 A, specify	115 VAC (±10%), 60 Hz, 14 A or 230 VAC (±10%), 50 Hz, 7 A, specify	115 VAC (±10%), 60 Hz, 16 A or 230 VAC (±10%), 50 Hz, 8 A, specify	230 VAC (±10%), 50 or 60 Hz, specify, 10 A
Volume	4.2 gal (15.9 liters)			
Size	14" W x 31" D x 42" H (37" from floor to tank access opening) (356 x 788 x 1067 mm) (940 mm from floor to tank access opening)			
Weight	72 lb. (33 kg)	103 lb. (47 kg)	105 lb. (48 kg)	167 lb. (76 kg)
Automation Package	Interface-*it* software and RS-232 included (IEEE-488 optional)			

†Rated at nominal 115 V (or optional 230 V) ‡Call for availability. These specs are preliminary.

Ordering Information

6331	Deep Compact Bath, 40°C to 300°C
7321	Deep Compact Bath, –20°C to 150°C
7341	Deep Compact Bath, –40°C to 150°C
7381	Deep Compact Bath, –80°C to 110°C‡
2012-DCB	Spare Access Cover, Plastic, 7321, 7341, 7381
2020-6331	Spare Access Cover, Stainless Steel, 6331
2019-DCB	Liquid-in-Glass Thermometer Calibration Kit (includes bath adapter tube and thermometer carousel)
2069	8X Magnifier Scope, with mounts (page 106)
2001-IEEE	IEEE-488 Interface

See our selection of bath fluids on page 104.

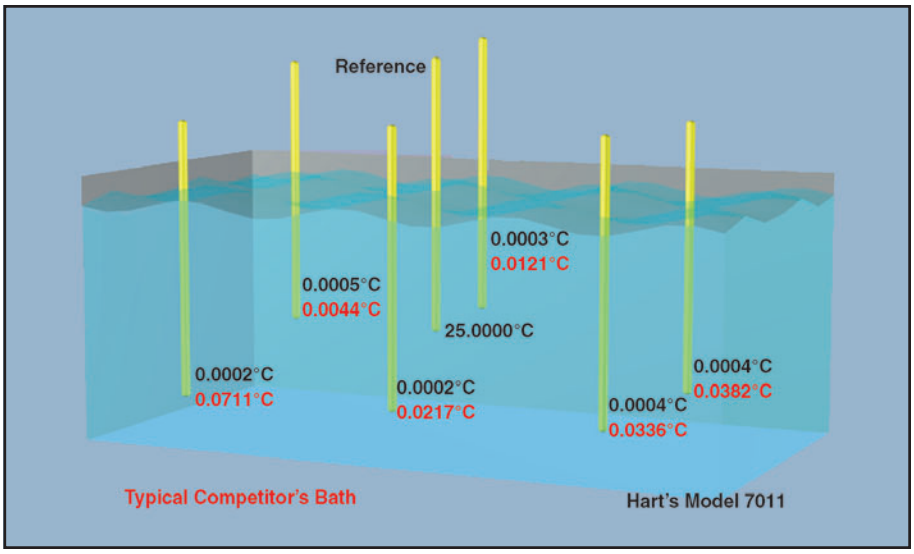
Have you considered a good reference thermometer? See page 36.

Dickens and Tolstoy are OK, but Rick's (electrical engineering) favorite books are all about Ohm's Law.

BUYING THE RIGHT BATH

During a European trip we visited a lab struggling through the lab accreditation process. The hold-up was their bath. They had already tested baths from two manufacturers. The first bath didn't meet specs and the maker would not rectify the situation, so the bath was returned. The second bath maker delivered a working bath, but when the accreditation auditor tested the bath he downgraded the lab's accuracy class because they couldn't meet the required stability and uniformity levels.

Most bath manufacturers tell you as little as possible about their baths' performance. In fact, a few years ago one of our competitors used to tell people that high bath stability wasn't even necessary for accurate calibrations. Some still don't publish stability specs, and some are so elusive about the meaning of their specs that you can only conclude they've got something to hide.



Deviations from a central reference temperature taken in water with a 1/4-inch-diameter PRT at 25°C.

Lab Accreditation

Accreditation guidelines published by NVLAP specify that the temperature stability and uniformity of the bath fluid should be at least *10 times better* than the required uncertainty of the sensor being calibrated. If you're testing a sensor with a modest specification of ±0.1°F over its whole range, your bath must be stable and uniform to ±0.01°F. Translated to Celsius, this figure becomes ±0.005°C, and you find yourself in need of a bath with performance to the third decimal place *at each of the temperatures you must test.* Several issues are involved in selecting a bath, and each item impacts your calibrations.

Stability

Stability is a measure of the bath's control performance. How well does it maintain a constant temperature? Short-term instability is normally seen as an oscillation around the control point with its peaks defined in a "2-sigma" or "±" statement. If the temperature of the bath fluid is changing during your measurements, you can't get reliable calibration results. Short-term stability is therefore absolutely crucial. Ask about short-term stability and define short-term as lasting at least 15 minutes. Less than that can prove very frustrating.

Long-term stability (over several hours, days, or weeks) is a convenience issue. If your work requires an exact or absolute value, say 25.000°C, and the bath has long-term drift, you must readjust the control set-point and wait for equilibration (attainment of short-term stability) before each use. So you really need to know both short-term and long-term stability before you know if a bath will meet your needs. Long-term instability normally takes the form of drift in a single direction, but in some baths it may be seen as a long-term oscillation.

A bath's stability will vary at different temperatures. Most baths perform best at temperatures close to ambient. The colder or hotter the set-point, the less stability. Too many sellers give you only one spec at or near ambient. Some give a single stability spec and don't ever mention that it applies only to one temperature or a narrow range. Ask about stability over the whole range that interests you.

Bath fluid also affects stability. The higher a fluid's viscosity and the lower its heat capacity, the larger the effect on stability. In addition to asking the temperature, ask what fluid was used when the spec was taken. For example, at 37°C a bath will be more stable with water as the medium. If you're going to use oil, expect somewhat larger instability. If your oil has high viscosity at 37°C, expect even greater degradation in stability.

Uniformity

A bath can have good stability but poor uniformity. The bath must be homogenous in temperature throughout the test zone where you'll make your comparison measurements. When you place two or more thermometers in the fluid, they should be at the same temperature during your measurement. The uniformity spec defines the peak value for this error source. The more probes you're testing, the larger the test zone, and the more important uniformity becomes.

Uniformity depends mostly on the mixing of the bath fluid. Does the bath use a circulator pump for mixing? If it does, are there thermal flow patterns in the bath that interfere with uniformity? Ask about both vertical and horizontal gradients.

In a laminar flow bath (one where the fluid is stirred in a circular pattern), there may be no horizontal gradient, but because the fluid is not mixed vertically, there are gradients between different depths in the bath. This is a problem if your reference probe and the probes under test are not the same length. For example, if you're testing 3-inch-long probes and your standard is a

19-inch SPRT, you've got a problem. You can only immerse the test probes to 3 inches, but if you immerse the SPRT to only 3 inches you don't have sufficient depth to avoid stem effects and light piping that will affect the measurement made by the SPRT. If you properly immerse the SPRT and your bath suffers from vertical gradients, you won't be measuring the temperature at the 3-inch depth of your probes under test.

Equilibration Blocks

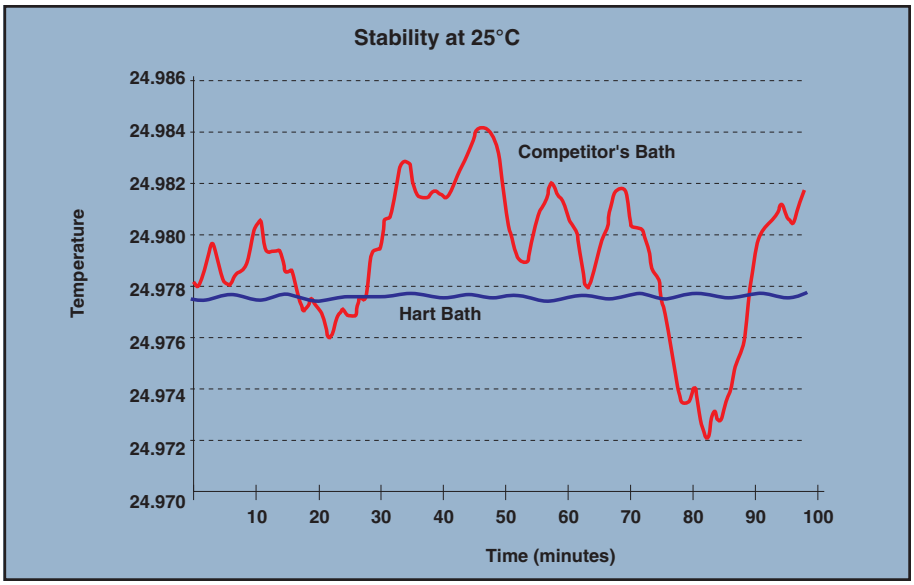
Accreditation guidelines recommend the use of a metal equilibration block to improve short-term stability during the measurement. It's certainly true that a block can increase the stability of your measurements.

However, a block can be inconvenient. The fixed location and diameter of its holes eliminate the flexibility of a bath to readily test any size or shape of thermometer. You'll need a new block for each probe type. Placing the probes in the block and the block in the bath is somewhat less convenient than simply dipping the probes directly in the liquid. Blocks also oxidize, and silicone oil will thicken and stick in the bottom of the holes. Regular cleaning is required to ensure continued performance levels. If you're testing many probes at a time, a block may not even work for you. It would be difficult to construct a block to properly test 20 thermometers at a time.

Evaluate your bath purchase on specifications taken directly in the bath's fluid. If you're given performance graphs, ask if a block was used. In your lab you can always add a block for the most critical measurements. Remember: *the bath that performs the best without a block will also be the bath that performs the best with a block.*

Temperature Range

The advertised temperature range of a bath is not necessarily the practical usable range. For example, a bath with a published range of –80°C to 150°C can be a bit misleading. The bath may operate over that temperature range, but currently there's no fluid to match that whole range. Those fluids that perform best at –80°C will evaporate too rapidly long before they get to 100°C, much less 150°C.



Hart baths can achieve stability better than 1 mK for extended periods of time.

An oil bath with an advertised range of 35°C to 300°C will be limited by the silicone oil you put in it. A good 300°C oil will be too viscous to deliver good performance below about 80°C, so with that fluid the bath's range is 80°C to 300°C. In another example, a Hart salt bath works quite well at 40°C with the right fluid. But salt is molten only above 150°C.

In addition to fluid, other factors mechanically limit a bath's range. These include refrigeration, insulation, heater types, and other design issues. Refrigeration gases break down above 150°C, thus limiting the life of the system. If a refrigerated bath is advertised with a higher range, ask if you must remove the cooling coil above a certain temperature. Some baths are advertised with ranges from –80°C to 300°C in a single bath. However, the refrigeration gases or coils must be removed before going to the higher end of the temperature range.

We could probably design a single bath that could operate from –100°C to 500°C. Besides the high price for such a bath, there would be no point. You would have to drain, clean, and refill the bath at least three times during a calibration run in order to cover that range. The best solution to cover –100°C to 500°C is at least three baths with three different fluids. This way each bath design is optimized for performance in the range of the fluid you would use. You'll get the best stability and uniformity while tripling your throughput.

Can You Ask Too Many Questions?

It's not likely that a manufacturer will have a test file covering every temperature and fluid combination that interests you, but you can look for representative numbers. How many numbers will they give you? The more the better.

If a salesman says his bath's stability spec of ±0.005°C applies to the whole range, ask for a graph at several temperatures. If you're buying a bath for use at 300°C and the maker can't give you performance data above 100°C, you need to be skeptical.

If a salesman talks about "calibration accuracy" instead of bath performance, ask for specific stability and uniformity data taken in the bath fluid. Finally, ask for a money-back guarantee of the performance. If you can't get what you need from the bath when it's in your lab, you need to know your supplier will be there for you.

REALLY COLD BATHS

Really Cold Baths — Models 7060, 7080, and 7100

- Self-contained refrigeration — no LN_2 or chiller required
- Temperatures as low as –100°C in real metrology baths
- Best stability and uniformity available at –60°C and below
- Large working areas for increased throughput

Do you need a bath that chills below –40°C to temperatures as low as –60°C or even –100°C? Would you like a bath that reaches those temperatures without using any external coolants? Hart has a variety of baths that meet these temperature requirements and give you the best stability in the industry.

These baths are completely self-contained. They require no auxiliary cooling fluids or devices to achieve their set-point temperatures. Using Hart's unique "heat-port" design, stability at –100°C is ±0.0025°C. No other company makes a bath that can match a Hart bath's performance, and Hart baths are backed by our guarantee that if they don't perform exactly the way we say they will, we'll take them back. No arguments. No ifs, ands, or buts. These baths work—period!

Automate each of these baths with an interface package and Hart's 9930 Interface-*it* software. If you want to completely automate the entire calibration process, see the description of Hart's MET/TEMP II software package on page 75.

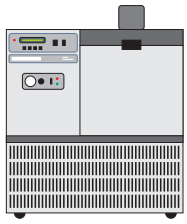
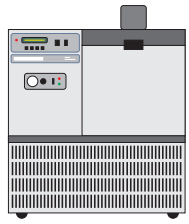
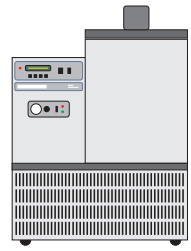
Forget commodity-like utility baths! They're not designed for high performance calibration needs. And be careful of companies that advertise performance specifications they don't meet. It's easy to write down numbers; it's more difficult to meet them with an instrument.

Remember, if our baths don't perform the way we say they will, just send them back. Our equipment won't disappoint you.

Ordering Information

7060	Standard Bath, –60°C to 110°C
7080	Standard Bath, –80°C to 110°C
7100	Standard Bath, –100°C to 110°C
2001-7060	Automation Package for 7060
2001-7080	Automation Package for 7080
2001-7100	Automation Package for 7100
2001-IEEE	Add for IEEE-488 (requires Automation Package)
2010	Access Cover, 5" x 10", Lexan
2007	Access Cover, 5" x 10", Stainless Steel
2011	Access Cover, 7.25" x 12.75", Lexan
2009	Access Cover, 7.25" x 12.75", Stainless Steel
2016-7060	Fluid Level Adapter, 7060 (page 106)
2016-7080	Fluid Level Adapter, 7080 (page 106)
2019-7100	Fluid Level Adapter, 7100 (page 106)
2069	8X Magnifier Scope, with mounts (page 106)
2030	Fast Start Cooler

No product durability test is too severe for Dave (mechanical engineering).

Specifications	7060	7080	7100
			
Range	–60°C to 110°C	–80°C to 110°C	–100°C to 110°C
Stability	±0.0025°C at –60°C (methanol) ±0.002°C at 0°C (methanol) ±0.0015°C at 25°C (water) ±0.003°C at 100°C (oil 5012)	±0.0025°C at –80°C (methanol) ±0.0015°C at 0°C (methanol) ±0.0015°C at 25°C (water) ±0.003°C at 100°C (oil 5012)	±0.003°C at –100°C (methanol)
Uniformity	±0.005°C at –60°C (methanol) ±0.005°C at 0°C (methanol) ±0.003°C at 25°C (water) ±0.005°C at 100°C (oil 5012)	±0.007°C at –80°C (methanol) ±0.005°C at 0°C (methanol) ±0.003°C at 25°C (water) ±0.005°C at 100°C (oil 5012)	±0.005°C at –100°C (methanol)
Temperature Setting	Digital display with push-button data entry		
Set-Point Resolution	0.01°C; high-resolution mode, 0.00007°C		
Display Resolution	0.01°C		
Digital Setting Accuracy	±1°C		
Digital Setting Repeatability	±0.01°C		
Heaters	500 and 1000 Watts		350 and 700 Watts
Access Opening (call for custom sizes)	5" x 10" (127 x 254 mm)		3.8" diameter (98 mm)
Depth	12" (305 mm)		16" (406 mm)
Wetted Parts	304 stainless steel		
Power	230 VAC (±10%), 50 or 60 Hz, 13 A, single phase, specify frequency		230 VAC (±10%), 50 or 60 Hz, 12 A, specify frequency
Volume	7.2 gallons (27 liters)		4.8 gallons (18 liters)
Weight	350 lb. (159 kg)		400 lb. (182 kg)
Size	46" H x 30.5" W x 19" D (1168 x 775 x 483 mm)		50" H x 32" W x 19" D (1270 x 813 x 483 mm)
Automation Package	Interface-*it* software and an RS-232 computer interface are available for setting the bath temperature via an external computer. For IEEE-488, add 2001-IEEE to the automation package.		

Technical Tip

Avoid Moisture Problems in Cold Baths

Water vapor from ambient air can condense into your cold bath at temperatures below the dew point. This can create problems for your bath's stability, uniformity, and ability to cool.

If you're using a water miscible bath fluid, like alcohol or ethylene glycol, the water is simply absorbed by the fluid. However, as the water content increases, ice crystals can form, increasing the viscosity of the fluid.

In fluids that do not absorb water (like silicone oils), water will collect as ice on the surfaces of bath tanks or exposed cooling coils. Eventually, the ice can form an insulating barrier between the cooled tank wall (or coils) and the bath fluid itself. In this case, the bath may develop trouble reaching its low temperature and keeping the fluid uniform and stable. In extreme cases, enough ice can build up to impede the stirring of the fluid. This moisture problem is obviously more pronounced in more humid environments.

Here's what you can do:

- Always keep the bath access cover in place to prevent moist ambient air from circulating into the bath.
- Supply a dry air positive pressure in the bath. You can do this by running a tube from a dry air source through a stoppered hole, like the bath fill hole. Be sure to adjust the gas flow so it's just enough to maintain a positive pressure flow.
- Periodically boil off the water at 100°C when using oils.
- Replace alcohol when it becomes saturated with water.

COLD BATHS

Cold Baths **Models 7008, 7011, 7012, 7030, 7037, and 7040**

- Stability to ±0.0007°C
- Best digital temperature controller available
- "Super Tweak" function provides set-point resolution to 0.00003°C
- Excellent for maintaining fixed-point cells

Hart Scientific's temperature calibration baths are known around the world as the best calibration baths made. If you're looking for a cold bath, no one gives you more choices than Hart.

These six baths operate at temperatures as low as –40°C, and each one is built using CFC-free refrigerants. Hart's proprietary controller design and unique tank construction produce bath stabilities to ±0.001°C or better. These baths are so stable and uniform that national labs use them for comparison calibrations and fixed-point cell maintenance.

Each bath (except the 7011) is fully automatable with a bath interface package and Hart's MET/TEMP II automation software package described on page 75. When we automate a bath, we automate it completely with computer-controlled solenoid valves for precision balancing of the heating and cooling system. MET/TEMP II performs all calibration tasks automatically, using your PC.

With a Hart cold bath, you can forget external coolants. Internal refrigeration systems are all that's needed to reach each bath's coldest temperature. Most cold baths may be ordered with an optional pumping lid for supplying external cooling requirements.

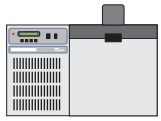
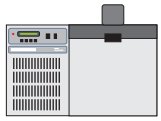
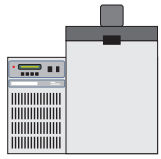
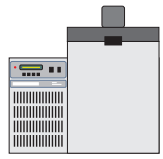
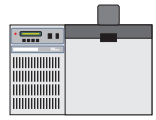
Not only are these the best-performing calibration baths in the industry, they're also the most reasonably priced. Hart is the largest manufacturer of temperature calibration baths, and larger volume means better pricing.

Each bath has unique characteristics that make it perfect for specific jobs. Some baths are excellent for SPRTs, some are great with thermistors, and some are perfect for maintaining triple point of water cells. A 7008IR bath can even be used to maintain the temperature of a blackbody cone.

Regardless of your application, Hart has a bath that gets the job done, and done better than anyone else can do it. Call us today and tell us about your application.

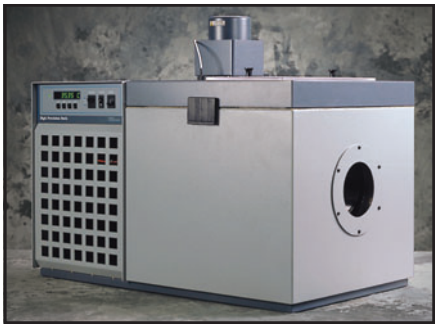
See our selection of bath fluids on page 104.

Ranges from –40°C to 150°C

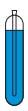
Specifications	7008	7040	7037	7012	7011	7030
						
Range	–5°C to 110°C	–40°C to 110°C		–10°C to 110°C		–30°C to 150°C
Stability	±0.0007°C at 25°C (water) ±0.001°C at 25°C (mineral oil)	±0.002°C at –40°C (ethanol) ±0.0015°C at 25°C (water) ±0.003°C at 100°C (oil 5012)		±0.0008°C at 0°C (ethanol) ±0.0008°C at 25°C (water) ±0.003°C at 100°C (oil 5012)		±0.006°C full range (oil 5012)
Uniformity	±0.003°C at 25°C (water) ±0.004°C at 25°C (mineral oil)	±0.004°C at –40°C (ethanol) ±0.002°C at 25°C (water) ±0.004°C at 100°C (oil 5012)		±0.003°C at 0°C (ethanol) ±0.002°C at 25°C (water) ±0.004°C at 100°C (oil 5012)		±0.010°C full range
Temperature Setting	Digital display with push-button data entry					
Set-Point Resolution	0.002°C; high-resolution mode, 0.00003°C	0.01°C; high-resolution mode, 0.00007°C		0.002°C; high-resolution mode, 0.00003°C		0.01°C; high-resolution mode, 0.00018°C
Display Resolution	0.01°C					
Digital Setting Accuracy	±1°C					
Digital Setting Repeatability	±0.01°C			±0.005°C		±0.01°C
Heaters	500 and 1000 Watts					
Access Opening (call for customs)	12.75" x 7.25" (324 x 184 mm)	5" x 10" (127 x 254 mm)	6.38" x 11.5" (162 x 292 mm)		5" x 10" (127 x 254 mm)	2.6″ diameter (66 mm)
Depth	13" (331 mm)	12" (305 mm)	18" (457 mm)		12" (305 mm)	11" (279 mm)
Wetted Parts	304 stainless steel					
Power	115 VAC (±10%), 60 Hz, 14 A or 230 VAC, 50 or 60 Hz, 8 A, specify	115 VAC (±10%), 60 Hz, 16 A or 230 VAC (±10%), 50 or 60 Hz, 9 A (specify voltage and frequency)		115 VAC (±10%), 60 Hz, 14 A or 230 VAC (±10%), 50 Hz, 7 A, specify		
Volume	11.2 gallons (42 liters)	7.2 gallons (27 liters)	11.2 gallons (42 liters)		7.2 gallons (27 liters)	1.6 gallons (6 liters)
Weight	135 lb. (61 kg)	140 pounds (63.5 kg)	150 pounds (68 kg)		125 pounds (56.7 kg)	120 pounds (54.4 kg)
Size	24" H x 30.5" W x 19" D (610 x 775 x 483 mm)	24.5" H x 30.25" W x 19" D (622 x 768 x 483 mm)	30.5" H x 30.25" W x 19" D (775 x 768 x 483 mm)	30" H x 27" W x 15.8" D (762 x 686 x 401 mm)	22" H x 27" W x 15.8" D (559 x 686 x 401 mm)	40" H x 15" W x 17" D (1016 x 381 x 432 mm)
Automation Package	Interface-*it* software and RS-232 computer interface are available for setting the bath temperature via an external computer. For IEEE-488, add the 2001-IEEE to the automation package. (Interfaces not available for Model 7011.)					

Ordering Information

7008	Standard Bath, –5°C to 110°C, high capacity
7011	Standard Bath, –10°C to 110°C
7012	Standard Bath, –10°C to 110°C, deep
7030	Standard Bath, –30°C to 150°C
7037	Standard Bath, –40°C to 110°C, deep
7040	Standard Bath, –40°C to 110°C
2001-7008	Automation Package for 7008
2001-7012	Automation Package for 7012
2001-7030	Automation Package for 7030
2001-7037	Automation Package for 7037
2001-7040	Automation Package for 7040
2001-IEEE	Add for IEEE-488 (requires Automation Package)
2007	Access Cover, 5" x 10", Stainless Steel (7011, 7037, 7040)
2010	Access Cover, 5" x 10", Lexan (7011, 7037, 7040)
2011	Access Cover, 7.25" x 12.75", Lexan (7008)
2016-7008	Fluid Level Adapter, 7008 (page 106)
2016-7011	Fluid Level Adapter, 7011 (page 106)
2016-7012	Fluid Level Adapter, 7012 (page 106)
2019-7030	Fluid Level Adapter, 7030 (page 106)
2016-7037	Fluid Level Adapter, 7037 (page 106)
2016-7040	Fluid Level Adapter, 7040 (page 106)
2071	Bath Cart, 7011, 7012 (12.3" H)
2073	Bath Cart, 7008, 7037, 7040 (8.5" H)
2027-5901	TPW Holding Fixture (7012, 7037)
2027-5903	Gallium Cell Holding Fixture (7012)
2069	8X Magnifier Scope, with mounts (page 106)
7008IR	7008, modified to accept an IR cone
2033	IR Cone (NIST design)



This Hart Model 7008-IR features a NIST-designed cone-shaped target.



See page 18 for triple point of water cells.

WHY A HART BATH?

Hart Scientific is the recognized leader in the design and manufacture of temperature calibration baths, with more Hart baths in calibration laboratories worldwide than any other bath supplier. We've achieved this position through delivering baths with a measurable difference. Hart baths were designed specifically for metrology, not adaptations of equipment designed for biology and chemistry laboratories. Hart baths provide performance you can trust and here's why.

Range of Baths

Four types of baths are available: standard baths, compact baths, new deep-immersion compact baths, and standard resistor baths. The wide range of baths means you'll absolutely find a bath to meet your application needs and your budget, whether you're working in a primary standards laboratory or an industrial workshop.

Standard baths, a favorite with National Metrology Institutes (NMI), are available for the range –100°C to 550°C and offer milli-Kelvin stability and uniformity. Hart standard baths have larger well openings than other baths. This makes them an excellent choice for sensor manufacturers and others that test large batches of sensors or special probes of unusual size and shape.

If you don't need the performance of a Hart standard bath, the Hart compact baths are the perfect alternative with ranges from –80°C to 300°C, more portability, and smaller fluid volumes. The new deep-immersion versions offer a full 18" of immersion depth with an optional fluid-level adaptor for calibration of total and partial-immersion liquid-in-glass thermometers.

For maintaining your standard resistors for electrical or temperature calibration work, a Hart resistor bath will provide unmatched stability and uniformity and a large working volume, up to 27.5" x 22" x 13".

Controllers

The first step in evaluating a bath is to look at its temperature controller. We designed our own proprietary control technology to deliver stability to ±0.0001°C with user convenience and productivity features. Our hybrid analog and digital design is unique. Set-point resolution is 0.01°C (0.002°C on some models), and our "Super-Tweak" resolution mode offsets the set-point so you can adjust the bath set-point to 0.00018°! If you need a bath set to exactly 25.000°C, a Hart bath gets you there with less effort than any other bath. Eight of your most frequently used set-point temperatures are stored for quick recall and faster bath setup. Temperature can be easily switched between Celsius and Fahrenheit. Safety cutout temperatures are also set on the LED display.

Hart baths are each fitted with a high-stability PRT or thermistor as the control sensor. Our controller uses special noise-rejection techniques to allow us to measure the very tiny resistance changes required for this level of bath stability. In this design we use current reversal techniques to cancel thermal EMF measurement errors. Custom, high-precision, low-coefficient resistors aid the short- and long-term stability of the temperature setting, and advanced filtering techniques force out line noise along with stray EMI and RFI.

A proportional, integrating control function directs power to the bath heaters. Factory tuning eliminates most overshoot and allows the bath to achieve maximum stability within 10 to 15 minutes after reaching the set-point temperature.

Other bath manufacturers use off-the-shelf process controllers, which just plain can't provide the low-noise, low-resistance measurement necessary for milli-Kelvin stability and uniformity over a bath's working range.

Automation

For improved productivity, automation is essential. You can select from an RS-232

interface or IEEE-488. The RS-232 packages come complete with 9930 Interface-*it* software so you can immediately start controlling your bath from a PC without any software programming skills.

With optional 9938 MET/TEMP II software, connect any Hart bath with an RS-232 interface to a Hart thermometer readout and you can perform fully automated probe calibrations.

Hart's compact baths use an automatic control for refrigeration power. However, the higher performance standard baths use a heating/cooling equilibrium design that's unique in the industry. A manual valve adjusts the cooling power to properly balance the refrigeration against the active control of the resistance heaters. Hart's standard bath interface packages include automated valves to make these adjustments automatically by your PC.

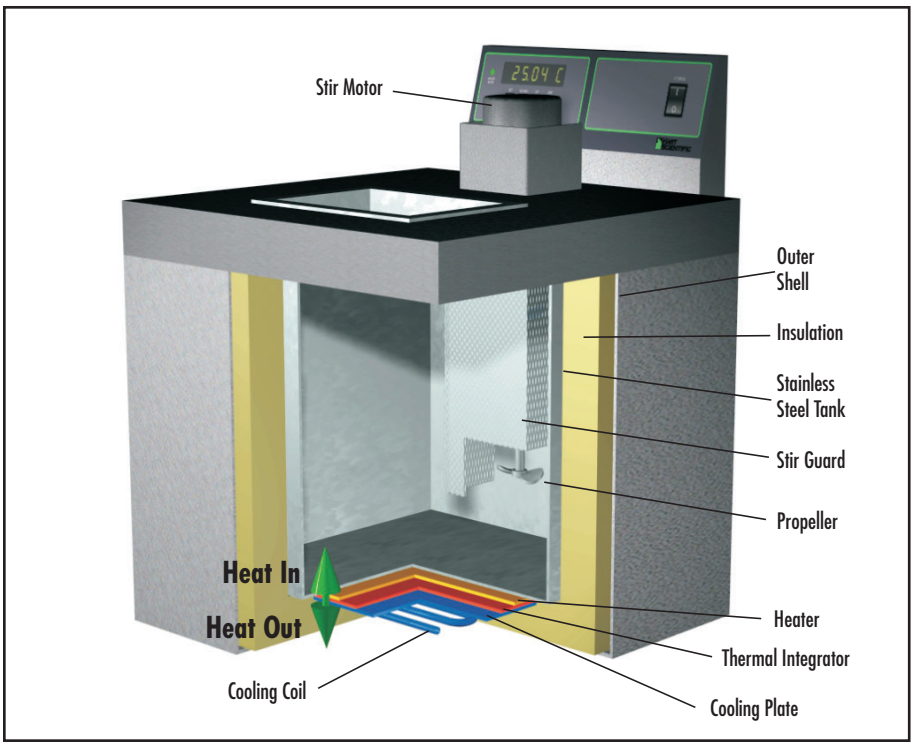
Heat-Port Technology

A major factor in Hart's standard bath performance is our heat-port technology. The cooling coil and the heater are sandwiched to the outside of the bath's stainless steel tank. The tank bottom becomes the heat port with most of the heat entering and exiting the bath through a single location. Providing well-designed insulation around the tank minimizes other heat leaks.

Mixing

For mixing the bath fluid, Hart uses a carefully balanced stirring mechanism. The number of propellers and the pitch of the blades are adjusted to thoroughly mix the bath medium and eliminate both horizontal and vertical gradients. We don't use circulating pumps because the tubular inlet and outlet design cause thermal-flow patterns in the bath that create unnecessary gradients. Our mixing scheme and the size and shape of our tanks all combine to deliver great performance.

All our baths use tanks made of heavy-gauge stainless steel that is fabricated and welded in our own factory so we can control quality. After more than 20 years we haven't had a single Hart bath weld develop a leak.



"Standard Bath" construction.

Maintenance

Hart baths are easy to maintain because our stirrer motors last longer and there are no pumps to unclog or repair. Our tanks are easier to clean because they allow 100% drainage of bath fluid. Since the stirrer motors are direct drive, you won't have to buy a supply of belts just to perform your calibrations.

These are the reasons we sell more temperature calibration baths than anybody else. And remember, if you don't find a bath in the catalog to meet your exact needs, talk to us. Chances are we've built one. With so many bath designs, it's impossible to list them all in the catalog. See page 103 for a sampling of our custom baths.

Blaine (master rutabaga farmer) shows us what good tools and a smile on your face can get you.

HOT BATHS

Hot Baths **Models 6020, 6022, and 6024**

- Large-capacity tanks for higher productivity
- Calibrations up to 300°C
- Built-in cooling coils for extended low range
- Stability to ±0.001°C

Comparison calibrations require a heat source that's stable and uniform, and for moderately high temperatures nothing provides a better heat source than a Hart oil bath.

Hart oil baths are stable to ±0.001°C and do not require calibration blocks or use of special calibration techniques to achieve that stability. The specifications of all Hart baths are "true" specifications representing the performance you can expect to achieve in your lab under your operating conditions. Other companies advertise specs that they know you will never see in your lab. When their baths fail to perform, they blame it on you.

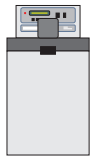
Hart baths are built using a unique tank design that guarantees the best uniformity possible in a liquid bath. This, coupled with the industry's best-selling digital bath controller, achieves uncompromised performance and ease of use.

Not only does Hart's digital controller have features like its "Super-Tweak" high-resolution mode so you can dial in the exact temperatures you want, it also lets you completely automate the calibration process using your PC and Hart's 9938 MET/TEMP II software (see page 75).

You'll love these baths, and once you've got one you'll never buy anything else. There's a bath to match any temperature range, depth, price, and performance you need.

See our selection of bath fluids on page 104.

See our calibration and data acquisition software packages on page 74.

Specifications	6020	6022	6024
			
Range	20°C to 300°C†		
Stability	±0.001°C at 40°C (water) ±0.003°C at 100°C (oil 5012) ±0.005°C at 300°C (oil 5017)		
Uniformity	±0.002°C at 40°C (water) ±0.004°C at 100°C (oil 5012) ±0.012°C at 300°C (oil 5017)		
Temperature Setting	Digital display with push-button data entry		
Set-Point Resolution	0.01°C; high-resolution mode, 0.00018°C		
Display Temperature Resolution	0.01°C		
Digital Setting Accuracy	±1°C		
Digital Setting Repeatability	±0.02°C		
Heaters	350 and 1050 watts		
Access Opening (call for custom openings)	5" x 10" (127 x 254 mm)		7.25" x 12.75" (184 x 324 mm)
Depth	12" (305 mm)	18.25" (464 mm)	13.25" (337 mm)
Wetted Parts	304 stainless steel		
Power	115 VAC (±10%), 50/60 Hz, 10 A or 230 VAC (±10%), 50/60 Hz, 5 A, specify		
Volume	7.2 gallons (27 liters)	11.2 gallons (42 liters)	
Weight	70 lb. (32 kg)	80 lb. (36 kg)	
Size	25.5" H x 16" W x 20" D (648 x 406 x 508 mm)	32" H x 16" W x 20" D (813 x 406 x 508 mm)	27.5" H x 19" W x 23" D (699 x 483 x 584 mm)
Automation Package	Interface-*it* software and RS-232 computer interface are available for setting bath temperature via remote computer. For IEEE-488, add the 2001-IEEE to the automation package.		

†External cooling required for operation below 40°C. Cooling coils are built into the bath walls. Tubing ports are accessible at the back of the bath for circulating chilled fluid or shop air to boost cooling.

Ordering Information

6020	Standard Bath, 20°C to 300°C
6022	Standard Bath, 20°C to 300°C, deep
6024	Standard Bath, 20°C to 300°C, high capacity
2001-6020	Automation Package for 6020
2001-6022	Automation Package for 6022
2001-6024	Automation Package for 6024
2001-IEEE	Add for IEEE-488 (requires Automation Package)
2007	Access Cover, 5" x 10", SST (6020, 6022)
2009	Access Cover, 7.25" x 12.75", SST (6024)
2016-6020	Fluid Level Adapter, 6020 (page 106)
2016-6022	Fluid Level Adapter, 6022 (page 106)
2016-6024	Fluid Level Adapter, 6024 (page 106)
2070	Bath Cart, 6020, 6022 (12.3" H)
2072	Bath Cart, 6024 (8.5" H)
2023	Fast-Start Heater, 16.5" (6022)
2024	Fast-Start Heater, 13.5" (6020, 6024)
2069	8X Magnifier Scope, with mounts (page 106)

Technical Tip

Uncertainty Evaluation and SPC with a Bath

Considerable emphasis is placed on uncertainty analysis and statistical process control (SPC) in the calibration lab. If you're using a calibration bath in your process, you may be wondering how to include the bath in the process evaluation. Basically, there are three approaches.

The first is to "calibrate" the bath to ensure that it meets published specifications and include the published specifications with the "type B" uncertainties in your evaluation just as you might do with any other instrument.

The second approach is to thoroughly test the bath stability and uniformity, perform statistical analysis of the results' uncertainties, and include the results with the "type A" uncertainties in your evaluation. This is often a better method and will provide more realistic results.

The third avenue is to use a "check standard" instrument in the process in such a way that the bath characteristics are included in the check-standard data, which is evaluated statistically and included with the "type A" evaluation. This approach is somewhat more time-consuming but will provide realistic results. When used in conjunction with the second method above, the best results will be obtained.

REALLY HOT BATHS

Really Hot Baths **Models 6045 and 6050H**

- Eliminates messy sand baths
- Electronically adjustable temperature cutouts
- Stability of ±0.008°C at 550°C

You'll find more Hart baths in national calibration labs than any other brand, and there's a reason for that. No one else can match the stability, uniformity, and performance of a Hart bath, and we absolutely guarantee it.

These models are designed for high-temperature work—up to 550°C. Most labs use them as salt baths for calibration of thermocouples, RTDs, and SPRTs. In fact, these baths are so good you can even do comparison calibrations of SPRTs with them. These baths are stable to ±0.005°C or better at 300°C.

Each bath has a drain, electronically adjustable temperature cutouts, optional floor carts, and optional automation software and interface packages. (The 6050H comes with an insulated cover.)

Hart is the only company that offers complete automated calibration software packages that work with the bath interface option. Our optional software is not just a data acquisition package; it actually controls the calibration, including bath temperatures.

Choose the model that most closely matches your needs. These baths are compatible with salt for higher temperatures and also with oils for lower temperatures.

Hart sells a complete selection of salt and fluids for your bath. You can find these on page 104. Salt baths offer better performance and less mess than sand baths. SPRT comparison calibrations in a sand bath aren't reliable the way they are in a Hart salt bath.

All options, including the automation interface package, are available for the 6050H. It is the finest-quality salt bath you can buy!

Model 6045

This bath has a temperature range of 60°C to 400°C and is perfect for thermocouples and RTDs.

It has a large well opening (5 by 10 inches) so you can calibrate a number of sensors at once. It's 12 inches deep and uses 27 liters of fluid.

The automation interface package gives you complete PC control of the bath, including precalibration setup. It's available with an RS-232 or IEEE-488 interface.

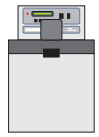
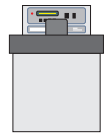
Model 6050H

If you need to reach the maximum temperature possible in a salt bath, the Hart 6050H goes to 550°C and is 10 to 100 times more stable than alternative calibration devices.

It, too, is 12 inches deep and has a 5-by-10-inch well opening for easy access. Ports in the rear of the bath access cooling coils if you want to cool the bath rapidly with external fluids.

Ordering Information

6045	Standard Bath, 60°C to 400°C
6050H	Standard Bath, 60°C to 550°C
2001-6045	Automation Package for 6045
2001-6050	Automation Package for 6050H
2001-IEEE	Add for IEEE-488 (requires Automation Package)
2072	Floor Cart with Casters
2007	Access Cover, 5" x 10", Stainless Steel (6045 only)
2014	Spare Access Cover (for use with salt only; included with 6050H; optional for 6045)
2196	Holding Fixture, 13 probes, 5" x 10"
5001	Bath Salt, 125 lb.
2024	Fast Start Heater, 13.5" (6045)
2023	Fast Start Heater, 16.5" (6050H)
2016-6045	Fluid Level Adapter, 6045 (page 106)
2016-6050H	Fluid Level Adapter, 6050H (page 106)
2069	8X Magnifier Scope, with mounts (page 106)
2035	Salt Drain Pan
5031	Salt Bath Safety Equipment Package (includes protective lab coat, heat-resistant gloves, and face shield)

Specifications	6045	6050H
		
Range	60°C to 400°C	60°C to 550°C
Stability	±0.002°C at 100°C (oil 5012) ±0.005°C at 300°C (oil 5017) ±0.004°C at 400°C (salt)	±0.002°C at 200°C (salt) ±0.004°C at 300°C (salt) ±0.008°C at 550°C (salt)
Uniformity	±0.004°C at 300°C (oil 5017) ±0.007°C at 400°C (salt)	±0.005°C at 200°C (salt) ±0.020°C at 550°C (salt)
Temperature Setting	Digital display with push-button data entry	
Set-Point Resolution	0.01°C; high-resolution mode, 0.00018°C	
Display Temperature Resolution	0.01°C	
Digital Setting Accuracy	±1°C	
Digital Setting Repeatability	±0.02°C	
Heaters	350, 1000, and 1700 Watts	400, 1200, and 2000 Watts
Access Opening	5" x 10" (127 x 254 mm)	
Depth	12" (305 mm)	
Wetted Parts	304 stainless steel	
Power	115 VAC (±10%), 18 A or 230 VAC (±10%), 9 A, specify, 50/60 Hz	230 VAC (±10%), 50/60 Hz, 10 A
Volume	7.1 gallons (27 liters), requires 112 lb. of bath salt	
Weight	160 lb. (73 kg)	180 lb. (82 kg)
Size	26.5" H x 19" W x 23" D (673 x 483 x 584 mm)	28.5" H x 20.4" W x 24.5" D (724 x 518 x 622 mm)
Automation Package	Interface-*it* software and RS-232 computer interface are available for setting bath temperature via remote computer. For IEEE-488, add the 2001-IEEE to the automation package.	

Technical Tip

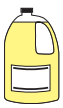
Periodic Bath Testing

All calibration apparatus should either be tested or calibrated. Calibration baths are no different. Although the accuracy is often of secondary importance, bath instability and non-uniformity directly affect calibration uncertainties.

To ensure continued performance, these bath characteristics should be tested periodically. The tests should be carried out at all temperatures commonly used and under typical conditions.

Additionally, since the goal of the tests is to determine the contribution to uncertainty, these tests should be conducted only over the "calibration zone" used in your process, not over the entire zone available. The tests can be conducted with several sensors or with a single sensor moved from one location to the next.

Map the differences and include them in your uncertainty analysis. In most cases, with a Hart bath, the values observed will be significantly smaller than the published specifications.



See our selection of bath fluids on page 104.

Read about our accredited calibration services on page 156.

DEEP-WELL BATHS

Deep-Well Baths **Models 7007, 6054, and 6055**

- Constant liquid levels through concentric-tube design
- Special design for sighting LIG thermometers
- Depth up to 24 inches (61 cm)
- Optional interface packages control all settings

The Hart Models 7007, 6054, and 6055 have extra-deep wells for use with liquid-in-glass thermometers, SPRT calibrations, or other thermometry work requiring extra tank depth. They were originally designed for NIST.

Well depths vary from 17 to 24 inches to eliminate stem conduction effects in probes that require more than 12 inches of immersion. Originally developed for a national standards lab, these baths are optimized for the visual calibration of liquid-in-glass thermometers.

The 7007 is designed for the temperature range of –5°C to 110°C, has built-in refrigeration, and is 24 inches deep. The 6054 covers the temperature range of 50°C to 300°C and is also 24 inches deep. The 6055 is engineered for the temperature range of 200°C to 550°C with salt and is 17 inches deep. Specific size differences and various specifications are shown in the comparison table.

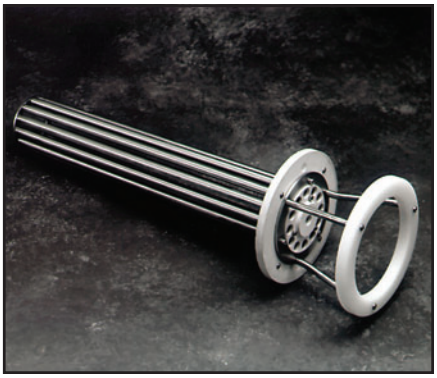
The Model 6055, operating up to 550°C, uses molten salts with a pumping system for maintaining the necessary consistent fluid level required for liquid-in-glass thermometer calibrations. A viewing channel is built into the top cover for a clear visual path to your glass thermometers.

The 6055 also has an optional thermometer carousel for holding several glass thermometers in the correct calibration position without exposing them to the hot salts in the bath. The Model 2018 Carousel is completely constructed of stainless steel and has an elevated handle for rotating your thermometers to the viewing position.

These deep-well baths are built to the same performance standards as all Hart baths, which means you can't find another bath that has better stability or uniformity.

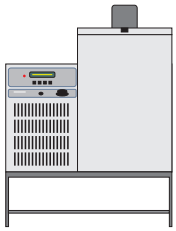
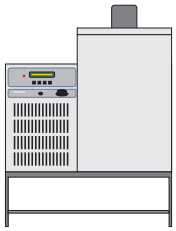
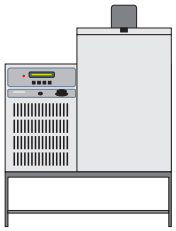
Ordering Information

7007	Refrigerated Deep-Well Bath
6054	Mid-Range Deep-Well Bath
6055	Hi-Temp Deep-Well Bath
2001-7007	Automation Package for 7007
2001-6054	Automation Package for 6054
2001-6055	Automation Package for 6055
2001-IEEE	Add for IEEE-488 (requires Automation Package)
2018	Carousel Holding Fixture for 6055
2069	LIG Telescope with Mounting, 8X magnification
2035	Spare Salt Drain Pan
5031	Salt Bath Safety Equipment Package (includes protective lab coat, heat-resistant gloves, and face shield)



Model 2018 carousel for protecting your glass thermometers.

See our selection of bath fluids on page 104.

Specifications	7007	6054	6055
			
Range	–5°C to 110°C	50°C to 300°C	200°C to 550°C
Stability	±0.001°C at 0°C (ethanol) ±0.003°C at 100°C (oil 5012)	±0.003°C at 100°C (oil 5012) ±0.005°C at 300°C (oil 5017)	±0.003°C at 200°C (salt) ±0.01°C at 550°C (salt)
Uniformity	±0.004°C at 0°C (ethanol) ±0.007°C at 100°C (oil 5012)	±0.007°C at 100°C (oil 5012) ±0.015°C at 300°C (oil 5017)	±0.005°C at 200°C (salt) ±0.010°C at 550°C (salt)
Temperature Setting	Digital display with push-button data entry		
Set-Point Resolution	0.002°C, high res. 0.00003°C	0.01°C, high res. 0.00018°C	
Display Temperature Resolution	0.01°C		
Digital Setting Accuracy	±1°C		
Digital Setting Repeatability	±0.005°C	±0.01°C	
Heaters	250 to 1000 W	250 to 1000 W	225 to 1800 W
Working Area	7" dia. (178 mm)	7.7" dia. (196 mm)	4.2" dia. (107 mm)
Depth	24" (610 mm) deep, 7" dia., removable polycarbonate cover	24" deep (610 mm), 7.7" dia., removable SST lid	17" deep (432 mm), 4.2" dia., removable SST lid, special viewing channel for LIG sighting
Wetted Parts	304 stainless steel		
Power	230 VAC (±10%), 50 or 60 Hz, 14 A (Specify frequency, contact Hart if CE mark required.)	230 VAC (±10%), 50/60 Hz, 10.7 A	230 VAC (±10%), 50/60 Hz, 7.8 A
Volume	11.2 gallons (42 liters)	13.2 gallons (50 liters)	5.2 gallons (19.8 liters, 95 lb. of bath salt)
Size	18.5" D x 30.5" W x 47" to working surface, 55" to top of stir motor, 36" to control panel	22.5" D x 30" W x 48" to working surface, 56" to top of stir motor box, 36" to control panel	22.5" D x 30.5" W x 48" to working surface, 60" to top of stir motor box, 36" to control panel
Distance from Line of Sight to Top of Fluid	3/8" (9.5 mm)	5/8" (15.9 mm)	
Automation Package	Interface-*it* software and RS-232 computer interface are available for setting bath temperature via remote computer. For IEEE-488, add the 2001-IEEE to the automaton package.		

Technical Tip

Viscosity Matters

Viscosity is a measure of resistance to fluid flow. The temperature homogeneity, or uniformity, within a bath is directly related to the ability of the stirrer to circulate the fluid around the tank. Any resistance to that fluid circulation will impede the mixing and transfer of heat throughout the bath that is necessary to establish temperature uniformity.

In general, the lower the viscosity, the better. Kinematic viscosity is measured in centistokes (cs). Water at 20°C has a viscosity of about 1 cs. A viscosity of less than 10 cs will give good performance. As a rule of thumb, as viscosities approach 50 cs (less for a Micro-Bath), uniformity in particular can be degraded. Keeping probes close together can stretch the useful viscosity range of a fluid.

Wally (Pacific Rim sales) has a palate so sensitive, he not only judges fine wines, he tastes our triple point water for quality control.

RESISTOR BATHS

Resistor Baths **Models 7015, 7009, and 7108**

- Three size options for any quantity of resistors
- Stability to ±0.0007°C
- Set-point resloution to 0.00003°C
- Minimal long-term drift

Regardless of the size and number of standard resistors you have to maintain, Hart has a bath that will do the job for you. Choose one of the three models described here or call us for information on other sizes.

Like all Hart baths, these resistor baths have unbeatable stability and uniformity. No other baths limit long-term and short-term drift—as well as gradients—better than these baths. Hart's proprietary controller senses temperature changes as small as 0.00001°C. This controller is the industry's best-selling temperature calibration controller for bath retrofits because it improves the stability of almost every other poorly performing bath. So why not buy the best to begin with?

Each bath can be delivered with any size resistor rack you want (a standard model is included with each bath), and the Model 7015 has several other special features that make your work easier.

Model 7015

The Model 7015 has a 95-liter tank and a temperature range of 0°C to 110°C. It's stable to ±0.0007°C.

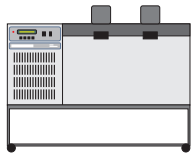
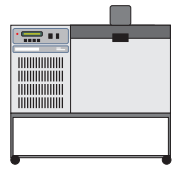
It has a one-piece stainless steel lid designed to drain spills and splashes back into the bath as you remove resistors. It has a large access opening to make handling large resistors, like the Thomas Design Standard resistors, easier. The tank has an electrically isolated resistor shelf.

This is truly a quality resistor bath, and it's backed by Hart's industry-leading service.

Model 7009

This is a large bath with a tank 27½ inches long by 22 inches wide. It has a temperature range of 0°C to 110°C and a stability of ±0.0007°C.

For a bath this size and with these specs, it is priced extremely well. The Model 7009's large tank can handle many resistors of any size.

Specifications	7015	7009	7108
			
Range	0°C to 110°C	0°C to 110°C	20°C to 30°C
Stability at 25°C	±0.0007°C (water) ±0.001°C (mineral oil 5011)		±0.002°C (water) ±0.004°C (mineral oil 5011)
Uniformity	±0.003°C at 25°C (water) ±0.005°C at 25°C (mineral oil 5011)		±0.005°C (water) ±0.008°C (mineral oil 5011)
Temperature Setting	Digital display with push-button data entry		
Set-Point Resolution	0.002°C; high-resolution mode, 0.00003°C		
Display Resolution	0.01°C		
Digital Setting Accuracy	±1°C		±0.5°C
Digital Setting Repeatability	±0.01°C		
Heaters	500 and 1000 Watts		Peltier heating/cooling
Cooling Capacity	100 to 200 Watts		100 W in ambient 23°C
Access Opening	27.5" x 11" (699 x 279 mm)	27.5" x 22" (669 x 559 mm)	14" x 14" (356 x 356 mm)
Bath Chamber Dimensions (unobstructed space)	27.5" W x 11" H x 13" D (3933 cubic inches)	27.5" W x 22" H x 13" D (7865 cubic inches)	14" W x 8" H x 14" D (355 x 203 x 355 mm)
Depth	13" (331 mm)		8" (203 mm)
Wetted Parts	304 stainless steel		Tank: 304 stainless steel Resistor rack: hard-anodized, perforated aluminum
Safety Cutout	Factory-set high temperature		n/a
Power	115 VAC (±10%), 60 Hz, 15 A or 230 VAC, 50 or 60 Hz, 8 A, specify	230 VAC (±10%), 50 or 60 Hz, 12 A (specify frequency)	115 VAC (±10%), 50/60 Hz, 3 A or 230 VAC (±10%), 50/60 Hz, 1.6 A, specify
Volume	25 gallons (95 liters)	44 gallons (167 liters)	13.2 gallons (51 liters)
Weight	310 lb. (141 kg)	330 lb. (150 kg)	75 lb. (35 kg)
Size	48" H x 44" W x 22" D (1219 x 1118 x 559 mm)	43" H x 44.5" W x 34" D (1092 x 1130 x 864 mm)	19.25" W x 22" H x 25" D (489 x 413 x 559 mm)
Automation Package	Interface-*it* software and RS-232 computer interface are available for setting the bath temperature via an external computer. (Both come standard with a 7108.) For IEEE-488, add the 2001-IEEE to the automation package.		

7108

This is the quietest resistor bath you've ever heard. The 7108 uses thermoelectric (Peltier) modules to provide heating and cooling over its range from 20°C to 30°C. Without a compressor, noise is dramatically reduced. Power requirements are also lower, so you save money running the bath and add less heat load to your lab.

With a 13.2-gallon (51-liter) tank, the 7108 holds plenty of resistors. A large 14" x 14" (356 x 356 mm) access opening allows you to easily move resistors in and out of the bath. A resistor rack comes with each unit that fits across the bottom of the tank. Made from hard-anodized perforated aluminum, this rack maintains the necessary electrical isolation between your resistors.

Hart baths have been used in primary temperature and electrical labs for years. Why shouldn't they be? They're the most stable baths in the world. Now they're even better. Try one.

Ordering Information

7015	Resistor Bath
7009	Resistor Bath, high capacity
7108	Resistor Bath, Peltier-cooled, includes RS-232
2001-7015	Automation Package for 7015
2001-7009	Automation Package for 7009
2001-IEEE	Add for IEEE-488 (requires Automation Package)
5011	Mineral Oil

Need a reliable standard resistor? See our selection on pages 28 and 29.

CONSTANT TEMPERATURE ICE BATH — Model 7911A2

Constant Temperature Ice Bath — Model 7911A2

- Lower uncertainty zero-point (to ±0.002°C uniformity)
- Affordable — amazing price for this uniformity & stability
- Many probes can be checked/calibrated at once

Take a look at this easy and affordable zero-point source for calibrating temperature sensors—the Hart Scientific 7911A2 Constant Temperature Ice Bath!

Now you can attain lower uncertainties from a simple ice bath! Most people don't realize just how much uncertainty a stationary ice mixture in a typical ice bath can have. Pockets of non-uniform temperature will wreak havoc on your calibration uncertainties. With a stirred ice bath, the uniformity and stability can easily drop to ±0.002°C. Now that's more like it!

The 7911A2 has a 5-liter tank with a depth of 12 inches. This gives you an optimal calibration zone of 2.5" diameter by 8" deep—enough space to calibrate several probes at once, including odd-shaped or short probes. Think how many thermocouple cold junctions you could put in this bath!

As with all Hart products, the model 7911A2 Constant Temperature Ice Bath is manufactured according to a proven design using the best components.

The vacuum-insulated stainless steel dewar is used to give your ice-point realization longevity (a well-prepared ice bath can be used for several hours without attention).

We use a Rosemount-designed "flow chute" stirring mechanism to saturate the bath water with air as it stirs. Having the same concentration of air in the mixture each time increases the repeatability of the ice point.

Using pure distilled or demineralized water for bath fluid and ice, you'll consistently produce a 0°C calibration environment with up to ±0.002°C accuracy.

For thermometer calibrations or for a thermocouple cold junction temperature source, if you want the best ice bath results, use the best equipment available—get the Hart 7911A2!

Specifications

Uniformity	±0.002°C†
Stability	±0.002°C†
Optimal Temp. Zone	2.5" dia. x 8" D (64 x 203 mm)
Size	7" dia. x 19" D (185 x 490 mm)
Tank Capacity	5 Liters, 6" dia. x 12" D (150 x 300 mm)
Weight	13.5 lb. (6.1 kg)
Power	115 VAC (±10%), 60 Hz, 1 A or 230 VAC (±10%), 50 Hz, 0.5 A

† based on a properly made ice bath mixture

Ordering Information

7911A2 Constant Temperature Ice Bath

Technical Tip

Preparing an Ice Bath

You wouldn't think that making a good, repeatable ice bath would be a difficult thing. Well, it's not if you follow some simple procedures, which you can find in the ASTM Standard Practice E563. Those are too detailed to cite here, but here are some quick thoughts:

- By always following the same procedure and using the same source for both water and ice, you'll improve the repeatability of the temperature you achieve.
- Remember that any impurities in the ice and water you use will affect the ice bath temperature. Pure distilled, demineralized, or deionized water is recommended for realizing the true ice point temperature, 0°C.
- Be sure to keep your bath container clean by rinsing it with pure water.

See page 18 for triple point of water cells.

CUSTOM BATHS

Have you read about Hart's line of standard baths? They're well constructed and very stable, and they have software available for automated calibrations. However, if your needs aren't met by our standard sizes and temperature ranges, then we can build a custom bath that is as reliable and as fine a calibration instrument as any bath we manufacture.

We can make them taller, wider, or deeper. We can put windows in them, change the temperature range, or make the tank bigger, smaller, or longer. Do you want it a different height or a particular shape, or do you just want to change the color?

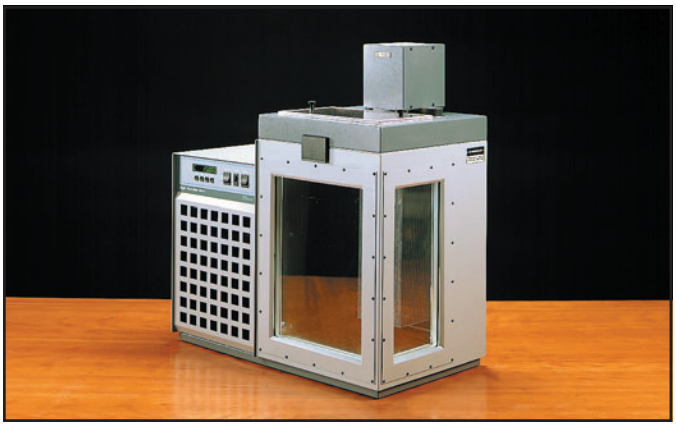
We can do all of that and more! Our engineers and designers know more about temperature calibration baths than anyone else. You'll find our baths throughout the best national and international temperature calibration labs, and they'll tell you exactly why they buy Hart baths.

It doesn't matter what type of calibration application you have: oceanography, missile optics, infrared, or down-hole tools. We've probably already built baths to do the job.

Call us and let us know what application you're working with. We'll provide you a calibration solution, and you can have it your way.

Get the latest product information at www.hartscientific.com

This two-baths-in-one design (Model 7013) is a favorite in many labs.



Hart's window baths enhance viscometry work and calibrations of complete-immersion thermometers.

A wide variety of sizes and shapes can be used to accommodate unique inserts.

BATH FLUIDS

Did you know there's a convenient source for small quantities of bath fluids for any temperature range? Why buy more than you need?

Hart Scientific carries a full line of bath fluids covering temperature ranges from –100°C to 550°C.

Viscosity, volatility, and other properties that change with temperature affect the performance of fluids in controlled baths and circulators. Hart has tested and used each of the fluids we sell. Over the ranges recommended in the following table, each fluid remains at a low enough viscosity to be adequately pumped or stirred. Whether your application is industrial or critical lab calibration work, Hart fluids give you top performance and stability.

For temperature ranges too high for oils, we have a bath salt with a viscosity in the molten state similar to the viscosity of water. For your convenience, it is shipped in a granular form, making it easy to fill your bath.

Between 180°C and 550°C, this salt has the highest temperature stability and uniformity available in a bath fluid. It does not smoke like oils or give off dust like "sand" or fluidized alumina baths. Check with your bath manufacturer before using this salt to make sure your equipment is compatible. Hart offers three standard bath models and custom-designed units for use with this salt.

Fluid Specifications

It's important to understand a few specifications before selecting a bath fluid. We've seen bath fluids advertised with a temperature range that spans from the freezing point to the flash point or beyond.

For example, type 710 silicone oil has a freezing point of –22°C, but freezing point has nothing to do with the point at which the oil becomes so thick it cannot be properly stirred. Type 710 oil should really only be used down to about 80°C. It's a viscosity issue, not a freezing-point issue. Usable range is the question. Suitability for calibration work is the specification that counts.

The usable viscosity range is determined by your bath's stirring or pumping design. Hart baths can be operated using fluids with up to 50 centistokes viscosity, which gives you additional usable range in the lower temperature levels of the fluid.

Some baths advertised as calibration baths require fluids with 10 centistokes or less viscosity to operate properly. The usable ranges in our table on the previous page assume the use of a Hart bath.

In addition to range and viscosity issues, there are a number of other issues to consider when choosing a bath fluid. The other considerations are:

- Thermal characteristics
- Lifetime
- Change in characteristics due to temperature cycling
- Absorption of water from the air
- Vaporization—fumes and fume hood requirements
- Expansion due to heat
- Contamination—mixing oils or introducing contamination with unclean probes
- Conductivity properties
- Effects of using fluids outside of their range—fire, explosion, polymerization
- Effects of altitude on boiling point

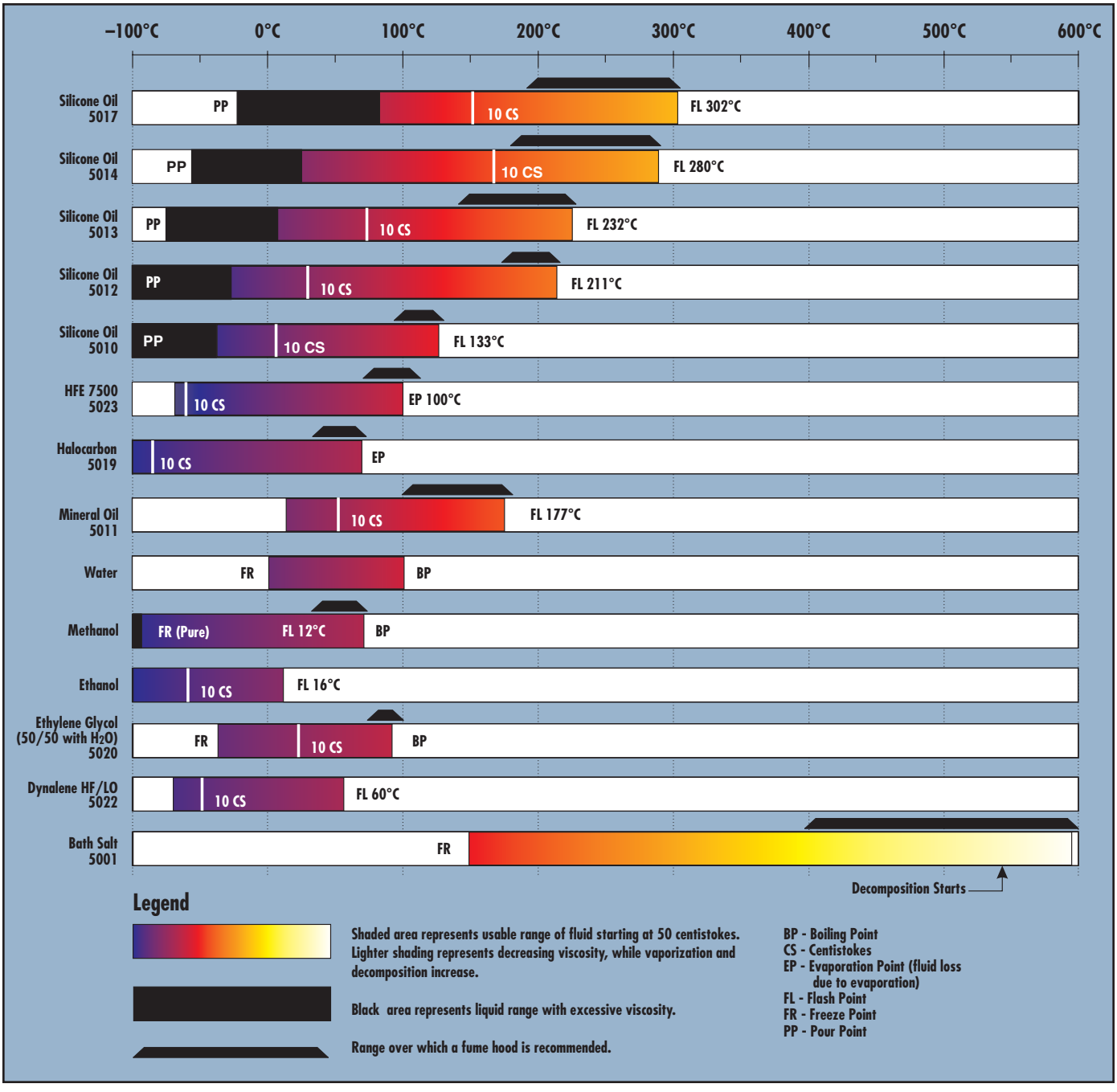
Call us and we'll discuss your fluid requirements for your operating needs.

Ordering Information

Model #	Fluid	Usable Range§	FlashPoint†
5019	Halocarbon 0.8 Cold Bath Fluid	–100°C to 70°C	n/a
5022	Dynalene HF/LO*	–65°C to 58°C	60°C
5023	HFE Cold Bath Fluid	–75°C to 100°C	n/a
5020	Ethylene Glycol (Mix 1:1 with water)	–30°C to 90°C	n/a
5010	Silicone Oil Type 200.05	–40°C to 130°C	133°C
5012	Silicone Oil Type 200.10	–30°C to 209°C	211°C
5013	Silicone Oil Type 200.20	10°C to 230°C	232°C
5014	Silicone Oil Type 200.50	30°C to 278°C	280°C
5017	Silicone Oil Type 710	80°C to 300°C	302°C
5011	Mineral Oil	10°C to 175°C	177°C
5001	Bath Salt, 125 lb.‡ Potassium Nitrate 53% Sodium Nitrite 40% Sodium Nitrate 7%	180°C to 550°C	n/a

§Atmospheric pressure affects the usable ranges of some fluids. The temperatures quoted are at sea level.
†Flash point is the temperature at which a vapor (not the fluid) will ignite if exposed to an open flame. When the flame is removed, the vapor will stop burning. (Open cup method.)
*Electrical resistivity is greater than 20 MΩ-cm.
‡125 lb. bath salt fills a 7.9-gallon tank.

MSDS available at www.hartscientific.com



Technical Tip

Can't a Single Fluid Cover My Bath's Entire Range?

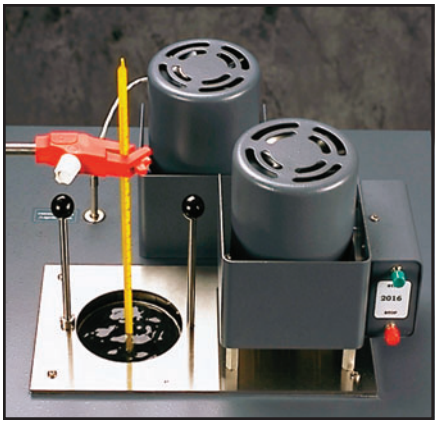
So, you want to cover the entire temperature range of your bath with one fluid? That would be nice. Unfortunately for all of us, this is often not possible.

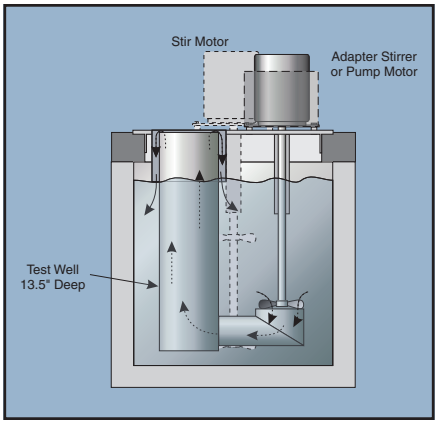
All fluids have temperature range limits for a variety of reasons. The properties of certain fluids just don't hold still over temperature. Not only do you have problems with freezing and boiling, but viscosity changes, evaporation, and flash points create limits for a fluid's useful temperature range.

The result is that one fluid may not cover the range you need within a single bath, leaving you with a choice between inconvenient fluid changes or multiple temperature-dedicated baths.

Read about our calibration training courses on page 153.

FLUID LEVEL ADAPTER — Model 2016





Add this accessory to your Hart bath for easy calibration of liquid-in-glass thermometers.

This fluid level adapter fits in the access opening of your bath. It includes a pump and a cylindrical test well. Bath fluid is pumped up through the test well to a level just below the surface of the bath lid, giving you a clear sighting of the liquid column in your thermometer.

The diameter of the test well is 3.5 inches. The adapter can be placed in your bath or easily removed with no complex installation assembly—simply plug it in.

The world's best baths for sensor calibrations are now the world's best baths for glass thermometer calibrations as well. If you're required to service glass thermometers, add this accessory to your bath purchase or to the Hart bath already in your lab.

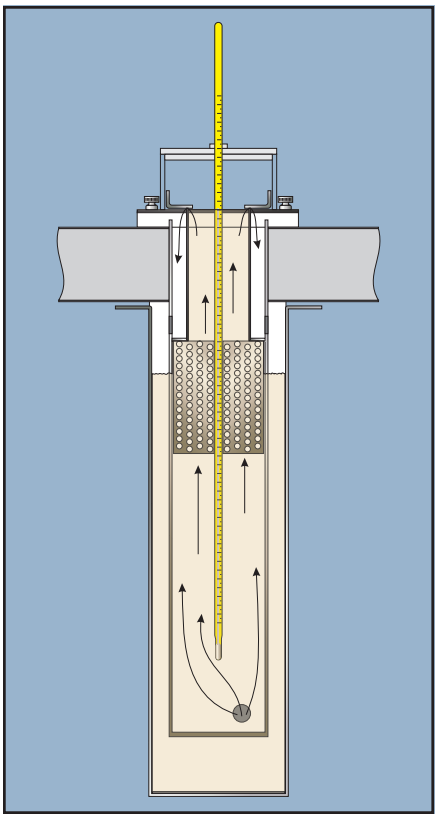
Ordering Information

2016-X	Fluid Level Adapter
2017	LIG Thermometer Holder for 2016-X, holds 10 thermometers

X = bath model number. Specify the bath model, its power requirements, and dimensions of its access opening.

FLUID LEVEL ADAPTER — Model 2019

For customers needing to calibrate glass thermometers, Hart engineers have designed a fluid level adapter that slides directly into the test wells of the 7030, 7013, and 7100 calibration baths. (See page 90, 103, and 88 respectively.)



The fluid level adapter creates a positive bath fluid surface. The bath fluid in the test well is pumped up to the surface of the bath and kept there. This puts the glass thermometer meniscus above the edge of the bath test well for clear viewing during calibration.

The clear acrylic adapter cover protects the bath fluid from ambient temperature effects for better bath stability. The cover can be drilled for any size probe.

The adapter is easily pulled from the bath test well to allow more room during calibration of other thermometers and sensors.

Ordering Information

2019-7030	Fluid Level Adapter, 7030
2019-7013	Fluid Level Adapter, 7013
2019-7100	Fluid Level Adapter, 7100

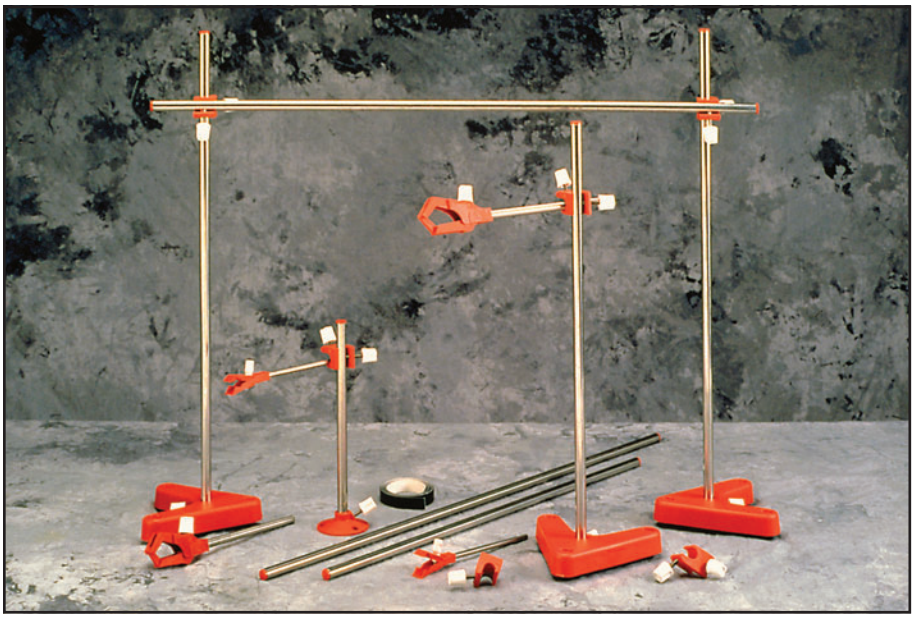
MAGNIFYING SCOPE — Model 2069

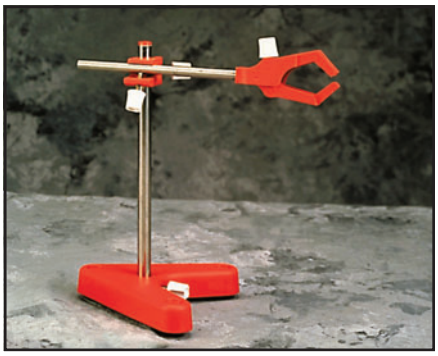
Using a magnifying scope when calibrating liquid-in-glass thermometers can lower your uncertainty by enlarging the thermometer's scale and providing improved viewing resolution. This inexpensive model from Hart mounts easily to the front of any Hart Standard Bath or Deep-Well Compact Bath and can be used in conjunction with a fluid level adapter for optimal viewing.

Ordering Information

2069	8X Magnifier Scope, with mounts

BATH ACCESSORIES





Single Probe Kit.

Ordering Information

Selected Kits		Model
Single Probe Kit	Includes: 1 medium clamp, 1 10-inch rod, 1 bosshead, and 1 V-base	**2051**
Economy Kit	Includes: 2 V-bases, 1 29-inch stainless steel rod, 2 23-inch rods, 5 bossheads, 2 micro-clamps, and 1 medium clamp	**2050**
Individual Hardware		
Micro-Clamp	Holds thermometers and probes with diameters to 0.75 inch.	**2055** (Pkg. of 2)
Medium Clamp	Holds diameters up to 1.75 inches.	**2056** (Pkg. of 1)
Non-Slip Tape	Increases grip on clamps and bossheads.	**2057** (1 roll)
Stainless Steel Rods	Used to assemble supports, frameworks, or scaffolds.	**2058** 10" (Pkg. of 1)
		2059 20" (Pkg. of 1)
		2060 23" (Pkg. of 1)
		2061 29" (Pkg. of 1)
Bosshead	Clamps two rods at right angles. Also attaches clamps to rods.	**2062** (Pkg. of 5)
Screw Base	Holds one rod and is screwed to the surface of your bench or bath lid. 2.5-inch-diameter base; screws included.	**2063** (Pkg. of 4)
V-Base	Holds one rod. Weighted for excellent stability. 2.2 pounds (1 kg).	**2064** (Pkg. of 1)
Large V-Base	Same as above but larger. Recommended for holding SPRTs and large probes. 4.4 pounds (2 kg). (May be too large for some baths.)	**2065** (Pkg. of 1)

Technical Tip

Improving Uniformity Performance

Want to reduce your bath uncertainties? Non-uniformity can be a significant factor in calibration uncertainty. Our uniformity specs cover the entire working volume of the bath. The "working volume" is typically one inch from all of the walls and three inches below the fluid surface.

For better results, keep your probes close together and adequately immersed. Bath uniformity is better within a small portion of the bath than it is over the entire working volume. Keeping probe tips close and adequately immersed can improve uniformity performance beyond the published specification. Leave about one-half inch of space around each probe to permit adequate fluid flow. Any more than that is unnecessary.

Mechanical Support for Probes

When setting up a new calibration bath, you need a way to suspend your probes in the bath fluid. We recommend our modular mechanical support systems. Made of fine-quality steel and machined parts, these support components combine in hundreds of ways to solve almost any probe suspension problem.

Single Probe Kit

Our single probe kit is a good way to get started. It has one medium clamp, one 10-inch rod, one bosshead, and one V-base for holding one probe. (See photo above.)

Economy Kit

Our economy kit includes two V-bases, one 29-inch stainless steel rod, two 23-inch rods, five bossheads, two micro-clamps, and one medium clamp. This will build a bench-mounted frame for suspending one rod and three clamps over a bath opening. Simply add to your setup as needed. Choose from any of the listed accessories.

Individual Hardware

Our selection of clamps and stands provides a simple way to hold probes and thermometers in baths during calibration. System components can be assembled in a number of ways to suit individual needs. Select clamps, rods, bossheads, and bases to fit your individual needs.

CONTROLLER FOR ROSEMOUNT-DESIGNED BATHS — Model 7900

Controller for Rosemount-Designed Baths — Model 7900

- All the features of the Hart 2100 Controller
- Installs easily
- Two independent over-temperature cutout circuits

Hart's bath controllers have long been recognized as the finest in the world. They're the most popular retrofit controller in the industry, and now they're available for Rosemount baths. The Model 7900 Controller installs easily and can replace the Rosemount Model 915 for all Rosemount bath models.

This controller uses the same circuitry as Hart's 2100 Controller to achieve long-lasting stabilities of ±0.001°C or better. Special noise-rejection techniques allow the 7900 to measure the very tiny resistance changes required for this level of stability. AC bridges are used within the controller to cancel thermal EMFs. Custom high-precision resistors contribute to short- and long-term stability and advanced filtering techniques force out troublesome line noise.

The Model 7900 includes a special circuit that monitors the controller's microprocessor and automatically resets it if its operations are interrupted. Two separate cutout systems are also included for keeping your bath's temperature within its normal range.

A software cutout uses an adjustable high-temperature limit that can be easily accessed through the front panel and set to match the requirements of your bath fluid. Should the control sensor measure a temperature beyond this upper limit, heating is shut down. If the bath's temperature falls below its normal operating range, the heaters are turned on and the LN_2 cooling shut off. A second, independent hardware cutout monitors the bath's temperature with a thermocouple and shuts down all heating and LN_2 cooling if the bath's temperature rises above its range.

These cutout features, combined with the superior reliability and long-term stability performance of the 7900, allow you to run your system for as long as you like between shut-downs—365 days a year, if you wish. Your bath can be ready for you to take measurements the minute you walk into your lab each day.

Specifications

Temperature Control Range	–100°C to 550°C
Optional Ranges	None
Stability	±0.003 (±0.001 typical)
Stabilization Time	30 minutes
Display Accuracy	±1°C
Cooling Control	LN_2 – automatic
Heating Control	2-position, firmware or user controlled
Firmware High-Temp Cutout	Yes, volatile, programmable (independent of the controller)
Hardware High-Temp Cutout	Thermocouple controlled
Memory	Non-volatile; 8 programmable set-points, each with ramp and soak features
Programmable Soak Time	1 to 500 minutes
Control Sensor	100-ohm PRT; alpha = 0.00385
Interface	RS-232 and IEEE standard
Software	Interface-*it*
Operating Temperature	5°C to 50°C
Operating Voltage	115 VAC (±10%), 60 Hz
CE Mark	Contact Hart
Current Rating	20 amps max.
Dimensions	12.25" W x 4.5" H x 11" D
Weight	9 pounds (4 kg)
Installation	Freestanding or rack mounted with optional hardware

Ordering Information

7900-B	Controller, Rosemount-Designed Baths, bottom stirred (includes control probe and thermocouple cutout)
7900-T	Controller, Rosemount-Designed Baths, top stirred (includes control probe and thermocouple cutout)
2079	Rack-Mount Kit

Get the latest product information at www.hartscientific.com

Baths

Benchtop Controllers — Models 2100 and 2200

- Most stable temperature controllers available
- Resolution as high as 0.00018°C
- RS-232 interface included for automating applications

It's no secret why Hart's temperature baths are the most stable baths in the world. In fact, right on page 92 of this catalog we explain that Hart baths use Hart temperature controllers, and they're flat out the best anywhere.

If you're using a homemade bath—or worse, a bath built by one of our competitors—there's a good chance you can drastically improve its performance by using one of Hart's two temperature controllers.

The Model 2100 controller can sense and respond to temperature changes as low as 0.00001°C, which means you can enjoy stabilities better than ±0.001°C in a mechanically sound bath.

The 2100 has set-point resolution of 0.002°C using a thermistor input and 0.01°C using an RTD input. In high-resolution mode you can adjust the set-point in increments smaller than 0.0002°C. Actual display resolution is 0.01°C.

Power output is provided on a standard IEC female power receptacle. An auxiliary power output provides constant line voltage to equipment accessories such as stirrers.

The Model 2200 controller is smaller and lighter than the 2100 and uses an RTD input to provide stabilities as good as ±0.015°C. Resolution is 0.01°C and temperature range is –100°C to 800°C.

If operated from any line power between 100 and 230 VAC, 50 or 60 Hz, the 2200 will supply up to 10 amps power output on a standard IEC female power receptacle.

Both models are programmed using the front-panel buttons and also come with an RS-232 interface.

Either of these benchtop controllers can turn an average temperature bath into a true calibration tool. Call us and tell us your application. We'll help you pick the best controller for your situation.

Specifications

Temperature Range	**2100:** –100°C to 670°C **2200:** –100°C to 800°C
Control Stability	**2100:** ±0.0005°C to ±0.002°C **2200:** ±0.005°C to ±0.02°C (depends on system design)
Display Accuracy (with probes shown below)	±1.0°C without system calibration
Display Resolution	0.01°
Set-Point Resolution	**2100:** 0.0002° in high-resolution mode **2200:** 0.01°
Auxiliary and Heater Output	**2100:** 100–125 nominal VAC or 230 nominal VAC (internally switchable), 50/60 Hz, 10 A max. **2200:** 100–230 VAC, 50/60 Hz, 10 A max.
Heater Output	Solid-state relay
Dimensions	**2100:** 2.83" H x 6.75" W x 9.86" D (72 x 172 x 250 mm) **2200:** 2.85" H x 4.5" W x 7" D (72 x 114 x 178 mm)
Probes	2620: RTD, 11" x 0.187" (280 x 4.8 mm), –100 to 550°C 2622: RTD, 9" x 0.187" (229 x 4.8 mm), –100 to 550°C 2624: RTD, 14" x 0.187" (356 x 4.8 mm), –100 to 550°C 2611: Thermistor, 9" x 0.218" (229 x 5.5 mm), –10°C to 110°C (2100 controller only) 5635: Type K thermocouple, 16" x 0.187" (406 x 4.7 mm), 1100°C for cutout
Automation Software	Both models include Hart's 9930 Interface-*it* software package (see page 74)

Ordering Information

2100	Controller
2200	Controller
2125	IEEE-488 Interface
2611	Thermistor Probe
5635-S	Thermocouple Cutout Probe
2620	RTD Probe, 11"
2622	RTD Probe, 9"
2624	RTD Probe, 14"

Read about our calibration training courses on page 153.

INDUSTRIAL CALIBRATOR SUMMARY

Micro-Baths	Model	Range	Accuracy	Description	Page
	6102 Micro-Bath	35°C to 200°C 95°F to 392°F	±0.25°C	World's smallest calibration bath. Stability to ±0.02°C. Stirred 2.5-inch-diameter tank.	112
	7102 Micro-Bath	–5°C to 125°C 23°F to 257°F	±0.25°C	Portable bath to –5°C. No refrigeration—solid-state cooling. Stability to ±0.015°C.	
	7103 Micro-Bath	–30°C to 125°C –22°F to 257°F	±0.25°C	Ultracold Micro-Bath reaches –30°C. No refrigeration or external cooling needed. Stability to ±0.03°C.	

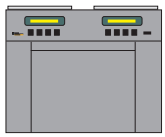
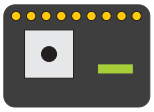
Handheld Dry-Wells	Model	Range	Accuracy	Description	Page
	9100S Handheld Dry-Well	35°C to 375°C 95°F to 707°F	±0.25°C at 100°C ±0.5°C at 375°C	World's smallest dry-well. Fixed block with 4-inch well depth. Four hole patterns available.	116
	9102S Handheld Dry-Well	–10°C to 122°C 14°F to 252°F	±0.5°C	Handheld unit cools to –10°C. Two 0.5-inch-diameter, removable sleeves.	

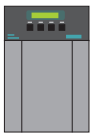
Field Dry-Wells	Model	Range	Accuracy	Description	Page
	9009 Dual-Block Calibrator	–15°C to 350°C 5°F to 662°F	Cold block: ±0.2°C Hot block: ±0.6°C	Dual-block industrial dry-well. Each block has two wells with removable sleeves. Water- and air-tight enclosure.	118
	9103 Field Dry-Well	–25°C to 140°C –13°F to 284°F	±0.25°C	Small, lightweight field calibrator reaches –25°C. Stability to ±0.02°C. Calibrates up to six probes at once.	120
	9140 Field Dry-Well	35°C to 350°C 95°F to 662°F	±0.5°C	Portable field calibrator. Choose from four multi-hole, removable inserts.	
	9141 Field Dry-Well	50°C to 650°C 122°F to 1202°F	±0.5°C to 400°C ±1°C to 650°C	High-temp field calibrator. Interface-it software and RS-232 included. Extremely small and fast for temperature range.	
	3125 Surface Calibrator	35°C to 400°C 95°F to 752°F	±0.5°C to 200°C ±1.0°C to 400°C	Calibrates surface sensors. Plate stability of ±0.3°C	135

Infrared Calibrators	Model	Range	Accuracy	Description	Page
	9132	50°C to 500°C 122°F to 932°F	±0.5°C at 100°C ±0.8°C at 500°C	Certifies most handheld pyrometers. Short heating and cooling times.	132
	9133	–30°C to 150°C –22°F to 302°F	±0.4°C	Calibrates at cold temperatures. Gets to desired temperature quickly.	
	9135 3-Pt. IR Calibrator	50°C, 100°C, 150°C 122°F, 212°F, 302°F	±1°C	Easiest to use IR calibrator. Three set-points—all reached quickly.	134

Industrial

INDUSTRIAL CALIBRATOR SUMMARY

Laboratory Dry-Wells	Model	Range	Accuracy	Description	Page
	9105 Low-Temp Dry-Well	–25°C to 140°C –13°F to 284°F	±0.1°C	Resolution: 0.01°C, stability: ±0.01°C. Heats or cools in less than 15 minutes. Four fixed wells, 6 inches deep, plus one well with interchangeable inserts.	124
	9107 –45°C Dry-Well	–45°C to 140°C –49°F to 284°F	±0.1°C	Reaches –45°C without aid from refrigeration, external cooling, or low ambient temperatures. Resolution: 0.01°C, stability: ±0.005°C at 0°C Four fixed wells, 6 inches deep, plus one well with interchangeable inserts.	
	9122A High-Capacity Dry-Well	50°C to 700°C 122°F to 1292°F	±0.1°C at 100°C ±0.3°C at 660°C	Calibrates nine probes at once. Five fixed holes, four inserts, 6 inches deep. Resolution: 0.01°C, stability: ±0.02°C at 300°C Ramp and soak programming.	
	9127 High-Speed Dry-Well	35°C to 600°C 95°F to 1112°F	±0.1°C at 100°C ±0.5°C at 600°C	Heats to 100°C in 6 min., 600°C in 30 min. Choose from four removable, multi-hole inserts. Calibrates up to eight probes at once. Resolution: 0.01°C, stability: ±0.05°C at 600°C.	
	9101 Zero Point Dry-Well	0°C 32°F	±0.05°C	Solid-state cooling. Replaces messy ice baths — easy to operate. Three wells, each 6 inches deep.	127
	9011 Hot Block Cold Block	50°C to 67°C 122°F to 1238°F –30°C to 140°C –22°F to 284°F	±0.15°C at 100°C ±0.65°C at 600°C ±0.25°C (Insert wells) ±0.65°C (Fixed wells)	Combined ranges from –30°C to 670°C, 1 unit – 2 blocks Two independent temperature controllers (hot and cold side) Stability: ±0.01°C Multi-hole inserts hold up to 8 probes at once	128
	9007 Portable Lab Dry-Well	–40°C to 140°C –40°F to 284°F	±0.15°C	–40°C with solid-state Peltier cooling. Rugged truck-, plane-, and sea-worthy enclosure.	130
	9023 Portable Lab Dry-Well	35°C to 650°C 95°F to 1202°F	±0.3°C to 350°C ±0.5°C to 650°C	650°C with stability better than ±0.1°C. Watertight housing meets tough MIL-Standard.	

Furnaces	Model	Range	Stability	Description	Page
	9150 Thermocouple Furnace	150°C to 1200°C 302°F to 2192°F	±0.5°C	Benchtop thermocouple furnace. Interchangeable insert sleeves. Fast heating and cooling.	137
	9112A Calibration Furnace	300°C to 1100°C 572°F to 2012°F	±0.1°C	Standard block fits five probes. Accommodates long probes. Gradients less than ±0.3°C at 1000°C.	138

MICRO-BATHS

Micro-Baths **Models 6102, 7102, and 7103**

- World's smallest portable calibration baths
- Calibrates sensors of any size or shape
- Stability to ±0.015°C
- Ranges from –30°C to 200°C

Need portability and extreme stability? Hart Micro-Baths have both. We invented the Micro-Bath. And, while many have tried to duplicate it, none of them use proprietary Hart Scientific controllers, so none of them deliver performance like a Hart bath. Micro-Baths can be used anywhere for any type of sensor. The Model 6102 weighs less than 10 pounds, with the fluid. It's lighter and smaller than most dry-wells, has a spill-proof lid, and is easier to carry than your lunch. You can take it where you need to go without carts or excessive effort. Micro-Baths can even be transported with the fluid in them.

Wherever you go with your Micro-Bath, you can count on its performance. Each model is stable to ±0.03°C or better, depending on the fluid you use. Uniformity is ±0.02°C or better for low uncertainties using a reference thermometer. Display accuracy has been improved to ±0.25°C for quick calibrations without a reference thermometer. In short, you get the stability and precision of a liquid bath in a dry-well-sized package. Don't be fooled by competitors who place a can of oil inside a dry-well and call it a bath. Hart Micro-Baths are maximized for true fluid-bath performance.

With a 1.9-inch diameter, 5.5-inch deep tank, a Micro-Bath can calibrate any type of sensor including short, square, or odd-shaped sensors. The problems of fit and immersion are virtually eliminated by using a fluid medium rather than a dry-block calibrator. Micro-Baths are perfect for liquid-in-glass and bimetal thermometers.

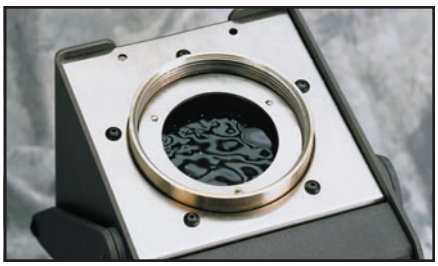
The 6102 has a temperature range from 35°C to 200°C, the 7102 covers –5°C to 125°C, and the 7103 extends from –30°C to 125°C. Stability, uniformity, and accuracy specifications cover the entire range for each bath, not just the best temperature.

All Micro-Baths have RS-232 ports, come with our Interface-*it* software, and can be used with Hart's MET/TEMP II software (described on page 75). Also included are contacts to calibrate a thermal switch, eight set-point memory storage, ramp-rate adjust, and over-temperature safety cutout.

You may have noticed we haven't touted our CFC-free refrigeration. Yes, cold Micro-Baths are CFC-free, and also compressor-free. That's right—no heavy, noisy compressor to lug around. We achieve our temperature range and stability with only one moving part. This means more durability and less weight.

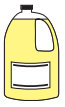
Hart manufactures and sells temperature calibration baths of every size and shape, and now we have the smallest and lightest baths in the industry to go with the dozens of other models we make.

Look at the specs, price, and value of these portable instruments and you'll know why Hart Scientific is the number-one company in this business.



A Micro-Bath's 1.9-inch-diameter tank lets you calibrate just about any size industrial sensor.

Don't forget a protective case!



See our selection of bath fluids on page 104.

Ranges from –30°C to 200°C

Specifications	6102	7102	7103
Range	35°C to 200°C (95°F to 392°F)	–5°C to 125°C (23°F to 257°F)	–30°C to 125°C (–22°F to 257°F)
Accuracy	±0.25°C		
Stability	±0.02°C at 100°C (oil 5013) ±0.03°C at 200°C (oil 5013)	±0.015°C at –5°C (oil 5010) ±0.03°C at 121°C (oil 5010)	±0.03°C at –25°C (oil 5010) ±0.05°C at 125°C (oil 5010)
Uniformity	±0.02°C		
Resolution	0.01°C/F		
Operating Temperature	5°C to 45°C		
Heating Time	25°C to 200°C: 40 minutes	25°C to 100°C: 30 minutes	25°C to 100°C: 35 minutes
Cooling Time	200°C to 100°C: 35 minutes	25°C to 0°C: 30 minutes	25°C to –20°C: 45 minutes
Well Size	2.5" dia. x 5.5" deep (64 x 139 mm) (access opening is 1.9" [48 mm] in diameter)		
Size	5.5" W x 10.38" H x 8" D (14 x 26 x 20 cm)	7.2" W x 12" H x 9.5" D (18 x 31 x 24 cm)	9" W x 13.2" H x 10.5" D (23 x 34 x 26 cm)
Weight	10 lb. (4.5 kg) with fluid	15 lb. (6.8 kg) with fluid	22 lb. (9.8 kg) with fluid
Volume	0.75 L	0.75 L	1.0 L
Power	115 VAC (±10%), 2.3 A or 230 VAC (±10%), 1.1 A, switchable, 50/60 Hz, 270 W	115 VAC (±10%), 1.8 A or 230 VAC (±10%), 0.9 A, switchable, 50/60 Hz, 200 W	94–234 VAC (±10%), 50/60 Hz, 400 W
Computer Interface	RS-232 included with free Interface-*it* software		
NIST-Traceable Calibration	Data at 50°C, 100°C, 150°C, and 200°C	Data at –5°C, 25°C, 55°, 90°C, and 121°C	Data at –25°C, 0°C, 25°C, 50°C, 75°C, 100°C, and 125°C

Ordering Information - 6102

6102	Micro-Bath, 35°C to 200°C (includes a transport seal lid and a 2082-M test lid)
2082-M	Spare test lid
2083	3-inch tank extension adapter (affects stability, uniformity, and range at extreme temperatures)
5013-L	Silicone oil, type 200.20, 1 liter (usable range: 10°C to 230°C)
9310	Carrying Case
2025-6102	X Cell Basket (see page 34)
3320	Spare Stir Bar, MicroBath

Ordering Information - 7102

7102	Micro-Bath, –5°C to 125°C (includes a transport seal lid and a 2082-P test lid)
2082-P	Spare test lid
2083	3-inch tank extension adapter (affects stability, uniformity, and range at extreme temperatures)
5010-L	Silicone oil, type 200.05, 1 liter (usable range: –40°C to 130°C)
9311	Carrying Case
2025-6102	X Cell Basket (see page 34)
3320	Spare Stir Bar, MicroBath

Ordering Information - 7103

7103	Micro-Bath, –30°C to 125°C (includes a transport seal lid and a 2085 test lid)
2085	Spare test lid
5010-L	Silicone oil, type 200.05, 1 liter (usable range: –40°C to 130°C)
9317	Carrying Case
2025-7103	X Cell Basket (see page 34)
3320	Spare Stir Bar, MicroBath

Use MET/TEMP II software and a reference thermometer to recalibrate your own heat sources!

Tim knows the rules—which makes us real glad he's our accountant.

SELECTING A DRY-WELL TEMPERATURE CALIBRATOR

If you have industrial temperature sensors such as RTDs, thermocouples, thermistors, bimetal thermometers, or liquid-in-glass thermometers to calibrate, you need a reliable heat source to verify accuracy.

A dry-well calibrator is a great combination of accuracy, portability, and price for industrial calibration applications. Typical dry-wells produce calibration accuracies of better than ±0.5°C over a range of –25°C to 650°C. In addition, for comparison of sensors in a dry-well's temperature block, hole-to-hole uniformity is commonly ±0.05°C. These uncertainties are well matched to the typical uncertainties of industrial temperature sensors.

To select the appropriate dry-well for your industrial sensors, you should consider:

- Temperature Range
- Accuracy and Stability
- Uniformity
- Well Flexibility
- Portability
- Sensor Immersion
- Throughput

Temperature Range

The temperature limits of the dry-well must meet your minimum test requirements for the sensors being calibrated. The ideal calibration spans the entire usable range of the test sensor. However, extrapolating a noncritical temperature point may save time while not affecting the overall system uncertainty.

Even after a full-range calibration of your temperature sensor, it's a good idea to check its accuracy in the precise range over which it is most often used. If you calibrate an RTD between 0°C and 100°C but are only monitoring room temperature, you may want to set your dry-well to 25°C and see how your calibrated sensor performs at its most important temperature.

Accuracy and Stability

The two most critical specs on a dry-well are accuracy and stability. Accuracy is how close the unit's well temperature is to the programmed set-point. Stability is the temperature fluctuation of the instrument around the desired set-point over time. If your dry-well does not meet your accuracy requirements and does not maintain a stable temperature, your probe could be reading a much different temperature than your display indicates.

A good rule of thumb is to make sure your dry-well is at least four times as accurate as the sensors you are checking. Also, make sure to get a certificate from the manufacturer certifying that the calibration is traceable to NIST. It shouldn't cost extra for the certificate.

Here's another tip. The dry-well should have at least the set-point resolution of the accuracy it claims for your target accuracy. For example, if you're calibrating an RTD to ±0.5°C at 100°C and your instrument only displays temperature to ±1°C, you obviously can't claim better than 1°C for your calibration.

Uniformity

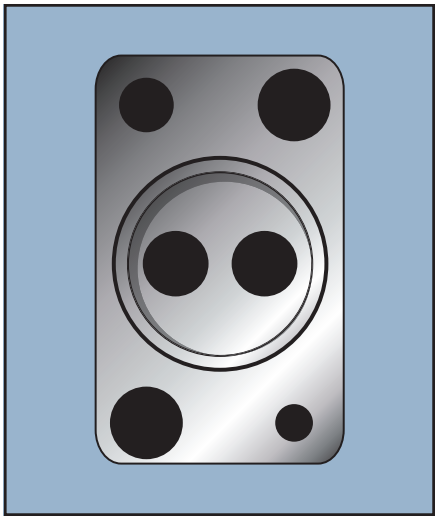
If you're using a reference thermometer, temperature uniformity throughout the block becomes critical. Gradients from the bottom of the block to the top of the block can be minimized by matching sensor depths (see "Sensor Immersion"). Well-to-well gradients are also inherent in the design and thermal characteristics of each dry-well and need to be factored into your total uncertainty calculation.

Some manufacturers confuse "accuracy" with well-to-well gradients, implying that their product is as "accurate" as its gradient. They fail to include stability and reference thermometer uncertainties, and they misrepresent their product's performance. Always consider how you are going to use your dry-well calibrator and then include the uncertainties that apply to your situation.

Well Flexibility

When purchasing a dry-well, make certain that the probes you need to test will fit in the unit's heated block. Most dry-wells use removable sleeves to size the main temperature well. This gives you the flexibility to calibrate a wider variety of probes with one instrument. The best accuracy comes from the holes that are drilled directly into the block because the contact between the sensor and the heated block is better. Using a removable sleeve can add additional uncertainty by introducing an air gap in the block.

Make sure that as you compare sensors in the same block, they are both in the same mass of metal. The manufacturer should be able to recommend the best way to compensate for the error in removable sleeves. For comparison calibrations in a dry-well, Hart Scientific recommends a specially designed sleeve with multiple holes in the same sleeve. This eliminates most of the introduced error.



A removable insert can be customized with two drilled holes for best accuracy.

Portability

If you carry a lot of instruments to field sites, portability may be a concern. Size, weight, and "carry-ability" are important factors to consider with many industrial applications. A dry-well should be designed for easy transport to the test site.

One of the most significant developments in dry-well technology was the emergence of the handheld dry-well. This brought dry-well technology to a new level of practicality. You can now pack a dry-block calibrator into your tool kit, whereas you previously had to put it on a cart to move it around.

Some of these handheld units can be battery powered for greater portability. What we used to call portable is now bulky and heavy. Make sure that your unit adds to

Handheld block calibrators have made industrial calibration more portable.

your calibration power, not to your back problems.

Sensor Immersion

Sensor immersion is a recurring topic when considering a dry-well for calibration of temperature probes. Immersion can be the single largest contributor to error in dry-well calibrations. In the ideal world, all of our sensor assemblies would be the same size and depth. Unfortunately, this is not the ideal world.

Immersing a 2-inch sensor assembly only 2 inches into a 6-inch well could yield an error up to 10°C. This is inherent in all dry-wells. In many cases, a bath is a better calibration medium, but not always practical. There are some techniques you can use to counter this error and bring a dry-well into a workable uncertainty level.

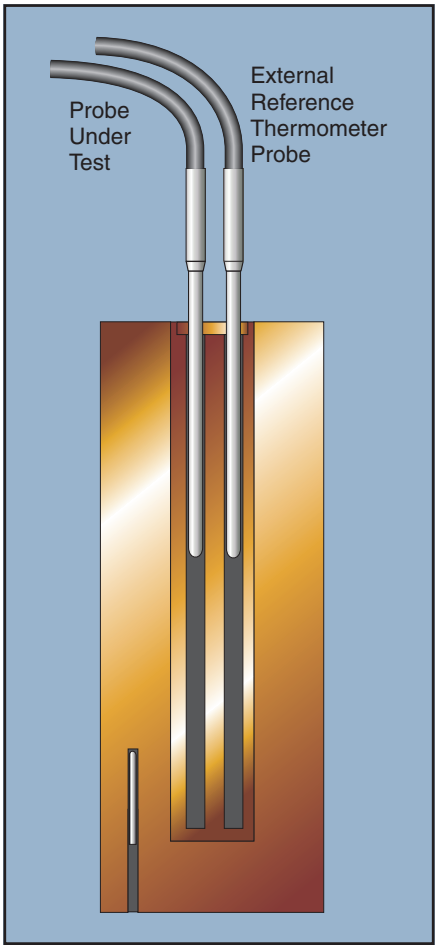
When calibrating a short-stem probe, always use a comparison technique. Do not compare the test reading to the dry-well display; it doesn't give you the best results. It's better to use a reference probe of similar type, size, and diameter. The closer the sizes match, the more accurate the comparison. Size impacts the amount of heat lost to ambient through the probe stem.

Immerse the similarly sized probes (the reference and test probes) at exactly the same depth into the block in holes that have a similar fit and distance from the heating source of the unit. What you are trying to achieve is identical heat properties inside the block, ensuring that both sensors are sensing the same temperatures in the same way. Any deviation will cause further error.

Throughput

If you're like the rest of the world, trying to calibrate as many sensors as possible in a limited time period, get a block calibrator that allows you to insert more than one probe at a time. If your unit only has one calibration well, have the manufacturer drill several holes into the removable sleeve.

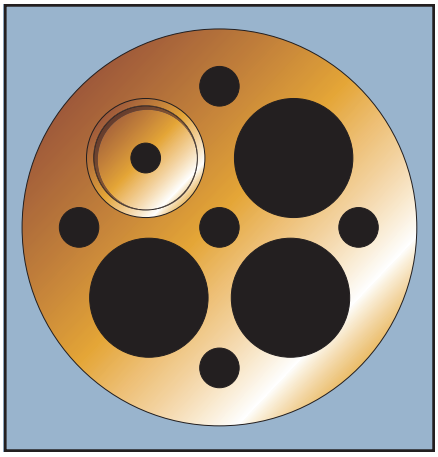
An additional consideration for increased throughput is automation. Make sure that you select a manufacturer that has truly automating calibration software for controlling the calibration of your probes. This can save you an enormous amount of time. Also, make sure the unit you select includes a PC link, like an RS-232 interface, so if you need to automate in the future to stay competitive, you can.



Short-stem sensors should be calibrated by comparison at the same depth when using a block calibrator.

Dry-wells have become the most practical tools in industrial temperature calibration. Units are now built that fit in your hand. Some are battery-powered and even accurate enough to be used as lab standards. Microprocessor-based controllers can store set-points and ramping cycles and even interface to your PC. Each unit is unique in its ability to satisfy the requirements of specific calibration applications.

Select the dry-well that best fits your application and you will have years of successful calibrating. If you have specific application concerns, call the manufacturer for help in selecting the unit that best fits all the considerations mentioned in this article.



Multiple-hole blocks can increase throughput by calibrating several probes simultaneously.

Call for custom inserts.

Read about our calibration training courses on page 153.

HANDHELD DRY-WELLS

Handheld Dry-Wells **Models 9100S and 9102S**

- Smallest dry-wells in the world
- Proprietary Hart Scientific controller
- Accuracy to ±0.25°C, stability of ±0.05°C at 0°C
- RS-232 interface with Hart Interface-*it* software

Hart's line of portable dry-wells is incredible. They're the smallest, lightest, and most portable dry-wells in the world. And now they're better than ever!

Model 9100S Dry-Well

Since we introduced the world's first truly handheld dry-well, many have tried to duplicate it—in vain. Despite its small size (2¼ inches high and 5 inches wide) and light weight, the 9100S outperforms every dry-well in its class in the world.

It's simple and convenient, too. Anyone can learn to use one in less than 15 minutes. It has a range to 375°C (707°F) and is perfect for checking RTDs, thermocouples, and small bimetal thermometers in the field.

Plug it in, switch it on, set the temperature with the front-panel buttons, and insert your probe into the properly sized well. Compare the reading of your device to the display temperature or to an external reference, and the difference is the error in your device. With a proprietary Hart Scientific temperature controller, the 9100S has a display resolution of 0.1 degrees. Display accuracy ranges from ±0.25°C to ±0.5°C and stability ranges from ±0.07°C to ±0.3°C, depending on set-point temperature.

Take the 9100S anywhere. It's the smallest dry-well in the world.

Model 9102S Dry-Well

For work in the temperature range of –10°C to 122°C, Hart's Model 9102S dry-well is another first in the industry, featuring display accuracy of ±0.25°C.

This dry-well is only four inches high and six inches wide, achieves temperatures as low as –10°C, includes a NIST-traceable calibration, and is stable to ±0.05°C. The Model 9102S is excellent for dial gauges, digital thermometers, bulb switches, and other sensors that need calibration below ambient.

The 9102S has two wells so you can use one for a reference thermometer to increase accuracy. Both wells are 1/2 inch (12.7 mm) in diameter, and each has inserts available for almost any sensor size. The 9102S also has a battery pack option that gives you approximately four hours of field use when AC power is unavailable.

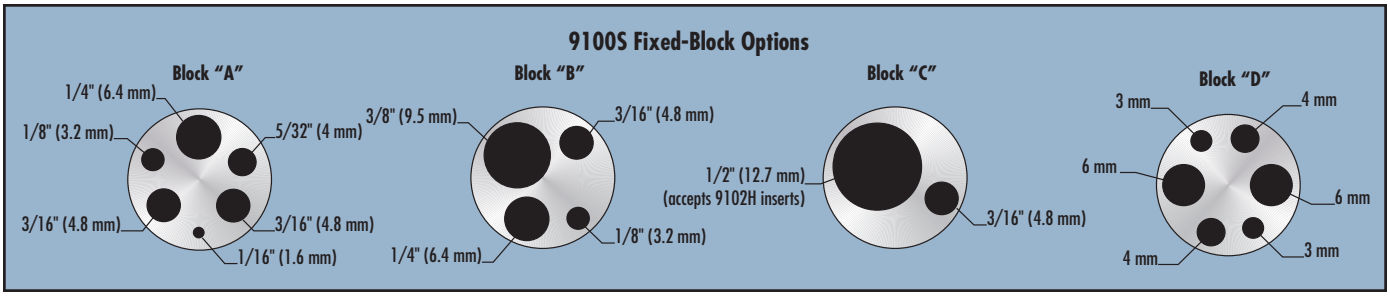
Model 9102S shown with battery pack, which includes a battery, carrying bag, cables, and charger.

Don't forget a protective case!

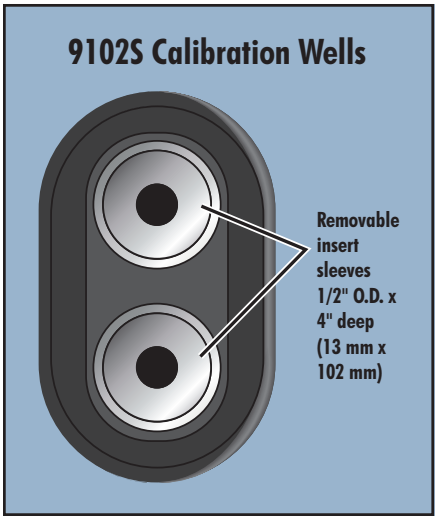
Have you considered a good reference thermometer? See page 36.

Industrial

Specifications	9100S	9102S
Range	35°C to 375°C (95°F to 707°F)	–10°C to 122°C (14°F to 252°F) at 23°C ambient
Accuracy	±0.25°C at 50°C; ±0.25°C at 100°C; ±0.5°C at 375°C	±0.25°C
Stability	±0.07°C at 50°C; ±0.1°C at 100°C; ±0.3°C at 375°C	±0.05°C
Well-to-Well Uniformity	±0.2°C with sensors of similar size at equal depths within wells	
Heating Times	ambient to 375°C: 9.5 minutes	ambient to 100°C: 10 minutes
Stabilization	5 minutes	7 minutes
Cooling Times	375°C to 100°C: 14 minutes	ambient to 0°C: 10 minutes
Well Depth	4 inches (102 mm); 1/16" (1.6 mm) hole is 3.5" (89 mm) deep	4 inches (102 mm)
Removable Inserts	N/A	Available in sizes from 1/16" (1.6 mm) to 7/16" (11.1 mm) [1/4" (6.4 mm) and 3/16" (4.8 mm) included]
Power	115 VAC (±10%), 1.5 A or 230 VAC (±10%), 0.8 A, specify, 50/60 Hz, 175 W	94-234 VAC (±10%), 50/60 Hz, 60 W; or 12 VDC
Size	2.25" H x 4.9" W x 5.9" D (57 x 125 x 150 mm)	3.9" H x 5.5" W x 6.9" D (99 x 140 x 175 mm)
Weight	2 lb. 3 oz. (1 kg)	4 lb. (1.8 kg)
Computer Interface	RS-232 included with free Interface-*it* software	
NIST-Traceable Calibration	Data at 50°C, 100°C, 150°C, 200°C, 250°C, 300°C, and 375°C	Data at –10°C, 0°C, 25°C, 50°C, 75°C, 100°C, and 122°C



9100S fixed-block options. Order number 9100S-A, 9100S-B, 9100S-C, or 9100S-D for the desired block option.



9102S block configuration. Instrument includes 1/4" and 3/16" inserts. Order additional sizes as needed.

Ordering Information - 9100S

9100S-A	HDRC Micro-Block A
9100S-B	HDRC Micro-Block B
9100S-C	HDRC Micro-Block C
9100S-D	HDRC Micro-Block D
9300	Rugged Carrying Case

Ordering Information - 9102S

9102S	HDRC Micro-Block
3102-0	Insert, blank
3102-1	Insert, 1/16" (1.6 mm)
3102-2	Insert, 1/8" (3.2 mm)
3102-3	Insert, 3/16" (4.8 mm)
3102-4	Insert, 1/4" (6.4 mm)
3102-5	Insert, 5/16" (7.9 mm)
3102-6	Insert, 3/8" (9.5 mm)
3102-7	Insert, 7/16" (11.1 mm)
3102-8	Insert, 5/32" (4 mm)
9320	Battery pack for 9102S
9308	Carrying Case

Get the latest product information at www.hartscientific.com

INDUSTRIAL DUAL-BLOCK CALIBRATOR

Industrial Dual-Block Calibrator **Model 9009**

- Temperatures from –15°C to 350°C in one unit
- Two wells in each block for simultaneous comparison calibrations
- Rugged, lightweight, watertight enclosure

You've been asking for it and now we're making it for you. Hart's 9009 Industrial Dual-Block Calibrator lets you calibrate at hot and cold temperatures at the same time. Double your productivity or cut your calibration time in half—either way you look at it, your in-field temperature calibrations just got easier.

The 9009 includes two independently controlled temperature blocks. The hot block provides temperatures from 50°C to 350°C, while the cold block covers the range –15°C to 110°C. Each block is controlled by a precision Hart Scientific temperature controller. These aren't some off-the-shelf controllers we glued into a box. These are Hart Scientific controllers from the leading temperature company in the world.

Each temperature block includes two wells with removable inserts. You can calibrate four probes at once, or you can calibrate two probes at the same time with an external reference (like Hart's 1521 LLK Thermometer on page 37), or you can use the two temperature wells to get quick "zero" and "span" references for transmitter calibrations.

Need portability and durability? The 9009 is housed in a tough Pelican™ case that is both airtight and watertight. It's a small package weighing only 10 pounds, yet it fits everything you need, including a power cord and four extra inserts. Inserts are available to accommodate sensors of any size from 1/16" (1.6 mm) to 7/16" (11.1 mm). This rugged system can go anywhere.

Of course, the 9009 also delivers the performance you expect from a Hart Scientific temperature source. The cold block is calibrated to within ±0.2°C with stability of ±0.05°C. The hot block's display is accurate to ±0.6°C with stability of ±0.05°C. A NIST-traceable calibration is included for each of the two test blocks.

For use with automated systems, the 9009 comes with an RS-232 connection and our Model 9930 Interface-*it* software, which allows you to control and monitor temperatures from your PC. For completely automated calibrations, Hart's MET/TEMP II software (page 75) also integrates with the 9009.

Two blocks in one unit, a total range of –15°C to 350°C, portability, durability, versatility, performance, and automation. Hart Scientific delivers it all.

The 9009 is built into a small, lightweight, rugged enclosure that holds everything you need and comes in black or yellow.

Technical Tip

Increase Dry-Well Performance with a Reference Thermometer

To increase the performance of a block calibrator and the accuracy level of your calibrations, add a reference thermometer to your system. The Tweener Thermometers and Handheld Thermometers on pages 37–41 can bring your NIST-traceable uncertainty from ±0.5°C to ±0.05°C.

Using a comparison technique, users insert both the test and reference probe into the same block at the same time, which yields a much better calibration. Both probes, if inserted at the same depth with similar size and diameters, will be sensing more of the same temperature than a single probe inserted and compared to the sensor that feeds the display.

Tweener and Handheld Thermometers are used with a high-accuracy reference PRT or thermistor calibrated to the ITS-90 scale and included with a certificate and calibration coefficients.

We designed many of our field calibrators with removable insert sleeves that have multiple holes drilled for use with a reference thermometer system.

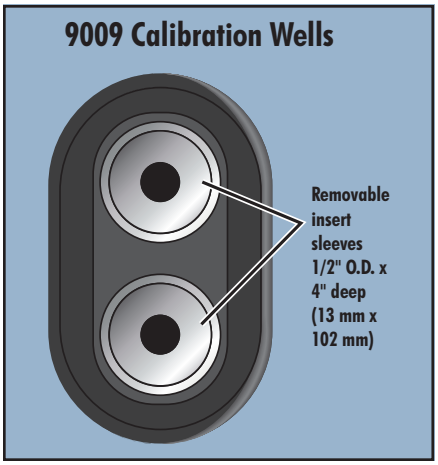
Ranges from –15°C to 350°C

Specifications	Hot Block	Cold Block
Range	50°C to 350°C (122°F to 662°F)	–15°C to 110°C (5°F to 230°F) (–8°C [18°F] with hot block at 350°C [662°F])
Accuracy	±0.6°C	±0.2°C
Stability	±0.05°C	
Well-to-Well Uniformity	±0.1°C	
Display Resolution	0.1°	
Heating Times	10 minutes from 25°C to 350°C	15 minutes from 25°C to 110°C
Cooling Times	30 minutes from 350°C to 100°C	16 minutes from 25°C to –15°C
Stabilization Times	8 minutes	
Well Depth	4" (102 mm)	
Removable Inserts	Two 1/4" (6.4 mm) and two 3/16" (4.8 mm) inserts included; see Ordering Information for other available inserts	
Computer Interface	RS-232 included with free Interface-*it* software	
Power	115 VAC (±10%), 3 A, or 230 VAC (±10%), 2 A, specify, 50/60 Hz, 280 W	
Size	7" H x 10.5" W x 9.75" D (178 x 267 x 248 mm)	
Weight	10 lb. (4.5 kg)	
NIST-Traceable Calibration	Data at 50°C, 100°C, 150°C, 200°C, 250°C, 300°C, and 350°C	Data at –8°C, 0°C, 25°C, 50°C, 75°C, 100°C, and 110°C

Ordering Information

9009-X	Industrial Dual-Block Dry-Well (X = case color. Specify "B" for black or "Y" for yellow.) Includes two 1/4" (6.4 mm) and two 3/16" (4.8 mm) insters.
3102-0	Insert, Blank
3102-1	Insert, 1/16" (1.6 mm)
3102-2	Insert, 1/8" (3.2 mm)
3102-3	Insert, 3/16" (4.8 mm)
3102-4	Insert, 1/4" (6.4 mm)
3102-5	Insert, 5/16" (7.9 mm)
3102-6	Insert, 3/8" (9.5 mm)
3102-7	Insert, 7/16" (11.1 mm)
3102-8	Insert, 5/32" (4 mm)

Use MET/TEMP II software and a reference thermometer to recalibrate your own heat sources!.



Each block contains two wells, which accept removable inserts. A 1/4" and a 3/16" insert are included for each block. Additional sizes (including custom sizes) are available.

Orem city gardening champ Barbara (international invoicing) gets ready to order her next set of seeds.

FIELD DRY-WELLS

Field Dry-Wells **Models 9103, 9140, and 9141**

- Lightweight and very portable
- Accuracy to ±0.25°C
- RS-232 and Interface-*it* software included
- Easy to recalibrate

If you've been using dry-well calibrators, you know there's a lot more to a dry-well than its temperature range and stability. Size, weight, speed, convenience, and software are also significant.

Dry-wells need to be portable, flexible, and suitable for high-volume calibrations or certifications. If they're not, you'll soon forget about the great stuff the sales rep told you and realize what you've really bought.

At Hart Scientific, we use dry-wells every day in our manufacturing and calibration work, and we know what makes a dry-well easy and productive to use—which is exactly how users describe our series of "field" dry-wells. These dry-wells work for you instead of you working for your dry-well.

These three units beat every other comparable dry-well in the industry in performance, size, weight, convenience, ease of calibration, software, and price. In addition, the heating and cooling rate of each of these dry-wells is adjustable from the front panel, thermal switches can be checked for actuation testing, and multiple-hole inserts are available for a variety of probe sizes.

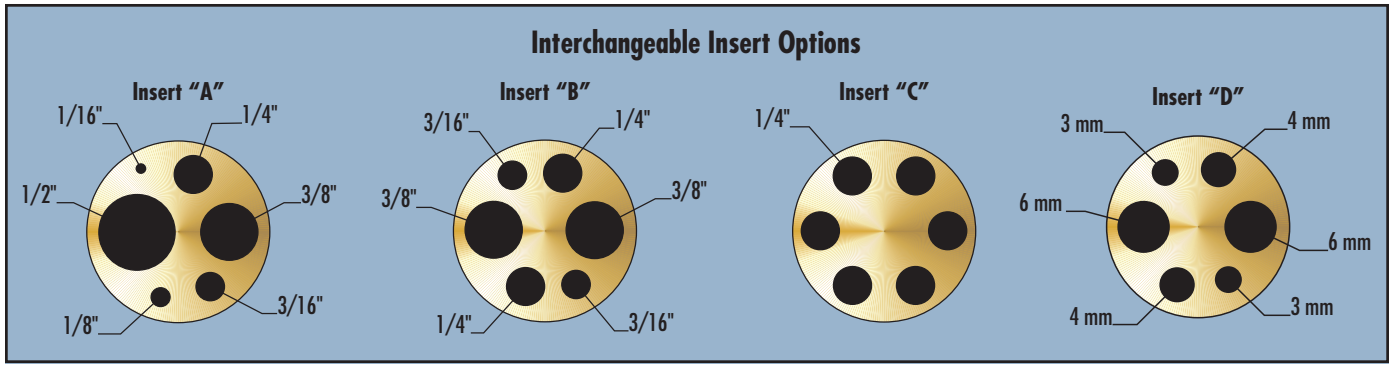
Hart dry-wells are easy to calibrate. You don't even have to open the case. This means less maintenance costs and less down time when they do need calibration.

Our Interface-*it* software lets you adjust set-points and ramp rates, log dry-well readings to a file, create an electronic strip chart, and perform thermal switch testing with data collection. The software is written for Windows and has a great graphical interface. It's the best dry-well software in the industry. Regardless of whether you want basic software or a completely automated calibration system, we've got what you want. Read about all our great packages starting on page 74.

Every dry-well we ship is tested at our factory, and every unit comes with a NIST-traceable calibration. There's no extra charge for the report, because we consider it an essential ingredient in our quality program. You shouldn't have to pay extra for calibration procedures we perform anyway.

Model 9103

The Model 9103 covers below-ambient temperatures as low as –25°C. The 9103 is stable to ±0.02°C, and its display is cali-



When ordering, replace the "X" with the appropriate insert letter. Order additional inserts as your applications require.

Specifications	9103	9140	9141
Range	–25°C to 140°C (–13°F to 284°F) at 23°C ambient	35°C to 350°C (95°F to 662°F)	50°C to 650°C (122°F to 1202°F)
Accuracy	±0.25°C	±0.5°C (holes greater than 1/4" [6.35 mm]: ±1°C)	±0.5°C to 400°C; ±1.0°C to 650°C (holes greater than 1/4": ±2°C)
Stability	±0.02°C at –25°C ±0.04°C at 140°C	±0.03°C at 50°C ±0.05°C at 350°C	±0.05°C at 100°C ±0.12°C at 500°C ±0.12°C at 650°C
Well-to-Well Uniformity	±0.1°C between similarly sized wells	±0.1°C with similarly sized wells	±0.1°C below 400°C, ±0.5°C above 400°C with similarly sized wells
Heating Times	18 minutes from ambient to 140°C	12 minutes from ambient to 350°C	12 minutes from ambient to 650°C
Cooling Times	20 minutes from ambient to –25°C	15 minutes from 350°C to 100°C	25 minutes from 650°C to 100°C
Stabilization Time	7 minutes		
Immersion Depth	4.875″ (124 mm)		
Inserts	Insert A, B, C, or D included (specify when ordering)		
Outside Insert Dimensions	1.25" diameter x 4.88" length (31.8 x 124 mm)		1.12" diameter x 4.88" length (28.5 x 124 mm)
Computer Interface	RS-232 included with free Interface-*it* software (Model 9930)		
Power	115 VAC (±10%), 1.3 A or 230 VAC (±10%), 0.7 A, switchable, 50/60 Hz, 150 W	115 VAC (±10%), 4.4 A or 230 VAC (±10%), 2.2 A, switchable, 50/60 Hz, 500 W	115 VAC (±10%), 8.8 A or 230 VAC (±10%), 4.4 A, switchable, 50/60 Hz, 1000 W
Size	5.63" W x 10.25" H x 9.63" D (143 x 261 x 245 mm)	6" W x 3.375" H x 7.75" D (152 x 86 x 197 mm)	4.3" W x 9.3" H x 7.3" D (109 x 236 x 185 mm)
Weight	12 lb. (5.7 kg)	6 lb. (2.7 kg)	8 lb. (3.6 kg)
NIST-Traceable Certificate	Data at –25°C, 0°C, 25°C, 50°C, 75°C, 100°C, and 140°	Data at 50°C, 100°C, 150°C, 200°C, 250°C, 300°C, and 350°C	Data at 100°C, 200°C, 300°C, 400°C, 500°C, and 600°C

brated to an accuracy of ±0.25°C at all temperatures within its range. 0°C is reached in just eight minutes, and 100°C is reached in six minutes, so your time is spent calibrating—not waiting.

The 9103 reaches temperatures 50°C below ambient, so –25°C is reached under normal ambient conditions. Our competitors like to advertise their units as reaching –45°C when they really mean –45°C below ambient, which typically means it will go to –20°C. Our unit doesn't require you to work in a walk-in freezer to achieve its full advertised range.

Choose one of three removable inserts sized for probes from 1/16 inch to 1/2 inch in diameter. Insert A handles a full range of probe sizes with a single well of each size. Insert B features two wells each of 3/8, 1/4, and 3/16 inches in diameter for doing comparison calibrations. Insert C has six 1/4-inch-diameter wells for multiple probe calibrations, and Insert D has three pairs of metric sized wells.

A special adapter sleeve is also available for maintaining X Cells (page 34) in a 9103 Dry-Well.

Model 9140

The Model 9140 has a temperature range of 35°C to 350°C, and it reaches its maximum temperature in 12 minutes. At six pounds, it's small enough to easily carry in one hand. It's truly a unique innovation in dry-wells.

The unit has a stability of ±0.05°C or better and a uniformity of at least 0.4°C in the largest-diameter wells and 0.1°C in the smaller wells. Despite its small size, this unit performs.

Use the display, calibrated to ±0.5°C, as your reference, or use an external thermometer for maximum calibration accuracy. With three removable inserts to choose from, the 9140 is as versatile as it is fast.

Model 9141

Here's an upright unit you're going to love. It does calibrations up to 650°C, weighs only eight pounds, and heats up to 650°C in only 12 minutes—12! This dry-well does everything but get legs and walk to the job for you. (And we're working on one that does that too.)

This four-inch-wide dry-well is amazing. You can control all functions from the front panel or hook it up to your PC with its built-in RS-232 port. And just like the 9140, it works with all of our software described on page 74.

It has three removable well inserts available, an optional carrying case, a NIST-traceable calibration, and the best price in the industry.

Have you considered a good reference thermometer? See page 36.

Ordering Information - 9103

9103-X	Dry-Well (specify X, X = A, B, C, or D included insert)
3103-1	Insert, blank
3103-2	Insert A
3103-3	Insert B
3103-4	Insert C
3103-5	X Cell Adapter Sleeve, 9103 (see page 34)
3103-6	Insert D
9316	Rugged Carrying Case

Ordering Information - 9140

9140-X	Dry-Well (specify X, X = A, B, C, or D included insert)
3140-1	Insert, blank
3140-2	Insert A
3140-3	Insert B
3140-4	Insert C
3140-6	Insert D
9308	Rugged Carrying Case
2032	Air Chiller, Dry-Well

Ordering Information - 9141

9141-X	Dry-Well (specify X, X = A, B, C, or D included insert)
3141-1	Insert, blank
3141-2	Insert A
3141-3	Insert B
3141-4	Insert C
3141-6	Insert D
9309	Rugged Carrying Case
2032	Air Chiller, Dry-Well

Hart not only includes an RS-232 port on the 9103, 9140, and 9141, but also gives you free Windows control software (Interface-*it*) *to automate your dry-well.*

Calibrations using dry-wells can be improved by using an external reference such as the 1502A Tweener Thermometer.

Technical Tip

Maximum Accuracy

To get the most accurate calibrations possible from a dry-well calibrator, you should use an external reference thermometer. If, however, you are *not* using an external reference, there are a few important things you should keep in mind.

First, you *are* using a reference. You're comparing the reading of your test probe against the display of the dry-well. The dry-well display is based on its own control sensor, usually located at the bottom of the well. Therefore, to make the best comparison, your test probe should be inserted to the same depth as the control sensor. This was the method used when the dry-well's display was calibrated at the factory.

Second, your test probe should fit snugly into one of the test wells. Again, this is how it was originally calibrated at the factory. If your probe is too loose, thermal contact is poor and a large error has been introduced. Custom inserts are available to help solve this problem.

Third, you should not introduce fluids into the wells of a dry-block in an attempt to improve thermal contact. It is too dangerous. If thermal contact is so poor that you're thinking about doing this, consider buying a fluid bath instead. Micro-Baths are now available that are just as portable and easy to use as dry-wells.

The point is that the accuracy specs of your dry-well are based upon how the manufacturer calibrates it. If you're relying on those specs, you need to use the dry-well the same way they do — with a good, snug fit at the bottom of the well.

Use MET/TEMP II software and a reference thermometer to recalibrate your own heat sources!.

Call for custom inserts.

Industrial

IMPROVING DRY-WELL CALIBRATIONS

Many customers use a dry-well as both a heat source and a reference thermometer. In other words, they put their thermometer or sensor to be tested in the well and compare its reading to the temperature on the display of the dry-well as shown in figure 1. The dry-well displays both the temperature the user set and the actual temperature measured by the dry-well's own control sensor. If this is your practice, be aware of the following cautions.

First, several dry-well manufacturers don't actually calibrate this display. When quoting the "accuracy" of their dry-well, some manufacturers actually give you the "potential" calibration accuracy if you use an adequate external thermometer to read the dry-well's temperature during the calibration. You can only guess what the actual accuracy of the dry-well's display is.

Second, several manufacturers who do calibrate their displays and print specifications for display accuracy don't include a traceable calibration report with the dry-well. You have to pay extra to get one. Both of these practices seem irresponsible to us. Hart dry-wells all feature a calibrated display of the well's temperature, and we include a traceable calibration report with every dry-well at no extra charge. If you're buying a calibration instrument, why should you pay extra for the piece of paper that makes your instrument a valid calibration tool?

The first two cautions don't apply if you buy a Hart dry-well. We design the electronics and sensor package for each dry-well to provide traceable accuracy that is reasonably adequate for many applications. However, your accuracy can be improved, even in a Hart dry-well, if you use a more accurate reference thermometer during your calibrations. Most of our blocks feature multiple holes, and you can order two-hole inserts for our other models. This allows you to put your reference thermometer in close proximity to the sensor you're testing as shown in figure 2.

Third, all dry-wells have some temperature gradient along the depth of the well. In a Hart dry-well these gradients are lower than competing units. However, if you're calibrating a short sensor that doesn't reach the bottom, it may not be exposed to the exact same temperature shown on the dry-well's display. You'll get more accurate results by using an external reference thermometer, as shown in figure 3, with its probe immersed in an adjacent well at the same depth as the unit under test.

Hart's model 1502A Tweener Thermometer is a perfect companion to a Hart dry-well. This traceable reference thermometer (page 40) is accurate to ±0.009°C at 100°C. The 1529 Chub-E4 (page 42) does even more by serving as both the reference thermometer and a meter to read the sensors you're testing. Using one of these thermometers as the reference during your calibrations can improve your total calibration accuracy to ±0.03°C or better. What's more, your reference thermometer can be combined with MET/TEMP II software to calibrate the display on your dry-well for those times you're not using an external reference.

Read about our calibration training courses on page 153.

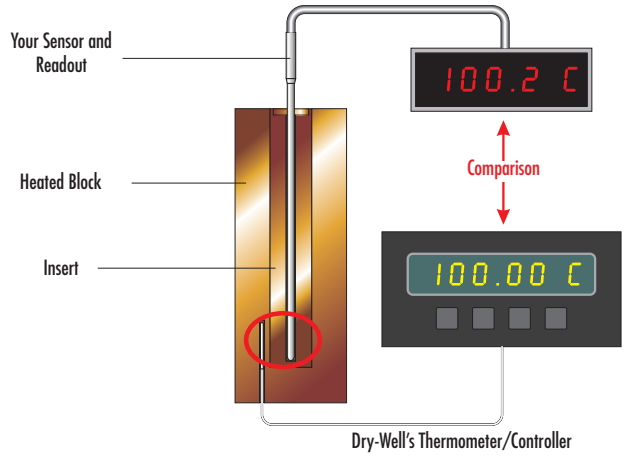


Figure 1
Dry-Well as Reference Standard

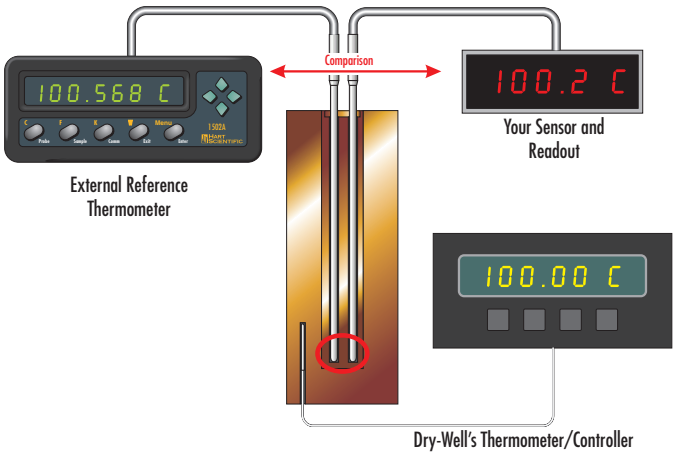


Figure 2
External Reference Standard

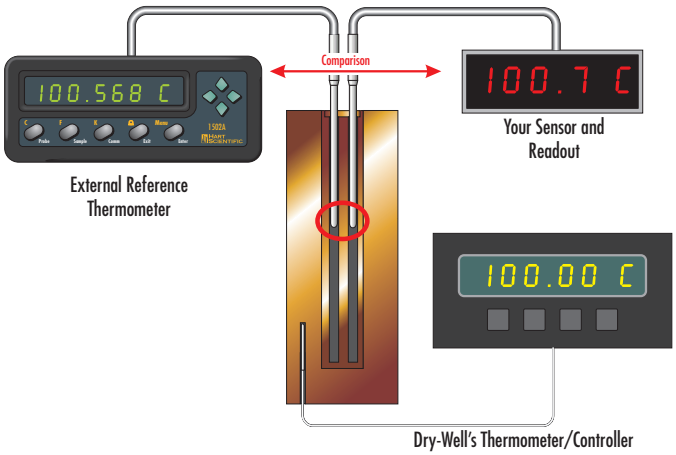


Figure 3
Calibrating Short Probes

HIGH-ACCURACY DRY-WELLS

High-Accuracy Dry-Wells **Models 9105, 9107, 9122A, and 9127**

- World's best dry-wells — accurate to 0.1°C, stable to ±0.005°C
- Largest-capacity temperature wells
- Model 9107 reaches lowest temperatures: –45°C in 23°C ambient
- Model 9122A provides temperatures to 700°C

Hart's dry-wells are the best in this industry, not only because of their performance specs, but because they're the easiest to use and have a variety of software packages available to fully automate the calibration of sensors.

These units are specifically built for the demanding requirements of temperature work in calibration labs. Each instrument has excellent stability, uniformity, and accuracy and features Hart's own proprietary controller for precision work; you can set the temperature with 0.01°C resolution. Our new Model 9107 Ultracold Dry-Well even reaches –45°C in normal room temperatures.

All four dry-wells come with an RS-232 port and have an optional IEEE interface available. However, unlike the competition, Hart dry-wells include our 9930 Interface-*it* software for controlling the unit with your PC. And if you want more, buy our 9938 MET/TEMP II software, which totally automates the calibration process for RTDs, thermocouples, and thermistors.

No other company offers software packages as good as these two from Hart. Our MET/TEMP II software is not entry-level data acquisition stuff. It is a total automation solution for the calibration process. These packages do everything but take the probe out of your dry-well when the calibration process is done, and we're working on a program that will do that too! (See page 75.)

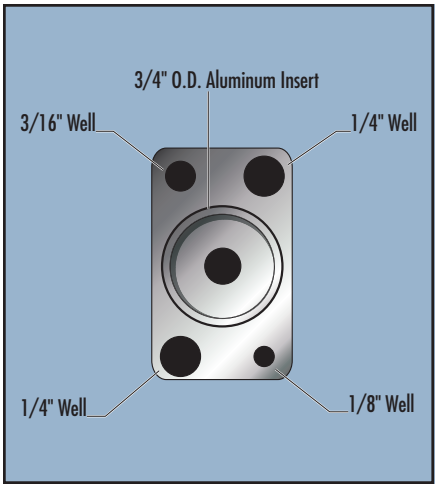
If you don't want to use a PC with these dry-wells, program them through the front panel to automatically set and hold up to eight temperatures in the sequence and duration of your choice. Each unit also has a "switch test" protocol that locks in the triggering temperature for thermal switches. The dry-well's ramp rate can be set to a speed of your choosing.

Each dry-well is completely tested and calibrated before shipment, and we don't charge extra for the traceability certificate. When accuracy and stability are important to your work, Hart is your best choice, especially when you compare prices.

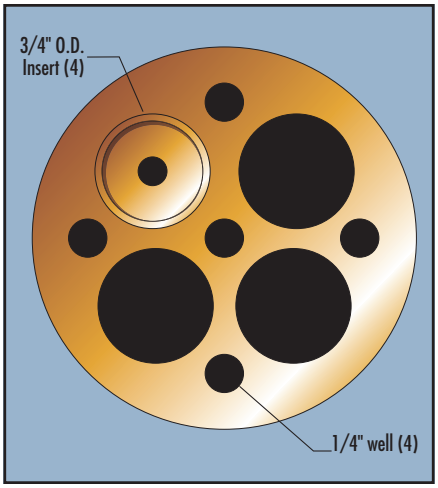
9105

The Model 9105 Dry-Well has a temperature range of –25°C to 140°C with a stability of ±0.01°C. It has four outside wells of various sizes and a removable center well as shown in the illustration. Well-to-well uniformity in the drilled wells is ±0.05°C.

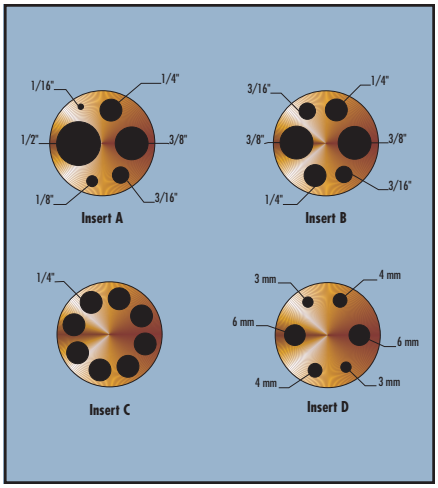
Used with a standards probe, the 9105 has the test well uniformity and the stability



The 9105 and 9107 blocks have five calibration wells, one of which accepts interchangeable inserts.



The 9122A has the most wells of any dry-well: 9 total with four that accept interchangeable inserts.



The 9127 block has one well that accepts interchangeable inserts.

to give you ±0.05°C calibration accuracy. The high-precision, microprocessor-based controller has 0.01 degrees of resolution.

You recalibrate your 9105 through its front panel, which reduces the cost and problems of recertifying your instrument. It comes with a NIST-traceable calibration at no additional cost, making the 9105 dry-well an even better value.

9107

Need temperatures colder than –25°C? The 9107 Ultracold Dry-Well gets you to –45°C in a 23°C ambient and still covers temperatures as high as 140°C. You won't find another dry-well anywhere that gets colder—or that is more stable.

The 9107 features five calibration wells, incredible accuracy, and stability better than ±0.005° over most of its range. Like the 9105, this ultracold dry-well doesn't use a compressor and doesn't require external cooling. Peltier modules do all the work so you don't have to worry about external hookups or cold ambient temperatures. Hart's dry-wells are simply easier to use and outperform everything else out there.

9122A

Too many probes to calibrate and too little time? The 9122A High Capacity Dry-Well comes with nine test wells, a display calibrated to 660°C, and an upper temperature limit of 700°C.

Test nine probes simultaneously or eight probes against a reference thermometer. Four of the nine wells accept removable inserts; the other five are drilled for 1/4" (6.35 mm) probes. The center well on the 9122A is accurate to ±0.3°C and stable to ±0.05°C at 660°C. No other unit on the market offers this combination of capacity, temperature range, and performance.

What's more, this unit makes a perfect annealing furnace. Reference PRTs (and thermocouples) generally benefit from periodic annealing at high temperatures to remove sensor strain and oxidation build-up. With capacity for nine probes and temperatures to 700°C, the 9122A offers a perfect solution.

9127

For work between 50°C and 600°C, the 9127 is one of our most popular instruments. It has a "smart" controller that automatically increases fan speed for cooling the block and then reduces the fan speed at a specific set-point temperature for maximum stability during calibrations.

It has an accuracy of ±0.15°C up to 300°C and ±0.5°C to 600°C. Resolution is 0.01°C and stability is ±0.02°C at 300°C. Inserts are available with multiple sensor holes for doing comparison calibrations. Uniformity between holes is ±0.05°C.

For fast cool-downs of a 9122A or 9127 dry-well, the optional 2032 Air Chiller connects directly to shop air to inject cool air into the well and reduce cooling times by more than 50%.

Our 9304 carrying case fits the 9105, 9107, and 9127 Super Dry-Well models. (Use the 9324 to carry and protect a 9122A.)

Use MET/TEMP II software and a reference thermometer to recalibrate your own heat sources!

Call for custom inserts.

Have you considered a good reference thermometer? See page 36.

Industrial

HIGH-ACCURACY DRY-WELLS — Ranges from –45°C to 700°C

Specifications	9105	9107	9122A	9127
Range	–25°C to 140°C (–13°F to 284°F) at 23°C ambient	–45°C to 140°C (–49°F to 284°F) at 23°C ambient	50°C to 700°C† (122°F to 1292°F)	50°C to 600°C (122°F to 1112°F)
Accuracy	**Center well:** ±0.1°C	**Center well:** ±0.1°C	**Center well:** ±0.1°C at 100°C ±0.1°C at 300°C ±0.3°C at 660°C	±0.1°C at 100°C ±0.15°C at 300°C ±0.5°C at 600°C
Stability	±0.01°C	±0.01°C at –40°C ±0.005°C at 0°C ±0.005°C at 100°C	±0.01°C at 100°C ±0.02°C at 300°C ±0.05°C at 660°C	±0.01°C to 100°C ±0.02°C to 300°C ±0.05°C to 600°C
Well-to-Well Uniformity	**Drilled wells:** ±0.05°C	**Drilled wells:** ±0.05°C	**Drilled wells:** ±0.025°C at 100°C ±0.1°C at 300°C ±0.3°C at 660°C	±0.05°C
Well Depth	6" (152 mm)			
Computer Interface	RS-232 Interface included with Model 9930 Interface-*it* control software, IEEE optional			
Heating Time to Max.	10 minutes	15 minutes	75 minutes	30 minutes
Cooling Time	25°C to –25°C: 15 minutes	25°C to –45°C: 35 minutes	700°C to 100°C: 280 minutes	600°C to 100°C: 125 minutes
Test Wells	5 wells: 2 at 1/4" (6.35 mm), 1 at 3/16" (4.8 mm), 1 at 1/8" (3.2 mm), and 1 interchangeable (3/4"/19.1 mm O.D.)	5 wells: 2 at 1/4" (6.35 mm), 1 at 3/16" (4.8 mm), 1 at 1/8" (3.2 mm), and 1 interchangeable (3/4"/19.1 mm O.D.)	9 wells: 4 interchangeable (3/4"/19.1 mm O.D.) and 5 at 1/4" (6.35 mm)	1 interchangeable well accommodates multi-hole insert (1.5"/38.1 mm O.D.)
Resolution	0.01°C or °F			
Display	LED, °C or °F, user-selectable			
Size	13.5" H x 7.8" W x 11.9" D (343 x 198 x 302 mm)			
Weight	26 lb. (11.8 kg)	22 lb. (10 kg)	25 lb. (11.3 kg)	25 lb. (11.3 kg)
Power	115 VAC (±10%), 3 A or 230 VAC (±10%), 1.6 A, specify, 50/60 Hz, 350 W	115 VAC (±10%), 4 A or 230 VAC (±10%), 3.15 A, specify, 50/60 Hz, 350 W	115 VAC (±10%), 8.8 A or 230 VAC (±10%), 4.4 A, specify, 50/60 Hz, 1000 W	115 VAC (±10%), 8.8 A or 230 VAC (±10%), 4.4 A, switchable, 50/60 Hz, 1000 W
NIST-Traceable Calibration	Data at –25°C, 0°C, 75°C, and 140°C	Data at –45°C, 0°C, 75°C, and 140°C	Data at 100°C, 200°C, 300°C, 400°C, 500°C, and 660°C	Data at 100°C, 200°C, 300°C, 400°C, 500°C, and 600°C

†Calibrated to 660°C; reference thermometer recommended at higher temperatures.

Ordering Information — 9105, 9107

9105	Low-Temp Dry-Well, includes 1/4" insert
9107	Ultra Low-Temp Dry-Well, includes 1/4" insert
2125	IEEE-488 Option
2168	Blank Insert
2169	1/16" Insert (1.6 mm)
2170	1/8" Insert (3.2 mm)
2171	5/32" Insert (4 mm)
2172	3/16" Insert (4.8 mm)
2173	1/4" Insert (6.35 mm)
2174	5/16" Insert (7.9 mm)
2175	3/8" Insert (9.5 mm)
2176	1/2" Insert (12.7 mm)
2177	5/8" Insert (15.9 mm)
2181	1 User-Specified Hole
2182	2 User-Specified Holes
9304	Carrying Case

Don't forget a protective case!

Ordering Information — 9122A

9122A	High-Capacity Dry-Well, includes 1/8", 3/16", 3/8", and ¼" inserts, and cleaning kit for wells and inserts
2125	IEEE-488 Option
2152	Blank Insert
2154	1/8" Insert (3.2 mm)
2155	5/32" Insert (4 mm)
2156	3/16" Insert (4.8 mm)
2157	1/4" Insert (6.35 mm)
2158	5/16" Insert (7.9 mm)
2159	3/8" Insert (9.5 mm)
2160	1/2" Insert (12.7 mm)
2161	5/8" Insert (15.9 mm)
2162	1 User-Specified Hole
2163	2 User-Specified Holes
9324	Carrying Case, 9122A
2032	Air Chiller, Dry-Well
2037	Well and Insert Cleaning Kit

Ordering Information — 9127

9127-X	High-Speed Dry-Well with removable multi-hole insert (specify X, X = A, B, C, or D included insert)
2125	IEEE-488 Option
3109-0	Insert, blank
3109-1	Insert A, holes at 1/16", 1/8", 3/16", 1/4", 3/8", 1/2" (1.6, 3.2, 4.8, 6.35, 9.5, 12.7 mm)
3109-2	Insert B, two holes each at 3/16", 1/4", 3/8" (4.8, 6.35, 9.5 mm)
3109-3	Insert C, eight holes each at 1/4" (6.35 mm)
3109-4	Insert D, two holes each at 3 mm, 4 mm, and 6 mm
9304	Carrying Case
2032	Air Chiller, Dry-Well

See our calibration and data acquisition software packages on page 74.

ZERO-POINT DRY-WELL — Range: 0°C

Zero-Point Dry-Well — Model 9101

- Bath-quality stability in a portable ice-point reference
- Easy recalibration for long-term reliability
- Ready light frees user's time and attention
- Solid-state cooling technology

Have you been thinking about buying a zero-point dry-well? Forget those ugly-looking units the competition makes. Now you can get a great-looking and great-performing zero-point dry-well from Hart Scientific.

The Hart Model 9101 has three test wells for inserting more than one probe at a time. All three wells are stable to ±0.005°C. One well accommodates changeable inserts for varying probe diameters.

The Model 9101 takes advantage of the latest solid-state cooling technology rather than relying on older, less reliable sealed-water-cell devices. This eliminates the possibility that the sealed-water cell will freeze and burst while transporting the unit to field locations. And our solid-state cooler is run by an adjustable electronic controller that can be recalibrated in your lab for convenient recertification. Simply place a certified standards thermometer in one of the wells and, if needed, tweak the 9101 controller until the standards thermometer reaches equilibrium at 0°C.

Since the unit is completely self-contained and doesn't require any user settings, you can run it on demand for instant access to an accurate, traceable zero point. Set it up with the reference junction of a thermocouple for high-accuracy thermocouple measurements.

Less costly than refrigerated baths, more accurate and less problematic than ice baths, and more durable and better looking than competitive units using sealed-water cells, the Hart Model 9101 Zero-Point Dry-Well is a great choice for any calibration lab!

Specifications

Temperature Range	0°C (32°F)
Stability	±0.005°C
Total Instrument Error	±0.02°C, typical; ±0.05°C max. (18–25°C ambient)
Stabilization Time	Approx. 30 minutes (the ready lamp indicates stable control at 0°C)
Temperature Coefficient	±0.005°C/°C
Size	12.25" H x 8.5" W x 5.75" D (311 x 216 x 146 mm)
Power	115 VAC (±10%), 1 A or 230 VAC (±10%), 0.5 A, specify, 50/60 Hz, 125 W
Well Dimensions	2 wells 0.25" dia. x 6" D (6.4 x 152 mm), 1 well 0.28" dia. x 6" D (7 x 152 mm). Includes one set of telescoping inserts to provide various smaller diameters
Weight	12 lb. (5.4 kg)
NIST-Traceable Calibration	Data at 0°C

Ordering Information

9101	Zero-Point Dry-Well (includes one set of telescoping inserts to provide various smaller diameters)
2130	Spare Well-Sizing Tube Set
9325	Rugged Carrying Case

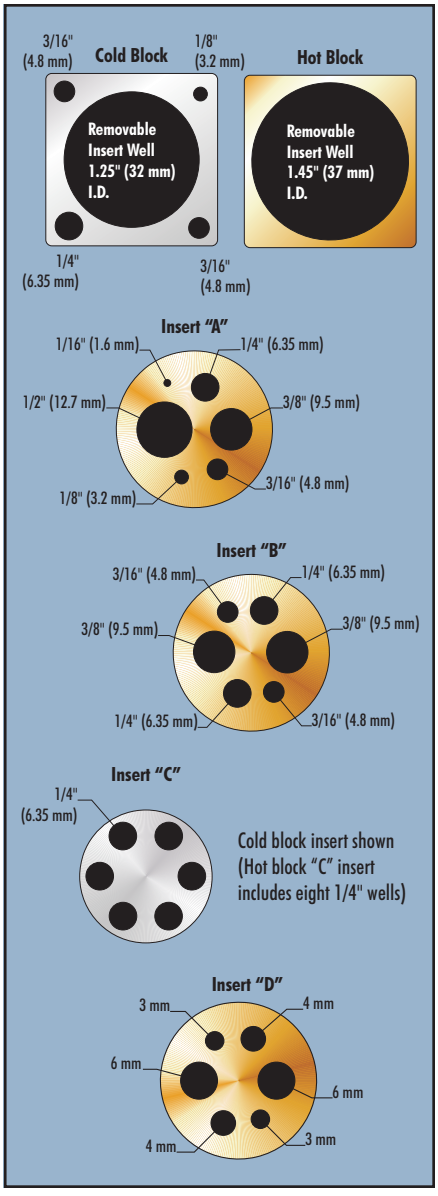
Technical Tip

Let's Keep It Clean!

Be sure to keep those dry-well inserts and blocks clean. They'll perform better and be easier to use (not to mention they'll look better). As needed, you should:

- Clean off any oxidation that has built up in the dry-well block or on an insert. Oxidation can make inserts difficult to remove. It can also cause probes not to fit properly. This oxidation occurs more rapidly at higher temperatures and in humid environments. It will clean up nicely with a Hart 2037 Dry-Well Cleaning Kit.
- Remove any foreign substances in the wells that can make operation difficult. Never intentionally put a foreign substance into a dry-well. Not only can you make probes and inserts difficult to remove, but you may also cause damage to the unit. If you're tempted to pour a fluid into a dry-well, stop. Give us a call and we'll set you up with a proper fluid bath.
- Clean probes before inserting them into the dry-well as a preventative measure.

HIGH-ACCURACY DUAL-WELL CALIBRATOR



High-Accuracy Dual-Well Calibrator **Model 9011**

- Combined ranges for calibrating from –30°C to 670°C; one unit – two blocks
- Two independent temperature controllers (hot and cold side)
- Stability to ±0.02°C
- Multi-hole wells calibrate up to eight probes simultaneously

To give you the widest temperature range available in a dry-well calibrator, we've combined two of our most popular units. The new 9011 allows temperature probes to be calibrated from –30°C to 670°C in a single unit.

The 9011 features two independently controlled temperature wells, which makes calibrating RTDs and thermocouples faster than ever. While readings are being taken at one temperature, the other well can be ramping up or down to the next point. Checking the zero and span points of temperature transmitters is a breeze. The cold block can even be used as a zero-point reference for a thermocouple making measurements in the hot block.

The 9011 is a high-accuracy unit that is capable of laboratory as well as field calibrations. Stabilities to ±0.02°C are possible, and display accuracy is better than ±0.25°C. Using multi-hole interchangeable inserts, you can calibrate more probes at the same time. With a single RS-232 port for both wells, you can automate your calibration work and be even more efficient. Add on Hart's 9938 MET/TEMP II software and totally automate your calibrations of RTDs, thermocouples, and thermistors.

Every dry-well we ship from the factory includes a full NIST-traceable calibration report with test data for each well at each point. There's no extra charge for the report or the test readings from your unit. We also include your choice of multi-hole inserts. If you don't find one that suits your applications, we'll provide a blank sleeve or have a custom one made.

At Hart, we continually develop new industrial calibration tools that make your work easier and better. We gave you the first Handheld Dry-Well, the first Micro-Bath, and now the widest ranging dry-well available. Whatever your temperature application, Hart has a solution.

Read about our calibration training courses on page 153.

Ranges from –30°C to 670°C

Specifications	Hot Block	Cold Block
Range	50°C to 670°C (122°F to 1238°F)	–30°C to 140°C (–22°F to 284°F)
Accuracy	±0.2°C at 50°C ±0.4°C at 400°C ±0.65°C at 600°C	±0.25°C (insert wells) ±0.65°C (fixed wells)
Stability	±0.02°C at 100°C ±0.06°C at 600°C	±0.02°C at –30°C ±0.04°C at 140°C
Uniformity	±0.2°C (±0.05°C typical)	±0.05°C (insert wells) ±0.25°C (fixed wells)
Well Depth	6" (152 mm)	4.875" (124 mm)
Heating Time to Max.	30 minutes	15 minutes
Cooling Times	120 minutes from 660°C to 100°C	30 minutes from 140°C to –30°C
Well Inserts	1 interchangeable well accommodates multi-hole insert	1 interchangeable well accommodates multi-hole insert, plus four outer wells, 1/4", 1/4", 3/16", and 1/8"
Computer Interface	RS-232 interface included with Model 9930 Interface-*it* control software	
Power	115 VAC (±10%), 10 A or 230 VAC (±10%), 5 A, switchable, 50/60 Hz, 1150 W	
Size	11.5" H x 15.5" W x 10.5" D (292 x 394 x 267 mm)	
Weight	36 lb. (16.4 kg)	
NIST-Traceable Certificate (8 points)	Data at 50°C, 100°C, 200°C, 300°C, 400°C, 500°C, 600°C, and 660°C	Data at –30°C, 0°C, 25°C, 50°C, 75°C, 100°C, 125°C, and 140°C

Technical Tip

The Sometimes Subtle Art of Specsmanship

"Specsmanship" is the careful wording of performance specifications to provide the expectation of better performance than practically achievable. We see this often as we work with customers who are comparing our products against others. Hart's philosophy is to provide meaningful, clearly written specifications that provide verifiable and guaranteed performance. Unfortunately, all manufacturers don't seem to share our approach, particularly when it comes to heat sources such as baths and dry-wells. Here are some terms to watch out for:

"Typical" or "Best" – While "typical" or "best" specifications may provide useful information, they offer no guarantee that the unit you buy is "typical" or capable of providing the "best" performance as listed. For calibration applications, worst-case or guaranteed performance specifications are required that include all natural variations in the product. "Typical" or "best" specifications are fine if accompanied by a guaranteed specification. If they're not, be sure you ask!

"Relative" Accuracy – "Relative" accuracy specs attempt to remove errors associated with the test standards or reference thermometers used in a heat source. This assumes that references contribute no measurement errors—an impossibility! Some may argue that "relative" specs allow the customer to add the error of their reference to obtain a complete specification unique to their situation. And we would agree, but the fact that the specification excludes these errors is too often relegated to the fine print and is simply misleading to less-informed readers. One thing's for sure. You can't directly compare "relative" specs to "absolute" specs, since the components of "relative" specs comprise a subset of the components of "absolute" specs.

"Comprehensive Evaluation Reports" – Evaluation reports are a very important method of determining the performance of a unit or sample of units. Evaluation reports can be misleading, however, if they are used to infer the performance of an entire population of instruments, or more importantly, the unit you are purchasing. Evaluation reports only provide information regarding the units that were evaluated and the conditions present during the evaluation. It takes extensive engineering analysis to use this information to produce a specification of performance that applies to all units being produced. Be sure whatever specs you rely on are the ones the manufacturer guarantees and will stand behind.

If you ever have a question about Hart's specifications, please talk to us and we'll gladly help you understand the performance you can expect from our products.

Ordering Information

9011	High-Accuracy Dual-Well Calibrator
3109-0	Insert, Blank (Hot Side)
3109-1	Insert A, Miscellaneous (Hot Side)
3109-2	Insert B, Comparison (Hot Side)
3109-3	Insert C, eight 1/4" Wells (Hot Side)
3109-4	Insert D, Comparison - Metric (Hot Side)
3109-5	X Cell Adapter Sleeve (Hot Side)
3103-1	Insert, Blank (Cold Side)
3103-2	Insert A, Miscellaneous (Cold Side)
3103-3	Insert B, Comparison (Cold Side)
3103-4	Insert C, six 1/4" Wells (Cold Side)
3103-5	X-Cell Adapter Sleeve (Cold Side)
3103-6	Insert D, Comparison - Metric (Cold Side)
2125-C	IEEE-488 Option (Serial to IEEE Converter Box)
9319	Large Instrument Case

Have you considered a good reference thermometer? See page 36.

Read about our accredited calibration services on page 156.

Call for custom inserts.

PORTABLE LAB DRY-WELLS — Ranges from –40° to 650°C

Portable Lab Dry-Wells — Models 9007 and 9023

- Designed for on-ship and on-the-go lab applications
- Two models covering –40°C to 650°C
- Includes three-inch and six-inch calibration zones

These calibrators, designed for the U.S. Navy, cover temperatures from –40°C to 650°C, deliver the performance you'll only find in true lab standards, and come in a totally portable case. If your work involves ocean vessels, aircraft, or service trucks, Hart's Portable Lab Dry-Wells were designed for you.

The 9007 covers –40°C to 140°C. No external cooling is needed, so you get –40°C in normal ambient. Set-point accuracy is ±0.15°C and stability is better than ±0.02°C.

For hotter temperatures, the 9023 extends from 35°C to 650°C. Heating time is only 45 minutes to 650°C. Set-point accuracy is ±0.3°C to 450°C and ±0.5°C to 650°C. Stability is better than ±0.08°C even at 600°C. (The 9023 is only available in quantities. Please call for availability.)

These dry-wells come with a unique calibration at the full, six-inch depth of the well and at a three-inch depth for short probes. Coefficients for each calibration are stored in the dry-well and can be easily selected from the top-panel control buttons to match the length of the probe being tested.

Both models are encased in all-aluminum enclosures that are durable, waterproof, and meet the standards of MIL-T-28800. Each unit comes with both RS-232 and IEEE-488 interface connections. A wide variety of inserts are available covering probe diameters from 1/16" (1.6 mm) to 7/8" (22 mm).

Specifications

Range	**9007:** –40°C to 140°C at 25°C **9023:** 35°C to 650°C
Accuracy	**9007:** ±0.15°C **9023:** ±0.3°C to 450°C, ±0.5°C to 650°C
Stability	**9007:** ±0.02°C **9023:** ±0.08°C
Heating Times	**9007:** 25°C to 140°C: 20 min. **9023:** 25°C to 650°C: 45 min.
Cooling Times	**9007:** 25°C to –40°C: 25 min. **9023:** 650°C to 100°C: 150 min.
Stabilization	10 minutes
Test Wells	**9007**: 3/4" dia. x 6" deep **9023**: 1" dia. x 6" deep
Communications	RS-232 and IEEE-488
Enclosure	Meets Type II, Class 3, Style D requirements of MIL-T-28800
Power	**9007:** 115 VAC (±10%), 3 A or 230 VAC (±10%), 1.5 A, switchable, 50/60 Hz, 560 W **9023:** 115 VAC (±10%), 7 A or 230 VAC (±10%), 3.4 A, specify, 50/60 Hz, 800 W
Size	13.8" H x 10.8" W x 16.9" D (35.1 x 27.4 x 42.9 cm)
Weight	36 lbs. (16.3 kg)
NIST-Traceable Calibration	**9007:** Data at –40°C, 0°C, 25°C, 75°C, and 140°C; **9023:** Data at 50°C, 100°C, 200°C, 300°C, 400°C, 500°C, and 650°C

See our calibration and data acquisition software packages on page 74.

Ordering Information

9007	Portable Lab Dry-Well, –40°C to 140°C, 1/4" insert
3107-2000	Blank insert
3107-2063	1/16" Insert (1.6 mm)
3107-2125	1/8" Insert (3.2 mm)
3107-2156	5/32" Insert (4 mm)
3107-2188	3/16" Insert (4.8 mm)
3107-2250	1/4" Insert (6.35 mm)
3107-2313	5/16" Insert (7.9 mm)
3107-2375	3/8" Insert (9.5 mm)
3107-2500	1/2" Insert (12.7 mm)
3107-2625	5/8" Insert (15.9 mm)
3107-2901	1 User-Specified Hole
3107-2902	2 User-Specified Holes

9023	Portable Lab Dry-Well, 35°C to 650°C, 1/4" insert
3123-2131	Blank insert
3123-2125	1/8" Insert (3.2 mm)
3123-2156	5/32" Insert (4 mm)
3123-2188	3/16" Insert (4.8 mm)
3123-2250	1/4" Insert (6.35 mm)
3123-2313	5/16" Insert (7.9 mm)
3123-2375	3/8" Insert (9.5 mm)
3123-2500	1/2" Insert (12.7 mm)
3123-2625	5/8" Insert (15.9 mm)
3123-2750	3/4" Insert (19 mm)
3123-2875	7/8" Insert (22 mm)
3123-2901	1 User-Specified Hole
3123-2902	2 User-Specified Holes

HALF THE WORK—TWICE THE RESULTS

Are you calibrating thermometers for process measurement and control? There's a possibility you're only doing half the job.

Many instrument shops calibrate industrial instruments with a simulator. Simulators produce an electronic signal that duplicates the correct signal made by a theoretically accurate thermocouple or RTD. This method is shown in Figure 1.

Once the simulator is connected to your readout or control instrument, you enter the desired output temperatures. You calibrate your instrument against the values entered in the simulator. This process calibrates the instrument to accurately read a sensor that conforms to the industry standard voltage, or resistance versus temperature curves. The calibration, of course, is only good if your sensor matches these industry specs, and as Figure 1 illustrates, the sensor is not part of a simulator-based calibration. Since up to 80% of industrial measurement error is normally in the sensor, you've got a problem if ISO or other quality standards require you to calibrate for system error.

In order to verify sensor compliance with industry standard curves, you'll have to have another device (in addition to the simulator) that generates an accurate temperature for the sensor to read and for you to calibrate against. Of course, this temperature must be read by a device that does not contribute significant error to the sensor reading. Figure 2 shows this configuration and the need for two additional instruments in the calibration process.

To avoid using a separate readout, you can buy a simulator that reads temperature accurately as well as generates signals. This is a good alternative if you want to use sensors interchangeably with your instruments and, therefore, really don't have a "true system" against which to calibrate.

Using sensors interchangeably has a weakness in that sensors can't be adjusted to meet theoretical standard curves; thus you have to live with the sensor error or reject the sensor. Figure 2 also illustrates this point with the dry-well set to 0.00°C and the sensor reading 0.8°C, a high reading. Although the meter is adjusted for no error at 0°C using the simulator, when the sensor is connected to the instrument the combination of the two produces an overall error of 0.8°C. The system error of this combination is 0.8°C.

If you are not using sensors interchangeably, then you should be calibrating for system error. System calibration is often less complicated and more reliable than calibration of each component of a system. Figure 3 shows a typical system calibration with the sensor in the dry-well attached to the readout instrument. The instrument is then adjusted for the error found in the combination of components. System calibration assures the highest possible accuracy for industrial thermometers.

Read about our calibration training courses on page 153.

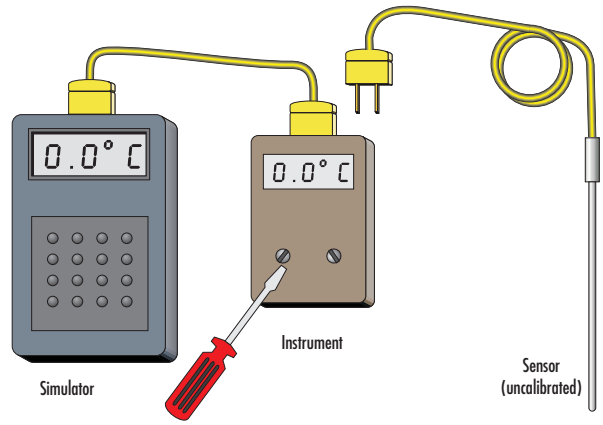


Figure 1
Meter adjustment only

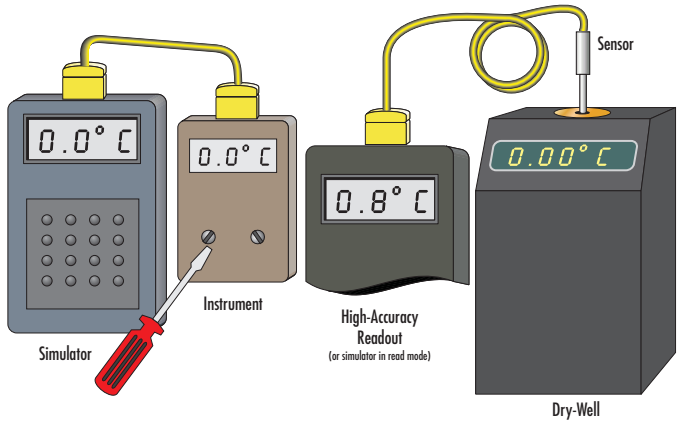


Figure 2
Separate meter and probe calibrations

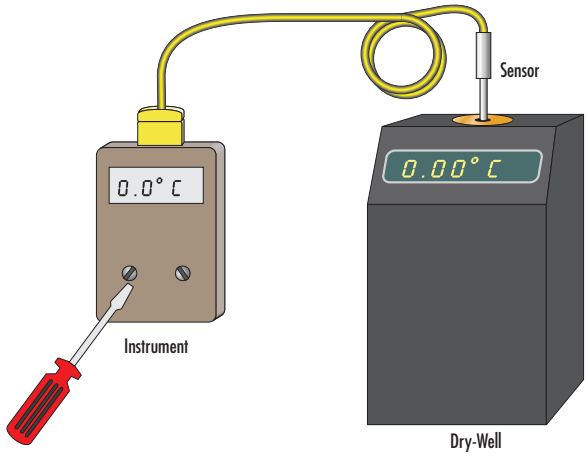


Figure 3
Combined meter and probe ("system") calibration

PORTABLE IR CALIBRATORS

Portable IR Calibrators **Models 9132 and 9133**

- Certify IR pyrometers from –30°C to 500°C (–22°F to 932°F)
- Large 2.25" (57 mm) blackbody target
- RTD reference well for high precision
- Small, compact design

Whether you're using in-line or handheld infrared pyrometers, you need good calibration standards to verify their accuracy. Our new portable IR calibrators provide stable blackbody targets for calibrating noncontact IR thermometers from –30°C to 500°C.

These new units feature a large, temperature controlled blackbody target with a diameter of 2.25" (57 mm), which offers a large field of view area for optical variations in infrared thermometers. The emissivity of the isothermal target is set at 0.95 (±0.02%), and the target temperature can be controlled in set-point increments of 0.1° from –30°C to 500°C.

For even higher precision, a well is located directly behind the blackbody surface for contact calibration of the blackbody.

These units are as easy to use as "point and shoot." Simply set the desired blackbody temperature from the convenient front panel control buttons, wait a few minutes for equilibrium, and point the gun at the target. The radiated energy from the blackbody is measured by your IR thermometer. Simply compare its reading to the display on the blackbody and record the difference.

9132

For IR calibrations above normal ambient, the 9132 provides a stable blackbody target up to 500°C (932°F). With accuracy to ±0.5°C and stability to ±0.1°C, this new portable IR unit can certify most handheld pyrometers.

Short heating and cooling times mean you won't have to wait long to get your work done. From room temperature to 500°C the 9132 will be stable within 30 minutes. You won't find a more compact IR calibrator.

9133

If you're calibrating IR guns at cold temperatures, you'll love our new 9133. With solid-state cooling technology, this new IR calibrator reaches –30°C (22°F) in normal ambient conditions. With a conveniently located dry gas fitting on the front bezel, ice build up on the target can be avoided. At the upper end of its range, the 9133 provides stable temperatures to 160°C (320°F).

With heating and cooling times of about 15 minutes from ambient to either extreme, the 9133 gets you to temperature quickly and performs when it gets there. Compare your IR devices to the temperature display—it's factory calibrated to be within ±0.4°C (±0.7°F).

No other IR calibrators give you this level of precision in such compact packages. Whatever your temperature application, trust a Hart product to solve it.

Large target for calibrating all IR thermometer types.

The 9133 includes a quick-attach fitting on the front bezel for dry air purging, which eliminates ice buildup on the target.

Specifications	9132	9133
Temperature Range	50°C to 500°C (122°F to 932°F)	–30°C to 150°C at 23°C ambient (–22°F to 302°F at 73°F ambient)
Accuracy	±0.5°C at 100°C (±0.9°F at 212°F) ±0.8°C at 500°C (±1.4°F at 932°F)	±0.4°C (±0.72°F)
Stability	±0.1°C at 100°C (±0.18°F at 212°F) ±0.3°C at 500°C (±0.54°F at 932°F)	±0.1°C (±0.18°F)
Target Size	2.25" (57 mm)	
Target Emissivity	0.95 (±0.02 from 8 to 14 μm)	
Resolution	0.1°	
Heating Time	30 minutes (50°C to 500°C)	15 minutes (25°C to 150°C)
Cooling Time	30 minutes (500°C to 100°C)	15 minutes (25°C to –20°C)
Computer Interface	RS-232 included with 9930 Interface-*it* software	
Power	115 VAC (±10%), 3 A or 230 VAC (±10%), 1.5 A, switchable, 50/60 Hz, 340 W	115 VAC (±10%), 1.5 A, or 230 VAC (±10%), 1.0 A, switchable, 50/60 Hz, 200 W
Size	4" H x 6" W x 7" D (102 x 152 x 178 mm)	6" H x 11.25" W x 10.5" D (152 x 286 x 267 mm)
Weight	4 lb. (1.8 kg)	10 lb. (4.6 kg)
NIST-Traceable Contact Calibration	Data at 50°C, 100°C, 200°C, 250°C, 300°C, 400°C, and 500°C	Data at –30°C, 0°C, 25°C, 75°C, 100°C, 125°C, and 150°C

Ordering Information

9132	Portable IR Calibrator, 500°C
9308	Rugged Carrying Case, 9132
9133	Portable IR Calibrator, –30°C
9302	Rugged Carrying Case, 9133

Don't forget a protective case!

Get the latest product information at www.hartscientific.com

Can four temperature metrologists make a good band? Not that we've discovered yet, but Matt's pretty good. (Ron, cal lab; Bryan, customer service; Mike, sales; Matt, primary standards)

3-POINT IR CALIBRATOR — Range: 50°C, 100°C, 150°C

3-Point IR Calibrator — Model 9135

- Fast and easy IR calibrations
- Three temperatures available: 50°C, 100°C, and 150°C
- NIST-traceable calibration included

Checking the accuracy of your infrared thermometer is now easier than it's ever been. Hart's 9135 IR Calibrator gives you fast, easy, and inexpensive verification of your handheld infrared meters.

The 9135 includes three set-points at 50°C, 100°C, and 150°C. Simply select a temperature, wait for the ready light to come on, aim your thermometer at the 1.5-inch-diameter blackbody, and take a reading. Set-points can be reached in less than five minutes, and stabilization time is only three minutes. It doesn't get any easier—or any faster.

Accuracy at any of the 9135's three set-points is better than ±1°C, and stability is within ±0.1°C. Each unit comes with a calibration certificate showing data at each of the three temperatures at no extra charge. Emissivity of the black-body target is 0.95.

At less than two inches thick and weighing less than two pounds, the 9135 is absolutely portable. It fits easily into a tool kit for on-site calibrations. Use it to check an IR thermometer at one temperature or to estimate its span error by checking at 50°C and 150°C.

All of our handheld dry-block calibrators are fast, small, and easier to use than any other manufacturer's dry-well. Now we're doing the same for IR thermometer users. Nobody else makes products that more directly meet your needs than Hart Scientific.

Select a temperature, wait about five minutes for stabilization, then point and click. Pyrometer calibrations couldn't be faster than with the Model 9135 3-Point IR Calibrator.

Specifications

Range	50°C, 100°C, 150°C (122°F, 212°F, 302°F)
Accuracy	±1°C
Stability	±0.1°C
Heating Time	25°C to 150°C: 3 min., typical
Cooling Time	150°C to 50°C: 25 min., typical
Stabilization Time	3 minutes, typical
Blackbody Diameter	1.5" (38 mm)
Blackbody Emissivity	0.95
Size	1.8" H x 4.4" W x 7.8" D (46 x 112 x 198 mm)
Weight	1.5 lb. (0.7 kg)
Power	115 VAC (±10%), 1.0 A or 230 VAC (±10%), 0.5 A, specify, 50/60 Hz, 125 W
NIST-Traceable Contact Calibration	Data at 50°C, 100°C, and 150°C

Ordering Information

9135	3-Point IR calibrator
9308	Rugged Carrying Case

Utah bowling champ Kurt (product service) turned down a promising career on the Pro Bowlers' Tour to work in Hart's service group. (No kidding.)

SURFACE CALIBRATOR — Range: 35°C to 400°C

Surface Calibrator — Model 3125

- Calibrates surface sensors up to 400°C
- Uses Hart 2200 Controller for excellent accuracy and stability
- NIST-traceable calibration included

Surface probes are difficult to calibrate because it's hard to find a flat, heated surface that's stable and uniform. Hart's new Model 3125 Surface Dry-Well takes advantage of our proprietary Model 2200 Temperature Controller (page 109) and gives you the best possible conditions for calibrating surface sensors.

Why buy a non-temperature calibration device designed for test tube sterilization or PC board repair when you can have a true calibration instrument? The 3125 has a uniform surface temperature and reaches temperatures as high as 400°C.

The test surface is milled aluminum for an absolutely smooth and true calibration work area with maximum thermal conductivity. The 12.25-square-inch test surface is large enough to calibrate more than one sensor at a time. The 3125 can be used with a reference surface sensor or PRT. PRTs (3/16" diameter, such as the 5613 on page 62) may be inserted through a drilled hole into the center of the block for use as reference thermometers or for easy recalibration of the unit's display.

With an accuracy of ±0.5°C to 200°C and ±1°C to 400°C, you can calibrate almost any surface probe, thermistor, thin film sensor, RTD, thermocouple, ribbon sensor, or surface mount cutouts, fuses, and switches. Stability is within ±0.3°C at 400°C and uniformity within the center three inches of the surface is ±0.6°C at 200°C. Don't buy "make-do" hot plates when you can have a legitimate calibration tool.

Specifications

Temperature Range	35°C to 400°C (95°F to 752°F)
Display Accuracy	±0.5°C to 200°C ±1.0°C to 400°C
Stability	±0.2°C to 300°C ±0.3°C to 400°C
Resolution	0.01°
Uniformity	±0.3°C at 100°C ±0.6°C at 200°C ±0.9°C at 300°C ±1.4°C at 400°C
Heating Time	25°C to 400°C: 22 minutes
Cooling Time	400°C to 100°C: 65 minutes
Stabilization Time	8 minutes
Controller	Hart Model 2200, microprocessor based, with RS-232 (see page 109)
Readout	°C or °F, switchable
Sensor	RTD, 100Ω
Heater	325-watt, solid-state controlled
Surface Plate	6061 aluminum; top surface machine finished to 0.000032" (0.0008 mm), 3.8" (96 mm) diameter accessible
Power	115 VAC (±10%), 2.8 A or 230 VAC (±10%), 1.4 A, specify, 50/60 Hz, 325 W
Weight	7 lb. (3.2 kg) with 2200 Controller
NIST-Traceable Calibration	Data at 50°C, 120°C, 190°C, 260°C, 330°C, and 400°C

Ordering Informaiton

3125	Surface Calibrator, (includes detachable Hart Model 2200 Controller)

Get the latest product information at www.hartscientific.com

Industrial

ORIGIN OF THE SPECIES

It's time for a new catalog and that means it's time for a new view of the homely, sometimes ugly, and mostly forgotten—rutabaga.

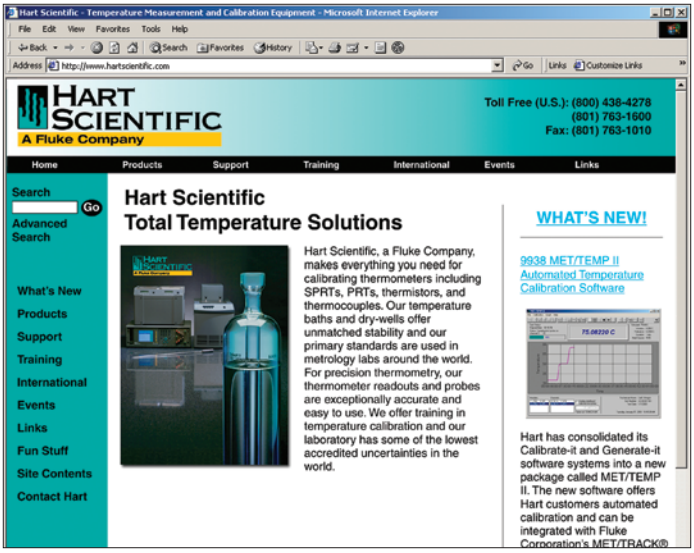
A lot of people believe the 'baga was a turnip-cabbage hybrid discovered sometime around the early 1600s. Well, that's an interesting theory, but not particularly accurate. First of all, it's well known that in 1600 no one could spell hybrid much less create one.

You're probably wondering exactly how hybridization occurs. We had the same question! So we decided to do a few scientific experiments to see if it could have been an act of nature rather than a deliberate attempt by scientists to introduce genetically altered food into the typical 17th-century cancer-free diet of mud pie and rocks.

We put a turnip and a cabbage on a large lab table fitted with a time-lapse camera. We left them there for 10 years and watched the tapes everyday. At no point in the experiment did we notice the turnip paying one moment of attention to the cabbage, much less making any kind of gesture that would indicate an eventual hybridization. However, we know these things take time and maybe a catalyst or two, so we've added a CD player and brought out a nice bottle of wine. We've dimmed the lights in the lab, and we'll give the cabbage some more time to catch the eye of the turnip. If, in a year or two, there are still no little rutabagas on the table, we'll drink the wine, publish our findings, and put another myth to bed, so to speak.

You can tell we're not keen on the hybridization theory. Right now we're advocating straight up genetic testing. First, we think DNA samples should be taken from several rutabagas and then compared to DNA samples from the prison population in general. You can never tell when something interesting might pop out of the data.

However, if nothing significant comes from the genetic studies, we would probably turn our attention to analyzing samples of dirt from UFO landings to see if any rutabaga leftovers are mixed in. The implications are obvious. If aliens are eating rutabagas, it's because they packed a nice sack lunch before they left home (it is a long trip), and they've probably got sharper knives than we have. In fact, it's possible that the Ginsu 10-piece knife set arrived here on earth prepackaged with an infomercial and some rutabagas. After all, Ginsu knives never need sharpening; you get the first knife for four easy payments of $19.95 and the other nine in the set are free.



While Hart's web site contains some pretty tasty rutabaga recipes, it also provides new product updates, technical papers, product service information, and a lot of other great stuff to keep you up-to-date with Hart Scientific and your temperature calibration questions.

Another interesting fact about rutabagas is their early use as Jack O'Lanterns. The pumpkin thing came along later when a shortage of large rutabagas threatened the old world economy and nearly ended in rioting. Little 17th-century kids always used rutabagas lit with a lump of coal because they had more rutabagas than hordes of marauding invaders. There's nothing like a good rutabaga Jack O'Lantern when you're going from hut to hut witch hunting. Attila the Hun costumes were very popular in those days!

Speaking of invading marauders, every year there's a rutabaga festival in Cumberland, Wisconsin. Wisconsin, as you might know, is the home of the cheese heads. They take the cheese head thing very seriously in Wisconsin. In fact, a cheese wedge hat is the only hat that can legally be worn at a Packers' game. Since there's a high probability that people who wear a cheese wedge on their heads drink too much beer and eat lots of rutabagas (probably raw), we're putting together a petition to change the law so both cheese wedges and rutabaga hats are acceptable gear during Packers' games and in church. That should give TV ratings a boost. Rutabaga heads at last!

We usually send a few employees to the rutabaga festival, but this year's travel budget only included enough money for a trip to the farmer's market, so we missed out on the week-long festival with something for "everybody," which loosely translated means approximately 6000 cases of beer and three new rutabaga recipes.

We're sad to say that right now, the rutabaga's share of the American market is shrinking. It was only 0.00000000032 percent of the tuber market this year. That's down from 0.00000000035 percent last year. The biggest year for rutabaga consumption was in 1932. This suggests that you might want to consider storing a few 'bagas in your basement just in case the stock market falls for the fourth straight year. A good meal might be really, really hard to come by.

Finally, we'll leave you with this last rutabaga thought. When you were talking to your high school guidance counselor about what you wanted to be when you grew up (and got out on parole), suggestions of fireman, doctor, lawyer, especially personal injury attorney, and of course, president were probably all mentioned. But how many guidance counselors suggested rutabaga farmer? Probably the same number that suggested metrologist. We really need to fix that!

THERMOCOUPLE FURNACE — Range: 150°C to 1200°C

Thermocouple Furnace — Model 9150

- Low-cost thermocouple furnace
- NIST-traceable calibration included
- RS-232 port standard

You told us you weren't satisfied with the competition's furnaces for checking industrial thermocouples. You said you wanted something new and more convenient to use—and you wanted it at a lower price than any other furnace available. Well, we've got what you asked for, and it's the Model 9150 Thermocouple Furnace from Hart Scientific.

With a stability of ±0.5°C, it has a temperature range to 1200°C and a display accuracy of ±5°C across its entire range.

With interchangeable temperature blocks, you can check thermocouples as small as 1/16 of an inch in diameter. The 9150 works with 115 or 230 VAC power.

The 9150 Thermocouple Furnace uses Hart's own microprocessor-based controller for great stability and set-point accuracy. It has a removable well insert for versatility. It has rapid cool-down and heat-up times. And it comes with an RS-232 port for connection to a PC.

You can now afford to check your thermocouples with this excellent cost-effective instrument. Why pay more for features you don't need and can't use? Each unit is factory-calibrated and comes with test data and a calibration traceable to NIST.

Ordering Information

9150-X	Thermocouple Furnace (specify X, X = A, B, C,or D included insert)
3150-1	Custom Insert
3150-2	Insert A
3150-3	Insert B
3150-4	Insert C
3150-6	Insert D
9315	Rugged Carrying Case

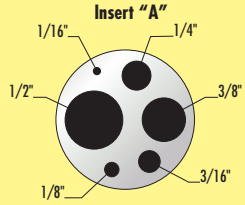
Call for custom inserts.

Specifications

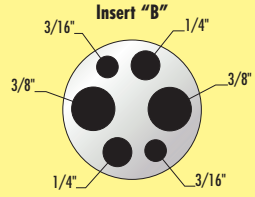
Temperature Range	150°C to 1200°C (302°F to 2192°F)
Display Resolution	0.1° to 999.9° 1° above 1000°
Stability	±0.5°C
Display Accuracy	±5°C
Well Diameter	1.25" (32 mm)
Well Depth	5.5" (140 mm); (4" [101 mm] in removable insert plus 1.5" [38 mm] in insulator)
Heating Time	35 minutes to 1200°C
Cooling Time	140 minutes with block
Well-to-Well Uniformity	±0.5°C to ±1.0°C (Insert "C" at 1200°C)
Stabilization	20 minutes
Power	115 VAC (±10%), 10.5 A or 230 VAC (±10%), 5.2 A, switchable, 50/60 Hz, 1200 W
Size	12.4" H x 8.2" W x 12.4" D (315 x 208 x 315 mm)
Weight	28 lb. (13 kg)
NIST-Traceable Calibration	Data at 150°C, 300°C, 450°C, 600°C, 800°C, 1000°C, and 1200°C

9150 Interchangeable Insert Options

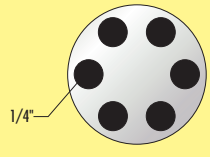
Insert "A"



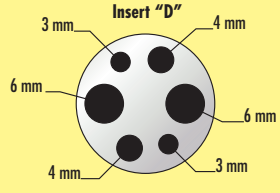
Insert "B"



Insert "C"



Insert "D"



Industrial

THERMOCOUPLE CALIBRATION FURNACE

Thermocouple Calibration Furnace **Model 9112A**

- Combined stability and uniformity better than ±0.4°C
- RS-232 serial interface standard
- High capacity for simultaneous comparison calibrations
- CE compliant

Need the most accurate thermocouple calibrations possible? The Hart Model 9112A Thermocouple Furnace gives you a broad temperature range to 1100°C, stability up to ±0.05°C, and all at an excellent price. In addition, you can take advantage of optional MET/TEMP II software that completely automates the furnace and calibration processes.

Alternative calibration tools such as a sand bath or fluidized alumina bath have been used for calibrations up to 700°C but with very poor comparative performance. Gradients of several degrees are common in a sand bath, along with poor stability, resulting in low-accuracy calibrations. Sand baths are also known to create a troublesome dust problem. Why buy poor performance and lab pollution?

Calibration furnaces are an excellent alternative to sand baths, especially for thermocouples, RTDs, and optical fiber probes. With a five-hole standard block and custom blocks available, the 9112A doesn't limit the size and shape of sensors you can calibrate the way other furnaces do. In addition, most calibration furnaces have poor stability.

Automation Software

Hart's 9938 MET/TEMP II software lets you use your PC to automate your calibrations. Not only does the software operate the furnace, it also automates Hart readouts along with the calibration procedures. Read more about our software packages starting on page 74.

Unique Engineering

The 9112A employs a special heater design for temperature uniformity and rapid heat rates. The heaters are embedded in a refractory ceramic-fiber material, forming a two-piece heating assembly. A quartz tube lines the entire test zone of the furnace, insulating the isothermal block and your work from the high-power heater windings while supporting the block and further equalizing temperature distribution.

The isothermal block assembly is machined from a high-nickel-content alloy for good thermal conductivity and resistance to high-temperature oxidation. The central block is sized for optimum balance between sufficient mass for good stability/uniformity and small enough mass for rapid heating/cooling and stabilization. The assembly makes use of two smaller alloy blocks as thermal barriers and heat sinks. Guide tubes connect the blocks and guide your probes to the heart of the block. A thermal shield at the front of the assembly prevents heat loss at the front of the furnace.

Multiple Probe Calibrations

The standard furnace block accepts up to four probes under test and one reference probe. The four test holes take 1/4-inch-diameter probes, and the reference hole accepts the slightly larger and typical standard type S thermocouple or an SPRT. Custom isothermal blocks can handle a specific number of probes with different diameters and depths. Call our sales department for a custom quote.

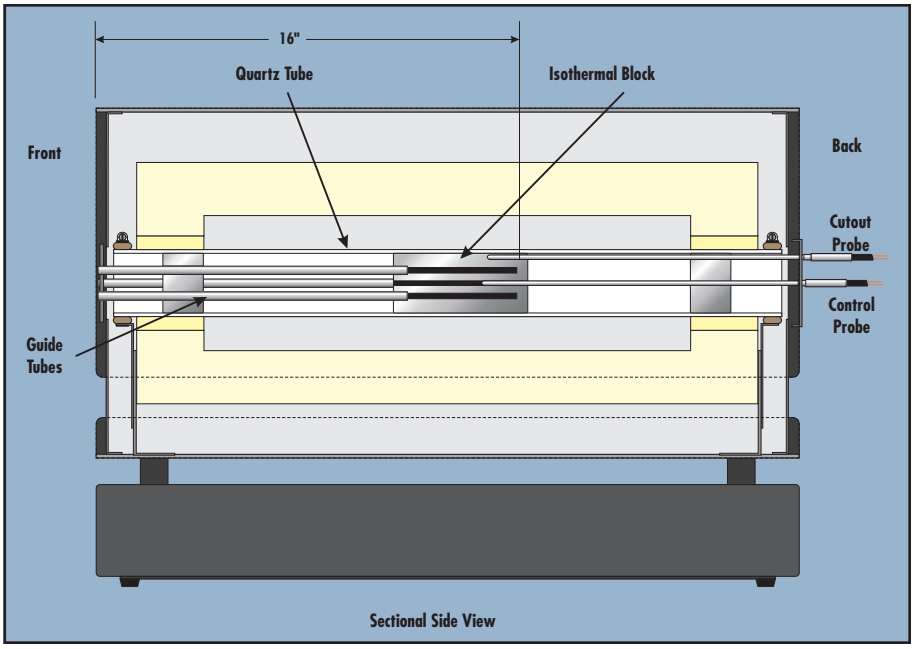
Microprocessor Control

A microprocessor-based digital temperature controller makes set-point adjustments fast and easy. Both set and actual temperatures are simultaneously displayed for your convenience. A fast push-button adjustment is used for manual temperature settings. The controller is factory tuned for best performance between 300°C and 1100°C when the tuning function is set for automatic conformity to the set-point requirements. When using the furnace below 300°C, controller adjustments are made to achieve high stability.

The isothermal block design and the controller auto-tuning combine to give you metrology-level performance. The "B" block delivers uniformity of ±0.1°C at the low end and ±0.3°C or better at the high-temperature end.

The stability figures quoted in our specification table are for mid-term to long-term stability. Short-term stability during a comparison calibration is even better.

Wide-range and high-temperature calibration work are now easier and more affordable due to Hart's innovative 9112A design. Thermocouples, RTDs, and other sensors are all calibrated with a greater level of confidence and accuracy.



Specifications

Range	300°C to 1100°C (572°F to 2012°F)
Stability	±0.05°C at 300°C ±0.1°C at 700°C ±0.1°C at 1100°C
Uniformity	±0.1°C at 300°C ±0.2°C at 700°C ±0.3°C at 1100°C
Heating Rates	25°C to 900°C: 35 minutes 900°C to 1100°C: 3 hours
Cooling Rates	Nom. at 800°C: ≥300°C/hour Nom. at 600°C: ≥180°C/hour
Stabilization Time	Typically 2 hours midrange, slower at low-temperature end (4 hours), faster at high-temperature end
Interface	RS-232 included on all units
Outside Dimensions	18" H x 14" W x 26" D (457 x 356 x 660 mm)
Thermal Block	16" (406 mm) immersion; includes four wells at 1/4" (6.35 mm) and one well at 0.28" (7.11 mm)
Weight	72.5 pounds (33 kg) with block
Power	230 VAC (±10%), 50/60 Hz, 16 A, 3700 W
Heater	3700 W
NIST-Traceable Calibration	Data at 420°C

Ordering Information

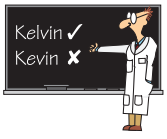
9112A-B	Calibration Furnace (includes standard 16" block)

Read about our accredited calibration services on page 156.

Assistant Scout Master Steve (electro-mechanical engineering) gets the most out of his product designs — and his weekends.

OTHER NEAT STUFF SUMMARY

Cool Lab Products	Product	Features	Page
	8508A Reference Multimeter	True ohms measurement. 20 amp current measurement. Stores up to 100 PRT coefficients.	141
	525A Temperature/Pressure Calibrator	Simulates and measures all ANSI thermocouples. Direct input for storage of ITS-90 RTD constants.	142
	5123 Field RTD Simulator	Accuracy to ±0.005%. 100 to 11,111Ω range with six decades.	143
	5124 RTD Simulator	Accuracy to ±0.01%. 10 to 1111.11Ω range.	
	5125 Standards Lab RTD Simulator	Accuracy to ±0.005%. 10 to 1111.11Ω range with 0.001Ω resolution.	
	5126 Precision RTD Simulator	Accuracy to ±0.02%. 20 to 1120Ω range with 0.01Ω resolution.	
	5121 Bench-Top Temperature /Humidity Generator	Full range accuracy ±0.5% RH. Large working volume for optimal throughput. NIST-developed two-pressure principal.	144
	5110 Relative Humidity Calibrator	Range from 0 to 99% RH with accuracy to 1%. Response time under 15 minutes.	146
	5109 Lab Humidity/Temperature Recorder	High-accuracy wall-mount recorder. Environmental condition recording for increased ISO compliance.	150
	5113 Temperature/Humidity Logger	Temperature/humidity recorder. Logs 8,100 measurements and includes data analysis software.	151
	2680A and 2686A 2680 Series Data Acquisition Systems	Precision thermocouple measurement. 120-channel capacity chassis (2,000 channels in a system). Powerful reporting, HMI development software, and OPC server software available.	147
	2620A Hydra™ Series Data Acquisition	20 universal channels. Precision measurements. Quick setups with menu-driven software.	148
	2640A and 2645A NetDAQ® Data Acquisition	Universal inputs. Precision temperature measurements. Real-time trending software.	149
	5577 Intrinsically Safe, Reference Thermometer	Ideal for use in hazardous environments, EX II 2G Eex ip IIB T4 rating. System accuracy to ±0.03°C (readout and probe). Battery powered.	152

AND THERE'S MORE...	Product	Description	Page
	Seminars	Three seminars covering topics from industrial field calibrations to primary standards lab calibrations. Each course mixes lectures, demonstrations, hands-on exercises, and question/answer sessions. Instructors include leading metrology experts with a wide variety of applications experience.	153
	Cal Lab Services	Calibration services for SPRTs, RTDs, thermocouples, and thermistors. Calibrations by fixed point and by comparison. Recalibrations of Hart dry-wells and thermometers.	157
	Books and Standards	Theoretical and practical publications on temperature calibration. ISO 9000 Guidelines, NIST Technical notes, and other technical papers.	160

FLUKE REFERENCE MULTIMETER — Model 8508A

Fluke Reference Multimeter — **Model 8508A**

- True Ohms measurement
- 20 amp current measurement
- Stores up to 100 PRT coefficients

At last, now there's a meter designed specifically for the measurement challenges faced by metrologists. The Fluke 8508A Reference Multimeter is simply the best you can buy. Not only does it provide the performance required for complex measurement tasks, it is also extremely easy to use. Moreover, it is specified in a way that lets you really understand the uncertainties of the measurements you make.

Accuracy and Stability

The Fluke 8508A features 8.5 digit resolution, exceptional linearity, and extremely low noise and stability, producing superior accuracy specifications as low as 3 ppm over one year. But measurements need to be repeatable, and the 8508A delivers that as well, with 24-hour stability as low as 0.5 ppm and a 20-minute stability of 0.16 ppm. This stability is maintained over a wide operating temperature range and achieved without requiring routine autocal or self-calibration, which can compromise measurement traceability and history. What's more, Fluke publishes a detailed 8508A Extended Specifications Brochure on www.fluke.com that specifies in absolute and relative terms, allowing you to replace Fluke's calibration uncertainty with those that represent traceability available locally.

Functional and Versatile

The Fluke 8508A lets you handle a wide range of applications and achieve your measurement requirements with a single instrument. In addition to AC and DC voltage, AC and DC current, resistance and frequency, the 8508A also includes a host of other features designed to increase the range of measurements you can make. True Ohms measurement using current reversal technique improves the accuracy of your resistance measurements. The PRT temperature readout extends the 8508A's functionality into precision temperature metrology. The Lo Current Ohms feature reduces measurement errors due to self-heating within the device being measured. A dual input channel ratio feature, under GPIB control, enables the 8508A to be used as a simple, fast, automated transfer standard. High current measurement (up to 20 A) extends the operational range to address your multi-product calibrator workload. Up to 200 V compliance on resistance ranges gives you greater scope to measure high resistances with greater accuracy.

Easy to Use

A clear control structure with Dual Paramatrix™ LCD displays and context-sensitive menus provides an intuitive interface that makes the 8508A easy to use. The menu structures have been designed especially for metrology applications, so you can focus on getting the best possible measurements without needing to work through complex sequential or multi-instrument setups, or having to repeatedly reference supporting documentation.

Specifications

DC Voltage	0 to ±1050 V 1 Year Spec: ±3 ppm of rdg†
AC Voltage	2 mV to 1050 V, 1 Hz to 1 MHz 1 Year Spec: ±65 ppm of rdg†
DC Current	0 to ±20 A 1 Year Spec: ±12 ppm of rdg†
AC Current	2 µA to 20 A, 1 Hz to 100 kHz 1 Year Spec: ±200 ppm of rdg†
Resistance	0 to 20 GΩ, ±7.5 ppm of rdg
Power	Voltage: 90–130 V or 180–260 V Frequency: 47–63 Hz Consumption: 37 VA
Weight	25.5 lb. (11.5 kg)
Size	3.5" x 16.8" x 19.2" (88 x 427 x 487 mm)

†Best guaranteed specification within measurement category.

Ordering Information

8508A	Reference Multimeter
8508A/01	Reference Multimeter with Front and Rear 4 mm binding posts and rear input ratio measurement
8508ALEAD	Lead kit including two pairs of 1 m six-wire PtFe cable terminated with gold flashed spaces connectors and 4 mm plugs
8508A-PRT	PRT (Hart 5626-15-D)
8508ASPRT	SPRT (Hart 5699-D with Cal 1911-4-7)
Y8508	Rack-Mount Kit
Y8508S	Rack-Mount Slide Kit

FLUKE TEMPERATURE/PRESSURE CALIBRATOR Model 525A

Fluke Temperature/Pressure Calibrator **Model 525A**

- Simulates and measures all ANSI thermocouples
- Direct input for storage of ITS-90 RTD constants

The Fluke 525A calibrator gives you a workhorse combination of high accuracy and broad functionality for temperature and pressure instrument calibration. Compact and economical, the 525A has an interface for automated calibration, providing wide workload coverage in instrument shops and calibration labs, as well as in ATE applications.

The 525A is the most accurate Fluke temperature calibrator, sourcing and measuring a complete range of RTDs, thermocouples, and thermistors. Its 0–100 V output and 0–100 mA current capabilities make it a versatile performer. It also measures pressure covering common ranges from 1 inch (6900 Pa) of water up to 10,000 PSI (69 Mpa) using the Fluke 700 Series or 525A-P pressure modules, with up to 0.01% accuracy. Plus, the 25 ppm DC voltage and 85 ppm current specifications of the 525A enable you to calibrate other process calibrators and a wide variety of other instruments with accuracy that rivals any calibrator in its price range.

The 525A supports automation using Fluke's MET/CAL® *Plus* Calibration Management Software or custom automated programs with standard RS-232C or optional GPIB interface.

From start to finish, the 525A is designed for ease of operation. The intuitive front panel design features large keypads and display. Plus, you can store frequently used constants for a variety of probes in memory for faster setup on the job. Eight user programmable set points allow quick recall of values for zero, span, and linearity checks during calibration.

An optional set of external pressure modules provides pressure measurement capability. The 525A can accept either the Fluke 700 Series or the Fluke model 525A-P pressure modules. Both module types plug directly into the calibrator's front panel Lemo connector; the 525A firmware auto-detects the type and value of the attached module.

If you're looking for a temperature/pressure calibrator that packs a lot of accuracy and functionality into an economical package, the Fluke 528A is the perfect solution for you.

Specifications

Voltage (source)	0 to 100 V 1 Year Spec: ±30 ppm of setting†
Current (source)	0 to 100 mA 1 Year Spec: ±100 ppm of setting†
Resistance (source/measure)	5 to 4,000 Ohms 1 Year Spec: ±0.03 Ohms†
Thermocouple (source/measure)	Standard TC ranges Types B, C, E, J, K, L, N, R, S, T, U 1 Year Spec: ±0.14°C (type E)†
RTD (source/measure)	–200°C to 800°C Pt 100, 200, 500, 1000 (0.00385 and 0.00392 TCR), Ni 120, Cu 10, YSI 400 thermistor 1 Year Spec: ±0.07°C (Pt 100†)
Interfaces	Standard, RS-232; Optional, IEEE-488 (GPIB)
Temperature Performance	Operating: 0°C to 50°C; Calibration (tcal): 15°C to 35°C; Storage: –20°C to 70°C
Temperature Coefficient	Temperature Coefficient for temperatures outside tcal +5°C is 10% of the 90-day specification (or 1-year, as applicable) per °C
Relative Humidity	Operating: < 80% to 30°C, < 70% to 40°C, < 40% to 50°C; Storage: < 95%, noncondensing
Safety	IEC 61010
EMC	Designed to comply with IEC 61326-1/1994 (EMC)
Line Power	100/120 V or 220/240 V, selectable, 10 VA
Size	5.25" x 12.85" x 13.1" (132 x 326 x 333 mm)
Weight (without options)	9 lb. (4 kg)

†Best guaranteed specification within source/measurement category.

Ordering Information

525A	Temperature/Pressure Calibrator
525A-GPIB	Temperature/Pressure Calibrator with GPIB Interface
525A-LEAD	Thermocouple and test lead set
Y525	19" Rack-Mount Kit
Call	Industrial 0.05% FS Pressure Modules
Call	Precision 0.01% FS Pressure Modules

FLUKE. *Check out www.fluke.com for all the latest Fluke product information.*

Standards Lab RTD Simulators — Models 5123—5126

- Lab-quality RTD simulation
- Accuracy from ±0.02% to ±0.005%
- Gold-plated, low-resistance contacts
- 0.001-ohm resolution

Okay, RTD simulators aren't very pretty, and not much has changed about them over the last 100 years or so. But, that's good because our customers really love these little boxes, and nothing beats their accuracy.

The **Model 5125** has the best combination of accuracy (±0.005%) and resolution (0.001 ohms). These are designed with "no adder accuracy," and the range is 10 to 1,111.11 ohms.

The **Model 5124** has a lower accuracy, ±0.01%, with the same resolution and range as the Model 5125 but with a lower price.

The **Model 5123** is designed for use with 1000-ohm platinum RTDs. It has the same accuracy as the Model 5125 but with a resolution of 0.01 ohms and a range to 11,111 ohms.

The **Model 5126** has an accuracy of ±0.02%, a resolution of 0.01 ohms, and a range of 20 to 1,121 ohms. It's easy to use and, because of its smaller size, makes a great field calibration tool.

While General Resistance does not put any bells or whistles on these boxes, there's no need to calculate or compensate for the error contribution due to contact resistance or "0" resistance because there is no "0" resistance. The Waidner-Wolf shunt design reduces these errors to a level of insignificance. These instruments are about absolute accuracy when only maximum accuracy will do.

Calibrate your lab or field RTD meters with one of our RTD simulators. You won't find a more accurate resistance simulator that's this easy to use.

Specifications

Resistance Range	**5123:** 100Ω to 11,111Ω **5124:** 10Ω to 1,111Ω **5125:** 10Ω to 1,111Ω **5126:** 20Ω to 1,121Ω
Resolution	**5123:** 0.01Ω **5124:** 0.001Ω **5125:** 0.001Ω **5126:** 0.01Ω
Absolute Accuracy	**5123:** ±0.005% **5124:** ±0.01% **5125:** ±0.005% **5126:** ±0.02%
Maximum Current	10Ω to 99.9Ω, 75 mA; above 100Ω, 25 mA (**5126:** 20Ω to 99.99Ω, 50 mA; above 100Ω, 15 mA)
Number of Decades	Six (**5126:** five)
Switch Life Rating	> 100,000 (**5126:** > 50,000)
Resistor Temp. Coefficient	3 ppm/°C typical, 5 ppm max.
Resistor Stability	±10 ppm/24 hours, ±35 ppm/1 year
Maximum Power	100 mW
Breakdown Voltage	750 VRMS
Operating Temperature	–55°C to 75°C
Dimensions	4" H x 17" W x 3.12" D; 102 x 432 x 79 mm (**5126:** 3" H x 5" W x 4" D; 76 x 127 x 102 mm)
Calibration	Includes manufacturer's certificate of NIST-traceable calibration without data.

Ordering Information

5123	RTD Simulator, 100Ω to 11,111Ω
5124	RTD Simulator, 10Ω to 1,111Ω
5125	RTD Simulator, 10Ω to 1,111Ω
5126	RTD Simulator, 20Ω to 1,121Ω

Need a reliable standard resistor? See our selection on pages 28 and 29.

BENCHTOP TEMPERATURE/HUMIDITY GENERATOR

Benchtop Temperature/Humidity Generator **Model 5121**

- Full range accuracy ±0.5% RH
- Large working volume for optimal throughput
- NIST-developed two-pressure principal
- RS-232 interface and ControLog automation software included

Tired of outsourcing your humidity calibrations? Why not buy a temperature/humidity generator and calibrate your humidity probes, data loggers, and chart recorders yourself? It's simple with the 5121 manufactured for Hart by Thunder Scientific. The 5121 is a self-contained generator that measures and controls humidity with high accuracy to ±0.5% and a large working volume of 15" x 15" x 12" (381 x 381 x 305 mm). Not only does it calibrate humidity probes but also entire chart recorders, data-loggers, and hygrometers (if the probe is not detachable, which is often the case).

5121 uses a "two-pressure" generation principal, which was originally developed by NIST and involves saturating a stream of air with water vapor at a known temperature and pressure. Relative humidity of the saturated air can be directly calculated through the following formula:

$$\%RH = \frac{f_s}{f_c} \cdot \frac{e_s}{e_c} \cdot \frac{P_c}{P_s} \cdot 100$$

To generate a known humidity, the 5121 controls the pressure ratio (P_c/P_s), utilizing an enhancement factor ratio (f_s/f_c) and the effective degree of saturation (e_s/e_c).

Humidity generated by this method is only dependant upon precision measurements of temperature and pressure, so the need to use an expensive chilled-mirror hygrometer as a reference is eliminated, reducing the cost of ownership. The 5121 generates RH with an accuracy of 0.5% over the range 0°C to 70°C and 10% RH to 98% RH. Chamber temperature accuracy is an amazing 0.06°C. With this performance, you can calibrate ambient-measuring, temperature-probes!

To assist with your own calibration uncertainty analysis, be sure to visit the Hart website and download a copy of the 5121 series evaluation report that includes the detailed temperature and humidity uncertainty analysis.

How about operating the 5121? It's so easy you'll be performing humidity calibrations minutes from switch-on. The generator is supplied as standard with all the equipment you'll need. Simply connect the generator to a clean, oil-free air supply, fill up the water reservoir, and plug it in; then place your chart recorders, data-loggers, or humidity sensors into the chamber, close the door, and program the desired temperature and humidity through the easy-to-use front panel display. You'll quickly be at set point and recording your calibration data! The front panel display provides loads of useful information, including chamber humidity and flow rates, as well as the saturation and chamber temperatures and pressures.

If you're looking for improved productivity in your humidity calibrations, try ControLog™ software, which allows you to program a series of humidity and temperature set-points, and automatically steps through the set-points to maintain stable calibration conditions for defined periods of time. What could be easier?

The 5121 series is a favorite with many national labs around the world, all branches of the U.S. military, and most of the major humidity sensor manufacturers.

We use a 5121 at Hart for calibration support of our environmental monitoring systems around our cal labs and in manufacturing. It performs reliably day-in and day-out. In fact, we like our 5121 so much, we wanted to offer one to you. So, if you calibrate humidity systems, visit with Hart and check out the 5121. You'll be glad you did!

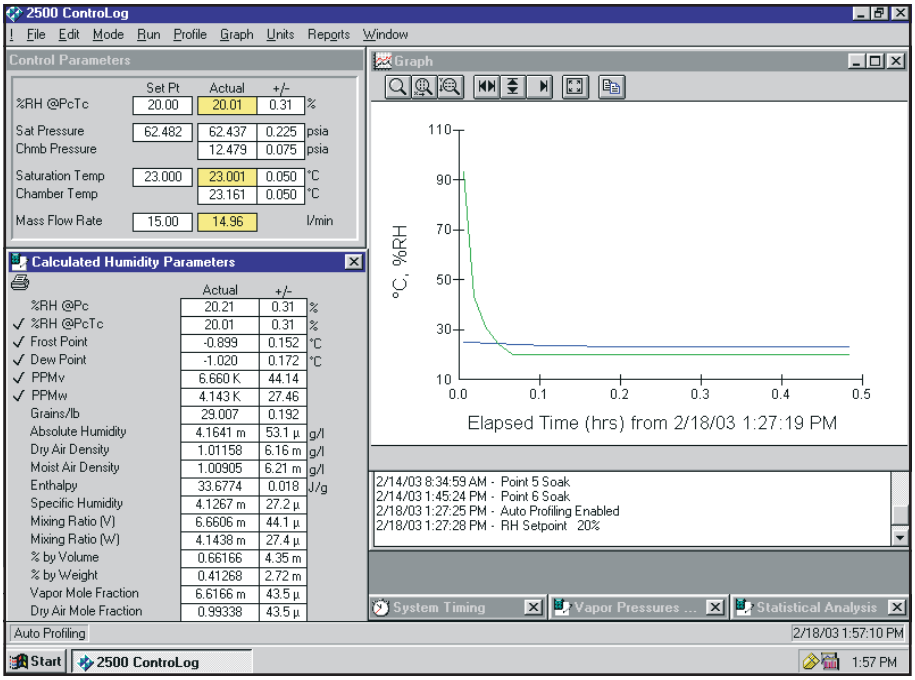
Specifications

Relative Humidity Range	10% to 98%
Relative Humidity Resolution	0.02%
Relative Humidity Accuracy	±0.5%
Chamber Temperature Range	0°C to 70°C
Chamber Temperature Resolution	0.02°
Chamber Temperature Uniformity	±0.1°C
Chamber Temperature Accuracy	0.06°C
Gas Flow Rate Range	5 to 20 slpm
Gas Type	Air or Nitrogen
Heating/Cooling Rate	0.4°C per minute
Interface	RS-232, Software ControLog™ and HumiCalc® included
Chamber Dimensions	15" x 15" x 12" (381 x 381 x 305 mm)
Power, Chamber	100/120V at 15A, 50/60Hz 200/240v at 8A, 50/60Hz
Power, Compressor	100/120V at 5A, 50/60Hz 200/240V at 2.5A, 50/60Hz
Air Supply	Clean, oil-free, instrument air at 175 psiG and 20 slpm
Calibration	NIST traceable temperature & humidity calibration with certificate & data
Warranty	12-months, parts-and-labor

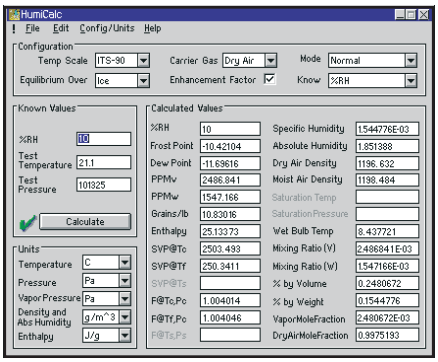
Ordering Information

5121	Humidity Generator, 2500ST (LT)(TPA)

Get the latest product information at www.hartscientific.com



ControLog™ software can completely automate the operation of your 5121. Run a single set-point or quickly create a profile with a series of set-point/time values and let your 5121 run unattended. ControLog™ collects data and includes a report editor for semi-custom reports. It can operate your system in a variety of modes including %RH, Frost Point, Dew Point, PPMv, and PPMw.



HumiCalc® software makes simple work of complex humidity conversions. A typical calculation requires only a temperature, a pressure, and one known humidity parameter. HumiCalc® then computes all the final humidity values for you and can export them to a spreadsheet.

Dallen (U.S. sales) got his first B-B gun for his third birthday. Enough said.

RELATIVE HUMIDITY CALIBRATOR — Model 5110

Relative Humidity Calibrator — Model 5110

- An affordable RH calibrator
- Wide range, 0 to 99.9% RH
- Maintains accuracies of 1.0% between 20% and 80% RH
- Completely portable with carrying case

Doing RH calibrations? The Model 5110 RH Calibrator from General Eastern is a complete system for relative humidity calibrations from 0.0% to 99.9% in increments of 0.1%. It includes a NIST-traceable calibration, has a 15-minute response time, an RS-232 port, repeatability of 0.2%, and optional software for creating a customized plot of RH versus time.

Calibrating your humidity instruments is a snap with the 5110 RH Calibrator. Forget limiting your test values to the fixed points provided by salt bottles. Test your equipment at the actual RH values within which they operate. Any set-point you select is stable and repeatable to 0.2% RH.

A divided air-flow system is used to generate the RH level quickly and accurately in the built-in test chamber. A column of air is separated into two precisely proportioned streams, one saturated and the other dry. The desired RH is created by precision mixing of the air streams.

Relative humidity is set on the LED display in 0.1% increments using the front-panel switch. Test profiles can be loaded into memory from your computer through the 5110's RS-232 port.

The covered test chamber is easily accessed through a lift-off acrylic lid that can be drilled and modified to your needs.

The Model 5110 RH Calibrator is convenient to use and totally self-contained for portability and versatility. It's a great instrument at an excellent price.

Read about our calibration training courses on page 153.

Read about our accredited calibration services on page 156.

Specifications

Generation Method	Divided flow
Operating Range	0.0% to 99.9% RH, 2°C to 40°C
Repeatability	0.2% RH
Accuracy	0 to 10%: ±4.0% RH 10 to 20%: ±2.0% RH 20 to 80%: ±1.0% RH 80 to 90%: ±2.0% RH 90 to 99.9%: ±4.0% RH
Response Time	Less than 15 minutes
Stability	0.2% RH
Test Well Size	3.2" x 5.8" x 3.7" D (81 x 147 x 94 mm)
Storage	Full: 0.5°C to 40°C Drained: –54°C to 50°C
Power	120 VAC or 240 VAC, specify, 50/60 Hz
Integral Power Supply	24 VDC, unregulated
Weight	12 lb. (5.4 kg)
Size	12" H x 16" W x 10" D (305 x 406 x 254 mm)
Calibration	Manufacturer's certificate of NIST-traceable calibration included

Ordering Information

5110	Relative Humidity Calibrator (110 VAC)
5110-220	Relative Humidity Calibrator (220 VAC)
5304-001	Spare Access Cover, 5110
5304-003	ProStep Software, 5110
5021	Dessicant, 5 lb. jar

We've seen a few dry-wells come back looking a lot like this door, but Norm (purchasing) does his damage on purpose.

FLUKE 2680 SERIES DATA ACQUISITION SYSTEMS 2680A and 2686A

Fluke 2680 Series Data Acquisition Systems **Models 2680A and 2686A**

- Precision thermocouple measurement
- 120-channel capacity chassis (2,000 channels in a system)
- Powerful reporting, HMI development software, and OPC server software available

The Fluke 2680 Series delivers the precision necessary for meticulous lab work along with the rugged flexibility to meet the ever-changing needs of industrial applications. Run one stand-alone data logging system with 20 to 120 universal channels or connect several networked data acquisition systems to serve more than 2,000 channels on your LAN.

Two basic chassis models are available. The 2680A Data Acquisition System is a front-end style chassis for multi-channel applications requiring reliable Ethernet communications. The Fluke 2686A Data Logging System writes data to a memory card, making it ideal for remote locations.

Both chassis models feature six slots. Five slots are available for any combination of 20-channel analog input modules. The sixth slot is reserved for a digital I/O relay module to add control capabilities, or for an additional input module.

The Fluke 2680A-PAI Precision Analog Input offers 300 V of isolation on two channels and 150 V on 18 channels, as well as 18-bit resolution and excellent thermocouple accuracy, all in a scalable system.

The 2680A-FAI Fast Analog Input module provides throughput rates of more than 3,000 channels-per-second. Specially manufactured field effect transistors (FETs) allow up to ±50 V input (well above the 15 V industry norm!) and channel-to-channel isolation to give you more confidence in your measurements.

For data acquisition systems that also require control functionality, the Fluke 2680A-DIO digital I/O and relay output module provides 20 digital I/O and eight hard-contact 1 amp form-C relays.

The Fluke 2680A Series systems come with Fluke's powerful, easy-to-use Fluke DAQ configuration software. Fluke DAQ enables you to quickly configure your 2680 Series unit, set up data files, collect and chart data, and manage PC card files. Fluke DAQ also enables you to integrate Fluke NetDAQ® 2640A and 2645A units seamlessly into a 2680 Series system.

But wait, there's more! Optional 2680A-DEVSW Indusoft Web Studio is an object-oriented application development program used to expand the functionality of your system. 2680A-OPC server software provides a link to any software package that supports OPC, allowing you to use other popular industrial software packages. The Fluke 2680A-DLL library provides the full DLL toolbox for application software developers.

Specifications

DC Volts	
2680A-PAI	90 mV to 150/300 V (0.019%)
2680A-FAI	90 mV to 50 V (0.02%)
AC Volts	
2680A-PAI	300 mV to 150/300 V (0.3%)
2680A-FAI	300 mV to 30 V (0.3%)
Resistance	
2680A-PAI	300Ω to 3MΩ (0.015%)
2680A-FAI	300Ω (0.02%)
Frequency	
2680A-PAI	15 Hz to 1 MHz (0.05%)
2680A-FAI	15 Hz to 1 MHz (0.05%)
RTD (Pt100)	
2680A-PAI	–200°C to 600°C (0.06°C)
2680A-FAI	–200°C to 600°C (0.16°C)
Thermistor	
2680A-PAI	–40°C to 150°C (0.3°C)
2680A-FAI	–40°C to 150°C (0.5°C)
Thermocouples	**J, K, T, R, S, B, N, L, U, E, C**
2680A-PAI	–270°C to 2640°C† (0.15°C)
2680A-FAI	–270°C to 2640°C† (0.7°C)
	(†thermocouple dependent)
Power	120/240 V AC or 9–42 V DC
Weight	18 lb. (8.2 kg) (chassis only) 2 lb. (0.9 kg) (modules)
Size	18.6" x 17" x 9.3" (473 x 423 x 237 mm)

Ordering Information

2680A	Data Acquisition System Chassis, 6 slots
2680A-FAI	Fast Analog Input Module
2680A-PAI	Precision Analog Input Module
2680A-DIO	Digital I/O and Relay Module
2680A-DE	Indusoft Web Studio, Development software for Fluke DAQ
2680A-DLL	DLL Library for 2680 Series
2680A-OPC	OPC Software for 2680 Series
2680A-180	Universal Input Module, extra connector
2680A-102	2680A-DIO Connector Module, extra connector
2686A	Data Logging System Chassis with ATA Flash Memory Drive; includes 16 MB memory card
2686A-101	Shunt Resistor Set (12 ea.), 10Ω, 1%
Y2680	Rack-Mount Kit for 2680 Series

FLUKE HYDRA™ SERIES DATA ACQUISITION — Models 2620A–2635T

Fluke Hydra Series Portable Data Acquisition — Models 2620A–2635T

- 20 universal channels
- Precision measurements
- Quick setups with menu-driven software

Many of our customers collect and monitor data about temperature and other parameters as well. Thanks to our partnership with Fluke Corporation, we can offer you a wide selection of data acquisition equipment, including the versatile Hydra Series of portable data loggers and recording thermometers.

The Hydra Series is available in three models to fit many application requirements. The 2620A Hydra Data Acquisition Unit is a compact front end for use with your PC. The portable 2625A Hydra Data Logger features non-volatile memory that stores more than 42,000 readings for stand-alone applications. And the 2635A Hydra Data Bucket™, with its removable memory card for data and setup storage, is the most versatile model—ideal for remote monitoring applications.

All models are easy to set up and reconfigure from the front panel. Additionally, all units have universal signal conditioning. The RS-232C interface enables control from a host computer. An optional GPIB/IEEE-488 interface is available for the 2620A only.

The Fluke 2620T and 2635T Recording Thermometers are precision 20-channel temperature recording and logging instruments that deliver up to 0.1° accuracy for temperature monitoring and calibration applications. Based on Fluke's popular 20-channel Hydra Series II data loggers, these units are matched with a precision PRT probe from Hart and calibrated as a system for maximum accuracy and precision. Both models include Hydra Logger software and are also compatible with Hart's MET/TEMP II software.

The 2620T and 2635T are just two examples of what can happen when two premier manufacturers combine forces to bring you the best solutions available. More innovative ideas are on the way from Hart and Fluke.

Specifications

DC Volts	90 mV to 150/300 V (±0.018 %)
AC Volts	90 mV to 150/300 V (±0.013 %)
Resistance	300Ω to 10 MΩ (±0.013 %)
Frequency	15 Hz to 1 MHz (±0.05 %)
RTD (PT100)	–200°C to 600°C (±0.05°C)
Thermocouples	**J, K, T, R, S, B, N, E, C** –270°C to 2640°C (±0.15°C), thermocouple dependent
Power	96 to 264 V AC 9 to 16 V DC
Weight	6.5 lb. (3.0 kg)
Size	11.5" x 8.5" x 3.5" (292 x 215 x 89 mm)

Hydra 2635A Memory Card Specifications

256 KB Memory Card Size	4 Channels Scanning: 8900 scans 10 Channels Scanning: 4800 scans 20 Channels Scanning: 2710 scans
1 MB Memory Card Size	4 Channels Scanning: 36,860 scans 10 Channels Scanning: 19,860 scans 20 Channels Scanning: 11,210 scans
2 MB Memory Card Size	4 Channels Scanning: 74,110 scans 10 Channels Scanning: 39,910 scans 20 Channels Scanning: 22,550 scans
4 MB Memory Card Size	4 Channels Scanning: 149,039 scans 10 Channels Scanning: 80,251 scans 20 Channels Scanning: 45,359 scans

Ordering Information

2620A	Hydra Data Acquisition Unit
2620A/05	Hydra Data Acquisition Unit with IEEE-488 interface
2620A-100	Extra I/O Connector Set
2620A-101	Current Shunt Set 0-100 mA (12/set)
2620T	Recording Thermometer
2625A	Hydra Data Logger
2635A	Hydra Data Bucket (256 KB memory card)
2635A-1MB	Hydra Data Bucket (1 MB memory card)
2635A-2MB	Hydra Data Bucket (2 MB memory card)
2635A-4MB	Hydra Data Bucket (4 MB memory card)
2635A-901	Hydra Logger Software
2635A-902	Hydra Logger with Trend Link
2635T	Recording Thermometer with memory card
2600A-101	Extra PRT Probe, 100Ω, with soft case
M00200834	Rack-Mount Kit

FLUKE NetDAQ® DATA ACQUISITION — Models 2640A and 2645A

Fluke NetDAQ® Networked Data Acquisition — Models 2640A and 2645A

- Universal inputs
- Precision temperature measurements
- Real-time trending software
- Distributed data collection

NetDAQ networked data acquisition units are a powerful combination of hardware and software seamlessly integrated to deliver precision measurements directly over an existing network. This family of Fluke systems, combined with Trend Link software, enables multiple users to view only the information they need in real time, from anywhere on the system. View current, temperature, voltage, and more on the same screen at the same time. NetDAQ replaces aging chart recorders and adds future expandability to your precision measurement system.

Combine from one to 20 NetDAQ units into an integrated NetDAQ system of up to 400 channels. Use an existing network or simply connect the system directly to your PC. Two models offer a choice of scan speeds (up to 1000 readings per second), and accuracy (up to 0.01%) to meet the needs of your specific operation.

NetDAQ 2640A

High accuracy and resolution provide calibration-level performance with the 2640A. It measures up to 300 V with 0.01% DC voltage accuracy and 18-bit resolution, scanning from 6 to 100 readings per second.

NetDAQ 2645A

NetDAQ delivers higher speed data acquisition, making it perfectly suited for applications that require more dynamic signal capture. The 2645A directly measures 20 inputs of up to 50 V at 1000 readings per second with 0.02% V DC accuracy and 16-bit resolution.

Easy Setup and Configuration

Fluke's intuitive NetDAQ Logger software makes it easy to set up and configure up to 20 NetDAQs. Combining NetDAQ Logger with the optional Trend Link trending software enables multiple users to monitor processes and import data into spreadsheet programs for even more analysis.

Specifications

DC Volts	
2640A	90 mV to 150/300 V (±0.01%)
2645A	90 mV to 50V (±0.01%)
AC Volts	
2640A	300 mV to 30 V (±0.3%)
2645A	30V to 50mV (±0.3%)
Resistance	
2640A	300Ω to 3 MΩ (±0.015%)
2645A	300Ω to 3MΩ (±0.02%*)
Frequency	
2640A	15 Hz to 1 MHz (±0.05%)
2645A	15 Hz to 1 MHz (±0.05%)
RTD (Pt100)	
2640A	–200°C to 600°C (±0.06°C)
2645A	–200°C to 600°C (±0.16°C)
Thermocouples	**J, K, T, R, S, B, N, L, U, E, C**
2640A	–270°C to 2264°C† (±0.35°C)
2645A	–270°C to 2264°C† (±0.7°C)
	(†thermocouple dependent)
Power	120/240 V AC or 9–16 V DC
Weight	8.2 lb. (3.7 kg)
Size	14.5" x 8.5" x 3.5" (368 x 215 x 89 mm)

Ordering Information

2640A	NetDAQ Data Acquisition Unit (100 rdgs/s)
2645A	NetDAQ Data Acquisition Unit (1000 rdgs/s)
2620A-100	Extra I/O Connector Set
264XA-803	PCMCIA to LAN Adapter (10Base2, 10BaseT)
2620A-101	Current Shunt Set, 0-100 mA (12/set)
Y2641	19" Rack-Mount Kit, single/dual
2600A-904	Trend Link for Fluke
2640A-911	NetDAQ Logger for Windows®
2640A-912	NetDAQ Logger w/ Trending

FLUKE *Check out www.fluke.com for all the latest Fluke product information.*

LAB HUMIDITY/TEMP RECORDER — Model 5109

Lab Humidity/Temp Recorder — Model 5109

- Document lab conditions for quality audits
- Note current RH and temperature for your cal certificates
- Calibrate the detachable probe in Hart's 5110 RH calibrator

Specifications

Temperature Ranges	User selectable: –20°F to 120°F, 40°F to 110°F, –20°C to 50°C, 5°C to 40°C
Temperature Accuracy	±1.8°F (±1.0°C)
Humidity Range	0 to 95% (non-condensing)
Humidity Accuracy	±2% between 0 and 60% RH, ±3% between 61 and 95% RH (at 73°F, 23°C)
Display Resolution	1°F (1°C), 1% RH
Chart Size	8" diameter (203 mm)
Temperature Sensor	Thermistor
Humidity Sensor	Thin film capacitor
Recording Time	User-selectable, 1-, 7-, and 31-day
Power	120 VAC adapter with four D batteries for backup power
Body Dimensions	10.5" x 13.2" x 2.8" (267 x 335 x 71 mm)
Probe Dimensions	0.92" dia. x 5.9" long (23.4 x 150 mm)
Weight	Approx. 7 lb. (3.2 kg)
Mounting	Portable or wall mountable
Calibration	Manufacturer's 1-point NIST-traceable calibration included
Alarms	Audio/visual high and low alarms
Response Time	Temperature: 30 seconds for a 63% step change at 1 cfm, RH: 20 seconds for a 63% step change at 1 cfm
Operating Range (Body)	10% RH to 90% RH, 32°F to 122°F (0°C to 50°C)

Need an excellent eight-inch chart recorder for collecting data on lab humidity and temperature? The Model 5109 Chart Recorder from Dickson gets the job done for you at a reasonable price.

The Model 5109 records humidity and temperature, or temperature and dew point. It's a microprocessor-based unit with a battery backup so you don't lose important data if the power fails. Read the temperature and humidity directly from the digital display without having to look at the circular chart.

Change the readout from °F to °C, set high/low alarms, and change the recording times to 1-, 7-, or 31-day intervals from the front panel. The humidity sensor is easily recalibrated with a Model 5110 Humidity Calibrator (shown on page 146).

Each recorder comes with two pens, an AC adapter, and a box of charts containing the range –20°F to 120°F for seven-day intervals. There's an optional 10-foot extension cable for locating the sensor away from the recorder or to assist in calibrating the sensor. Longer cables, up to 100 feet, are also available.

The Model 5109 is accurate to ±1.0°C and ±2% between 0 and 60% RH and 3% between 61 and 95% RH.

Ordering Information

5109	RH/Temp Recorder (includes certificate of NIST-traceable calibration and one set of 5311-C417 charts)
5109-220	RH/Temp Recorder, 220 V
5311-001	10 ft. Probe Cable
5311-002	Pens, pkg. of 6
5311-003	AC Adapter, 220 V
5311-005	50 ft. Probe Cable
5311-006	100 ft. Probe Cable
5311-XXXX	Charts *See table at right.*
1980	Calibration by Hart, see page 156

Replace XXXX in Model 5311-XXXX with code from this table (60 charts per package):

Temperature Range	24-Hour Chart	7-Day Chart	31-Day Chart
–20°F to 120°F	C415	C417	C480
40°F to 110°F	C476	C477	C481
–20°C to 50°C	C472	C473	C482
5°C to 40°C	C478	C479	C483

Get the latest product information at www.hartscientific.com

TEMPERATURE/HUMIDITY LOGGER Model 5113

Temperature/Humidity Logger Model 5113

- Replaces paper-based recorders
- Easily mounts on a wall or fits in a pocket
- Windows-based analysis software included

For easy, paperless, environmental monitoring, check out the 5113 Temperature and Humidity Logger from Sato. No other product offers this combination of convenience, accuracy, and price.

The 5113 records temperature and humidity using either internal or external sensors. Measurements are made every second and are accurate to ±0.5°C and ±2.0%, respectively. Readings are displayed in large, easy-to-view letters on the LCD display and can even be viewed while logging data.

Up to 8,100 lines of date- and time-stamped data may be logged in memory for each sensor. With the included Windows based software, analysis of your data is easy both graphically and statistically. Real-time data acquisition is also possible with optional software.

At roughly the size of a PalmPilot™, the 5113 mounts easily onto a wall or can be carried in a pocket to any place you need to monitor. Thirteen logging intervals can be selected, from 1 second to 60 minutes, and delayed start times can be preprogrammed through your PC. Using a measurement interval of 30 minutes, the 5113 can provide up to four months of power from AA batteries. And data is retained in memory when the unit is powered off—even when changing batteries.

No other humidity and temperature logger is this easy to use. Programming the correct date and time, selecting temperature units, starting and stopping logging, and selecting logging intervals are all easily done through the front-panel buttons. A bar chart on the front-panel display even shows the amount of memory used.

We use several of these to report ambient conditions at our calibration benches, and we love them. You will too.

Specifications

Measurement Range	Temp: –10°C to 60°C (14°F to 140°F) Hum: 20 to 99.9%
Measurement Accuracy	Temp: ±0.5°C (±0.9°F) Hum: ±5%, internal sensor; ±2%, external sensor
Resolution	Temp: 0.1° Hum: 0.1%
Sensors	Temp: thermistor Hum: high polymer resistance-change humidity sensor
Sampling Rate	Approximately 1 second
Log Intervals	13 options from 1 second to 60 minutes
Memory Capacity	8,100 lines of data, each channel
Communication	RS-232 (cable included)
Software	Compatible with Windows 95/98/ME/2000/NT 4.0; analysis software also included; real-time data acquisition software optional
Calibration	Factory certificate included with data (Sato, Japan)
Power Supply	Four 6-VDC alkaline batteries included; AC adapter optional
Battery Lifetime	4 months (using 30-minute log interval)
Size	4.7" W x 3.3" H x 1.1" D (120 x 84 x 28 mm)
Weight	8 oz. (227 g), including batteries

Ordering Information

5113	Temp/Humidity Logger (includes internal and external sensors, Windows–based download and analyze software, batteries, wrist strap, and RS-232 cable)
5306-002	AC Adapter, 115 VAC
5306-003	Real-Time Data Acquisition Software
9300	Rugged Carrying Case
5306-006	AC Adapter, 230 VAC
1980	Calibration by Hart, see page 156

INTRINSICALLY SAFE REFERENCE THERMOMETER — Model 5577

Intrinsically Safe Portable Reference Thermometer — Model 5577

- Certified to ATEX directive — EX II 2G EEx ib IIB T4 rating
- System accuracy to ±0.05°C (readout and probe!)
- Battery powered
- Dual channel with differential measurement

We get many requests every year from our customers for an intrinsically safe reference thermometer for use in hazardous areas. Up to now, there have been very few intrinsically safe thermometers available—and certainly no reference-grade thermometers.

Now we're excited to offer the 5577 from Dostmann, which combines an ATEX IS rating with high accuracy (±0.05°C over the entire range –100°C to 135°C) for the readout and probe together. It doesn't get any better than this!

So how do we achieve such high performance? The 5577 uses Pt100 probes and a calibration procedure that uses system calibration data to marry the probe and the readout, which ensures high-accuracy measurements across a complete temperature range. System calibrations—done by Hart—are NIST-traceable and NVLAP-accredited.

The 5577 can be used with one or two probes and will display both measurement channels simultaneously along with their difference—a perfect tool for checking temperature gradients. Several probe designs are available depending on what process you're measuring. An optional convenient carrying-case provides storage for one readout and up to two probes.

Since the 5577 is battery powered, the thermometer is lightweight and extremely portable—perfect for measurements in those hard-to-get-to places out on the pipeline. A standard IS-rated 9V "D" cell powers the thermometer for up to 20 hours.

If you're making critical temperature measurements and need an IS-rated thermometer, the 5577 is an essential part of your tool-kit. You shouldn't leave the safety of your home without one!

Don't forget a protective case!

Specifications

Temperature Range	–100°C to 135°C
System Accuracy† (calibration plus repeatability)	±0.05°C
Drift (1 year)	±0.05°C (assumes proper handling of probes)
Resolution	0.01°
Sensor Type	Pt100, 4-wire, DIN '385' Alpha
Communications	RS-232 (not for use within hazardous environments)
Power Supply	9V IS-rated battery
Battery Life	20 hours
Display	2-line LCD
Operating Range	0°C to 40°C
IS Rating	EX II 2G EEx ib IIB T4 rating; Certified by CENELEC to European ATEX directive
Dimensions	8" H x 3.5" W x 1.5" D (20 x 8.5 x 4 cm)
Weight	0.7 lb. (0.3 kg)
Calibration	NIST-traceable, NVLAP accredited system cal from Hart with data

Ordering Information

5577	Handheld IS-Rated Thermometer Readout, P655-EX
5315-001	Immersion Probe†, –100°C to 135°C, 150 x 3 mm
5315-002	Immersion Probe†, –100°C to 135°C, 300 x 3 mm
5315-003	Immersion Probe†, –100°C to 135°C, 300 x 6 mm
5315-005	IS-Approved Spare Battery
9326	Carrying Case (fits 5577 and two 300 mm probes)

†*Note: Each purchased probe must be system calibrated with its 5577 to achieve specified accuracy.*

CENELEC IS Markings	
EX	EC Examination Mark
II	ATEX Gas Groups – Group II is for gases in non-mining industries
2G	ATEX Zones – 2G identifies zones in which an explosive gas/air mixture is likely to be present
EEx	European Mark for Explosion Protected
ib	Explosion Protection Type and Zones – ib indicates intrinsic safety in zones in which an explosive gas/air mixture is at least likely to be present
IIB	Explosive Gas Groups – IIB is for atmospheres containing ethylene or gases of an equivalent hazard
T4	Temperature Classification – T4 has an upper temperature limit to 135°C

TEMPERATURE CALIBRATION TRAINING

How about a little education? Hart Scientific can provide it for you through our courses in temperature calibration.

Each one of these classes has been specifically designed for the work you do. You'll hear from some of the best metrologists in the world, as well as from applications specialists, metrology scientists, and equipment designers. You'll get hands-on experience and demonstrations to support many of the techniques taught in each class. You'll also get a chance to tour our calibration laboratory and primary standards lab, and you'll have chances to get all your questions answered by any of our world-class instructors.

Xumo, Kay, Mike, Tom, and Rick share their seminar notes.

"Temperature measurement is one of my weak areas, where I have a tendency to question my techniques. I have greater confidence now since the seminar."

Our courses have become known as the standard for temperature calibration training. Most classes sell out long before the registration deadline. Attendees tell us they like our classes more than any others they've attended. Our casual atmosphere makes learning these challenging concepts enjoyable.

We absolutely guarantee that if you come to one of our classes we'll make it one of the most memorable experiences that you have ever had in continuing education! And these classes meet your lab accreditation needs.

Courses

Industrial Temperature Calibration

- Course length: 2½ days
- Class size: 25

This one is about fundamentals. We'll explore the theory and practice of temperature measurement and calibration across an accuracy range of 1°C to 0.1°C. In this class we go directly to the center of industrial temperature calibration and accuracy issues. We focus on practical applications and hands-on experience with classroom discussion of the theory behind the technique.

We'll show you how to calibrate thermocouples, thermistors, PRTs, LIG thermometers, and anything else you can think of. We'll explain how to properly use heat sources such as dry-wells and portable baths to achieve the accuracy you need with the least amount of anxiety over your technique.

"The course was very informative, with enough technical content—yet not overbearing."

Whether you're new to temperature calibration or you've been performing field calibrations for years, you'll go home more confident and ready to expand your role in calibration.

Temperature Metrology

- Course length: 2½ days
- Class size: 25

This is an intermediate course in practical lab skills for comparison calibrations of various sensor types, along with other calibration techniques for greater accuracy. You'll leave knowing how to use SPRTs and other high-accuracy standards to keep your working standards performing at their highest levels.

Comparison calibration labs need practical information on how to implement ITS-90, and you'll get it from this course. Come and talk with people who know the theory and practice of calibrating everything you see on a daily basis. Not only will they teach you technique, they'll explain the logic behind what they're teaching. You'll learn more than you thought possible in only a couple of days. We'll address the world of accuracy from 0.1°C to 0.01°C.

Are you working on laboratory accreditation? In this course we also discuss accreditation and compliance, especially dealing with ISO 17025 issues.

"I learned enough to more than justify the cost of the seminar. I've got a start now for implementing changes for the better in our lab."

TEMPERATURE CALIBRATION TRAINING

Course	Industrial Calibration	Temperature Metrology	ITS-90 Seminar
Qualifications and Prerequisites	None	Some experience in sensor calibrations	Some experience with comparison calibration techniques; some familiarity with the ITS-90
Typical Uncertainties Discussed	±5°C to ±0.1°C	±0.5°C to ±0.005°C	±0.1°C to ±0.001°C
Coverage of Fixed Points	Brief introduction to water triple point cells; demonstration of mini WTP cells.	Theory, demonstrations, and hands-on experience with water triple point cells.	Theory of all ITS-90 fixed points; demonstrations of WTP freeze and tin and gallium realizations.
Who Should Come	Anyone new to temperature metrology and anyone performing in-field calibrations of working sensors—typically using portable calibrators—with or without reference thermometers.	Those responsible for calibrating in-field standards. Metrologists who do not work heavily with ITS-90 fixed points, but who seek lower uncertainties through comparison calibrations.	Metrologists responsible for calibrating SPRTs or other laboratory standards. Those seeking the lowest possible uncertainties through comparison or fixed-point calibrations.

Not only will we cover actual calibration techniques, we'll show you how various instruments such as readouts, dry-wells, and calibration baths work and why they work the way they do. You'll learn how to pick the right equipment for any calibration, how to verify the uncertainty of what you are doing, and the most cost-effective approach for specific jobs. Bring your questions; we'll answer them better than anybody ever has.

Realizing and Approximating ITS-90

- Course length: 2½ days

"I liked the detail of technical information without much of a sales pitch. It gave me many ideas to use. I also enjoyed the light, casual attitude."

- Class size: 25

Buckle up because this is the big one. This is the only course of its kind that is this thorough on realizing and approximating ITS-90. We cover it all!

In this class we're going to take you on an adventure from 0.01°C all the way to 0.001°C, and beyond. We'll explore SPRT calibrations using fixed-point cells; we'll teach you the proper way to use a water triple point cell and how often to use it to verify the calibration of your working standards. We'll show you everything that impacts SPRTs and other laboratory standards down to 0.1 mK. You'll learn how SPRTs get contaminated and how to stop it. We'll demonstrate the usage of fixed-point cells and explain all the alternative methods for using fixed points in your lab.

Don't just bring your questions; bring the hardest, most unusual temperature calibration questions you can think of. We'll answer them. Nobody explains the problems, theories, and techniques of 1 mK work better than we do! Previous attendees from some of the best labs in the world tell us that what we're promising you is what we delivered to them. It's two-and-a-half days of temperature calibration camp at its best!

How Do I Register?

Call us at…
(801) 763-1600
(800) 438-4278

Fax us at…
(801) 763-1010

E-mail us at…
seminars@hartscientific.com

or register online at…
www.hartscientific.com

Remember, you can check our web site for dates and times of classes. Once you register, we'll send you the necessary visitor information on where to stay and how to get here. We're located just 40 minutes from Salt Lake City International Airport with plenty of inexpensive hotels nearby.

Want to learn how to use Hart products? Would you like to learn how they work and how you can get the most out of them? Would you like to send your staff to be trained on Hart instruments?

While our seminars offer two-and-a-half days of theory, demonstrations, hands-on exercises, and panel discussions, our Product Training Sessions give you up to two full days of additional hands-on experience.

These post-seminar classes are broken into four half-day sessions covering thermometers, baths, dry-wells, and software. Product Training Sessions are held during the same week as our seminars, so they provide the perfect follow-up to our regular seminar course work. The enrollment fee includes all four of the half-day sessions.

These sessions offer the perfect opportunity to learn to maximize the advantages you get from Hart products. You'll leave knowing exactly how to use your favorite temperature calibration products, how to achieve the best results from them, and how to get the most productivity out of your calibration work.

An experienced product group expert at Hart Scientific guides each Product Training Session. Enrollment is limited so everyone gets plenty of time with the equipment and no one lacks individual attention. You're guaranteed to get all your questions answered.

Each session includes experience with a large number of products that represent Hart's entire line for that particular product group. In the thermometer session, for example, you'll get to work (and play) with a Little Lord Logger, a Chub-E4, a *Black Stack*, and a Super-Thermometer. Likewise for the other sessions.

You just need to register to enjoy using the best temperature calibration products in the world. Try them out and you'll understand what we mean.

Industrial Temperature Calibration, Course Outline

An introduction to the basic principles and techniques for testing or calibrating common sensors and thermometers.

Overview
- ITS-90, international agreements
- Terminology review
- Traceability & hierarchy

Unit Under Test Fundamentals
- Types, characteristics, and limitations
- Thermometer configurations

Calibration Methods
- Simulators
- Reference heat sources
- Reference thermometers
- Introduction to accuracy
- How accuracy is determined
- Error sources
- Special cases and challenges

Calibration Equipment
- Learn the characteristics and applications
- Heat sources
- Thermometers and readouts
- Standards—what is suitable as a reference

Case Studies

Other Issues
- Quality issues—ISO 17025, Z540, reports, record keeping
- Math applications
- Introduction to high-precision equipment
- Q&A with the experts

Demonstrations

Temperature Metrology, Course Outline

An intermediate course in practical lab skills for comparison calibration of thermistors, RTDs, thermocouples, and other thermometers.

Introduction to Temperature Metrology
- Scales, ITS-90, and fixed points
- Uncertainty and traceability

Thermometer Types
- SPRTs, PRTs, RTDs, and thermistors
- Thermocouples—noble vs. base metal
- Liquid-in-Glass—procedures for accuracy
- Reference thermometers

Components of Uncertainty
- Heat sources
- Readouts

Common Calibration Techniques
- Thermistors & PRTs
- Thermocouples—ASTM, spool testing
- LIG—ASTM—specific requirements

Optimizing Your Measurement
- Test uncertainty ratios
- Error budgeting
- Profiling a heat source
- Mathematics

Maintaining Your Standards
- Frequency of calibration
- Uncertainty analysis and SPC

Compliance Issues
- Reports, tables—pleasing the auditor
- ISO/IEC17025, incorporating the new reqirements

Demonstrations

Realizing and Approximating ITS-90, Course Outline

An advanced seminar in temperature metrology.

Realizing ITS-90 Introduction
- History of ITS-90
- Learn how and why the scale changed

Fixed-Point Fundamentals
- Fixed-point vs. thermodynamic scale
- Uncertainties

Practical Fixed-Point Realization
- In-depth review of each fixed point
- Equipment: cells, apparatus, bridges
- Methodology, procedures, and demos

Resistance Thermometers
- SPRTs and HTPRTs
- Annealing procedures

Approximating the Scale
- Choosing to do comparison calibrations

Techniques
- Getting the most accuracy
- How to select calibration points
- Choosing a technique and demos

Equipment
- PRTs and thermistors
- Heat sources: LN_2, furnaces, baths
- Readouts: DMMs, "thermometers"

Uncertainty
- Error analysis and uncertainty
- Statistical process control

Demonstrations

Product Training

Software Training - You'll learn how to…
- automate control of your heat sources
- automate calibrations entirely
- generate probe data easily
- log temperature data and analyze it

You'll use…
- 9938 MET/TEMP II
- 9935 Log*War*e II

Thermometer Training - You'll learn how to…
- use the menu systems for each readout
- match a probe to a readout
- select the best probe and handle it correctly
- get the most productivity from your readout

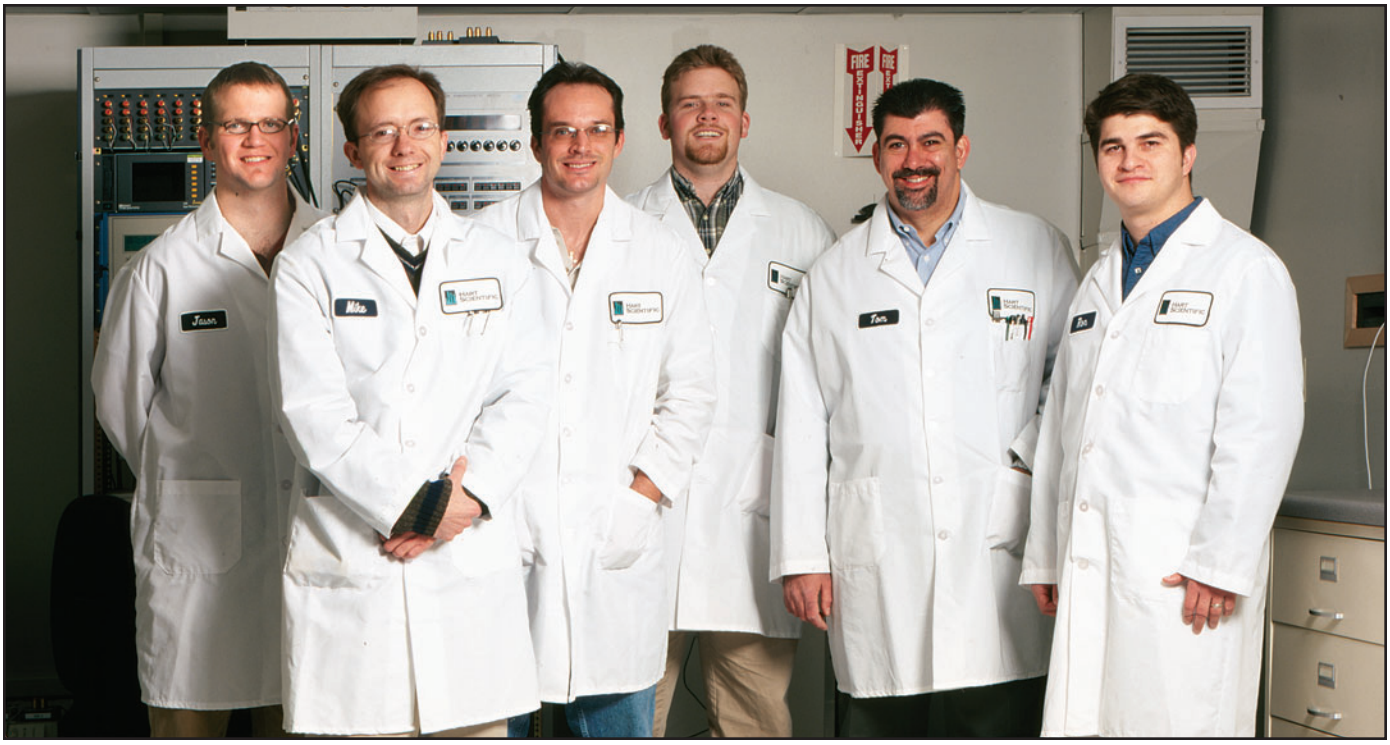
You'll use…
- 1522 Little Lord Logger
- 1529 Chub-E4
- 1560 *Black Stack*
- 1590 Super-Thermometer II

Dry-Well Training - You'll learn how to…
- use all dry-well controller functions
- recalibrate your own dry-well
- use a reference thermometer
- maximize dry-well productivity

You'll use…
- lab dry-wells
- field dry-wells
- handheld dry-wells
- Micro-Baths
- Interface-*it* software

Bath Training - You'll learn how to…
- profile a bath to minimize uncertainty
- use different types of bath fluids
- use Hart bath controllers
- get the most from a reference thermometer

You'll use…
- Model 7380 –80°C Bath
- Model 6022 Oil Bath
- Model 1590 Super-Thermometer II



Hart's American Fork calibration crew: (left to right) Jason Sanders, Mike Coleman, Steve Claxton, Tom Harper, Tom Wiandt, and Ron Ainsworth.

Hart's NVLAP accredited Metrology Laboratory (lab code 200348) in American Fork, Utah provides temperature calibrations from approximately –200°C to 1000°C using fixed-point and comparison methods. Our accredited uncertainties are among the lowest commercially available anywhere in the world. Our prices are very competitive and our turn-around times are excellent. Our reports are comprehensive and include as-found and as-left data as well as pass/fail criteria (where applicable) and a concise statement of the method used. Calibrations performed at Hart are traceable to NIST and meet the new ISO 17025 requirements as described in the following pages.

For fixed-point calibrations, we use Hart fixed-point cells and apparatus, Hart SPRTs as check standards, and conventional DC bridges with DC standard resistors. Our fixed-point calibration procedures are based on CCT procedures, so you can be confident that the technique is current, correct, and thorough.

For comparison calibrations, we use Hart baths, Hart SPRTs, and Hart readouts. We use several different techniques to minimize uncertainties while maximizing efficiency to keep the costs as low as possible without compromising quality. All Hart-manufactured instruments (except SPRTs and some thermocouples, which come uncalibrated) are certified before they are shipped to you. We don't simply provide a "certificate of conformance" with a couple of NIST numbers like some other manufacturers and then sock you with a high fee if you require a proper calibration. We are the laboratory of choice for many of our customers because they know that they can depend on us for correct, complete, and on-time calibrations at reasonable prices.

New European Lab!

In 2003, after extensive planning and a significant capital investment, Hart Scientific opened a primary temperature calibration laboratory in Europe. This new lab in Norwich, England, will service the precision temperature calibration needs of customers in Europe, the Middle East, and Africa. The UK lab uses the same great Hart fixed point cells, furnaces, baths, and thermometers used in the American Fork, Utah lab. We even have similarly excellent metrology experts in this lab. Watch for us to also have UKAS accreditation here soon, with similar uncertainties to that of Hart's American Fork, Utah lab!

Peter Crisp manages Hart's new European Primary Temperature Laboratory in Norwich, UK.

SPRT Calibration by ITS-90 Fixed Point — NVLAP Accredited

All calibrations in this section include the following: (1) calibration at two levels of current and extrapolation to zero power, (2) ITS-90 deviation function coefficients and interpolation tables for the nominal current calibration and the zero-power calibration in W vs. T_{90}, and (3) analysis for compliance to ITS-90 criteria for a standard interpolating instrument of the ITS-90. This represents our best measurement capability(BMC) for SPRTs. Recommended when you absolutely must have the best uncertainty possible. Only Excellent SPRTs qualify.

Order No.	Temperature	ITS-90 Subranges	Fixed Points Used
1910-4-7	–200°C to 660°C	4, 7	comp at NBPLN2, TPHg, TPW, FPSn, FPZn, FPAl
1910-4-8	–200°C to 420°C	4, 8	comp at NBPLN2, TPHg, TPW, FPSn, FPZn
1910-4-9	–200°C to 232°C	4, 9	comp at NBPLN2, TPHg, TPW, FPIn, FPSn
1910-5-7	–40°C to 660°C	5, 7	TPHg, TPW, MPGa, FPSn, FPZn, FPAl
1910-5-10	–40°C to 157°C	5, 10	TPHg, TPW, MPGa, FPIn
1910-7	0°C to 660°C	7	TPW, FPSn, FPZn, FPAl
1910-8	0°C to 420°C	8	TPW, FPSn, FPZn

Temperature	Uncertainty
–197°C (LN_2)	0.6 mK
–38.8344°C (TPHg)	0.4 mK
0.010°C (TPW)	0.2 mK
29.7646°C (MPGa)	0.4 mK
156.599°C (FPIn)	0.9 mK
231.928°C (FPSn)	0.9 mK
419.527°C (FPZn)	1.1 mK
660.323 °C (FPAl)	2.1mK
961.78°C (FPAg)	10.0 mK

SPRT Calibration by ITS-90 Fixed Point — NVLAP Accredited

All calibrations in this section include the following: (1) calibration at two levels of current and extrapolation to zero power, (2) ITS-90 deviation function coefficients and interpolation tables for the nominal current calibration and the zero-power calibration W vs. T90, and (3) analysis for compliance to ITS-90 criteria for a standard interpolating instrument of the ITS-90. Recommended for working standard SPRTs, when slightly larger uncertainties are acceptable.

Order No.	Temperature	ITS-90 Subranges	Fixed Points Used
1911-4-7	–200°C to 660°C	4, 7	comp at NBPLN2, TPHg, TPW, FPSn, FPZn, FPAl
1911-4-8	–200°C to 420°C	4, 8	comp at NBPLN2, TPHg, TPW, FPSn, FPZn
1911-4-9	–200°C to 232°C	4, 9	comp at NBPLN2, TPHg, TPW, FPIn, FPSn
1911-5-7	–40°C to 660°C	5, 7	TPHg, TPW, MPGa, FPSn, FPZn, FPAl
1911-5-10	–40°C to 157°C	5, 10	TPHg, TPW, MPGa, FPIn
1911-7	0°C to 660°C	7	TPW, FPSn, FPZn, FPAl
1911-8	0°C to 420°C	8	TPW, FPSn, FPZn

Temperature	Uncertainty
–197 °C (LN2)	1.0 mK
–38.8344 °C (TPHg)	0.8 mK
0.010 °C (TPW)	0.5 mK
29.7646 °C (MPGa)	0.8 mK
156.599 °C (FPIn)	1.5 mK
231.928 °C (FPSn)	1.5 mK
419.527 °C (FPZn)	1.8 mK
660.323 °C (FPAl)	3.0 mK

SPRT Calibration by ITS-90 Fixed Point — NVLAP Accredited

All calibrations in this section include the following: (1) ITS-90 deviation function coefficients and interpolation table for the nominal current calibration W vs. T90, and (2) analysis for compliance to ITS-90 criteria for a standard interpolating instrument of the ITS-90. This larger uncertainty SPRT calibration is still better than most offered in the industry, and is easier on the wallet. Recommended for any SPRT.

Order No.	Temperature	ITS-90 Subranges	Fixed Points Used
1912-4-7	–200°C to 660°C	4, 7	comp at NBPLN2, TPHg, TPW, FPSn, FPZn, FPAl
1912-4-8	–200°C to 420°C	4, 8	comp at NBPLN2, TPHg, TPW, FPSn, FPZn
1912-4-9	–200°C to 232°C	4, 9	comp at NBPLN2, TPHg, TPW, FPIn, FPSn
1912-5-8	–40°C to 420°C	5, 8	TPHg, TPW, MPGa, FPSn, FPZn
1912-5-9	–40°C to 232°C	5, 9	TPHg, TPW, MPGa, FPIn, FPSn
1912-5-10	–40°C to 157°C	5, 10	TPHg, TPW, MPGa, FPIn
1912-7	0°C to 660°C	7	TPW, FPSn, FPZn, FPAl
1912-8	0°C to 420°C	8	TPW, FPSn, FPZn

Temperature	Uncertainty
–197°C (LN2)	2.0 mK
–38.8344°C (TPHg)	2.0 mK
0.010°C (TPW)	2.0 mK
29.7646°C (MPGa)	2.0 mK
156.599°C (FPIn)	3.0 mK
231.928°C (FPSn)	4.0 mK
419.527°C (FPZn)	6.0 mK
660.323°C (FPAl)	8.0 mK

Precision PRT Calibration by ITS-90 Fixed Point — NVLAP Accredited

All calibrations in this section include the following: (1) ITS-90 deviation function coefficients and interpolation tables for the nominal current calibration in resistance vs. T90. Recommended for high quality, secondary standard PRTs only. Hart models 5626, 5628, and 5614 qualify.

Order No.	Temperature	ITS-90 Subranges	Fixed Points Used
1913-4-7	–200°C to 660°C	4, 7	comp at NBPLN2, TPHg, TPW, FPSn, FPZn, FPAl
1913-4-8	–200°C to 420°C	4, 8	comp at NBPLN2, TPHg, TPW, FPSn, FPZn
1913-4-9	–200°C to 232°C	4, 9	comp at NBPLN2, TPHg, TPW, FPIn, FPSn
1913-5-8	–40°C to 420°C	5, 8	TPHg, TPW, FPSn, FPZn
1913-5-9	–40°C to 232°C	5, 9	TPHg, TPW, FPIn, FPSn
1913-7	0°C to 660°C	7	TPW, FPSn, FPZn, FPAl
1913-8	0°C to 420°C	8	TPW, FPSn, FPZn,

Temperature	Uncertainty
–197 °C (LN2)	6.0 mK
–100 °C	10.0 mK
–38.8344 °C (TPHg)	6.0 mK
0.010 °C (TPW)	4.0 mK
156.599 °C (FPIn)	6.0 mK
231.928 °C (FPSn)	6.0 mK
419.527 °C (FPZn)	9.0 mK
660.323 °C (FPAl)	14.0 mK

CALIBRATION SERVICES

Precision PRT Calibration by Comparison — NVLAP Accredited

All calibrations in this section include the following: (1) ITS-90 deviation function coefficients, and (2) interpolation table in 1-degree increments in terms of resistance vs. T90. Recommended for high quality, secondary standard PRTs, where higher uncertainty is acceptable. Hart models 5626, 5628, 5612, 5613, and 5614 qualify.

Order No.	Temperature	Comparison Points Used
1922-4-R	–200°C to 660°C	–197.0°C, –38.8°C, 0.01°C, 231.9°C, 419.5°C, 500°C
1922-4-8	–200°C to 420°C	–197.0°C, –38.8°C, 0.01°C, 231.9°C, 419.5°C
1922-D-R	–100°C to 660°C	–100.0°C, –38.8°C, 0.01°C, 231.9°C, 419.5°C, 500°C
1922-D-8	–100°C to 420°C	–100.0°C, –38.8°C, 0.01°C, 231.9°C, 419.5°C
1922-5-8	–40°C to 420°C	–38.8°C, 0.01°C, 231.9°C, 419.5°C
1922-5-9	–40°C to 232°C	–38.8°C, 0.01°C, 156.6°C, 231.9°C
1922-R	0°C to 660°C	0.01°C, 231.9°C, 419.5°C, 500°C
1922-8	0°C to 420°C	0.01°C, 231.9°C, 419.5°C

Temperature	Uncertainty
–200°C	10 mK
–100 to –50°C	10 mK
–50 to 0°C	8 mK
0.010°C	6 mK
0 to 200°C	9 mK
200 to 300°C	12 mK
300 to 400°C	14 mK
400 to 550°C	16 mK

PRT (RTD) Calibration by Comparison — NVLAP Accredited

All calibrations in this section include the following: (1) fitted results with an appropriate equation and (2) interpolation table in 1-degree increments in terms of resistance vs. T90. Recommended for all industrial level PRT (RTD) probes. Hart models 5627, 5622, and 5618A qualify.

Order No.	Temperature	Comparison Points Used
1923-4-R	–200°C to 660°C	–197.0°C, –100.0°C, –38.8°C, 0.01°C, 156.6°C, 231.9°C, 419.5°C, 500°C
1923-4-8	–200°C to 420°C	–197.0°C, –100.0°C, –38.8°C, 0.01°C, 156.6°C, 231.9°C, 419.5°C
1923-4-N	–200°C to 300°C	–197.0°C, –100.0°C, –38.8°C, 0.01°C, 156.6°C, 231.9°C, 300°C
1923-4-9	–200°C to 232°C	–197.0°C, –100.0°C, –38.8°C, 0.01°C, 156.6°C, 231.9°C
1923-D-8	–100°C to 420°C	–100.0°C, –38.8°C, 0.01°C, 156.6°C, 231.9°C, 419.5°C
1923-D-N	–100°C to 300°C	–100.0°C, –38.8°C, 0.01°C, 156.6°C, 231.9°C, 300°C
1923-D-9	–100°C to 232°C	–100.0°C, –38.8°C, 0.01°C, 156.6°C, 231.9°C
1923-5-8	–40°C to 420°C	–38.8°C, 0.01°C, 156.6°C, 231.9°C, 419.5°C
1923-5-N	–40°C to 300°C	–38.8°C, 0.01°C, 156.6°C, 231.9°C, 300°C
1923-5-9	–40°C to 232°C	–38.8°C, 0.01°C, 156.6°C, 231.9°C
1923-N	0°C to 300°C	0.01°C, 156.6°C, 231.9°C, 300°C
1923-9	0°C to 232°C	0.01°C, 156.6°C, 231.9°C
1923-10	0°C to 157°C	0.01°C, 100°C, 156.6°C

Temperature	Uncertainty
–200 °C	25 mK
–100 to –50 °C	25 mK
–50 to 0 °C	25 mK
0.010 °C	10 mK
0 to 200 °C	25 mK
200 to 300 °C	25 mK
300 to 400 °C	40 mK
400 to 550 °C	50 mK

Precision Thermistor Calibration by Comparison — NVLAP Accredited

All calibrations in this section include the following: (1) polynomial solution with coefficients in Steinhart-Hart or third order, and (2) bound interpolation table in 0.01- or 0.1-degree increments (depending upon span of calibration) in terms of resistance vs. T90. Order the 1925-A for secondary thermistors with 100°C range, like the Hart 5610 & 5611 probes. The 1925-B&C calibrations are recommended for very high accuracy thermistor standards like the Hart 5640-44 series probes.

Order No.	Temperature	Comparison Points Used	Uncertainty (k=2)
1925-A	100°C span	6 points over span	10 mK
1925-B	60°C span	7 points over span	1.5 mK
1925-C	100°C span	11 points over span	2.5 mK
1925-D	10°C span	4 points over span	<10 mK

Noble-Metal Thermocouple Calibration by ITS-90 Fixed Point — NVLAP Accredited

All calibrations in this section include the following: (1) ITS-90 polynomial coefficients in accordance with NIST Monograph 175, and (2) bound interpolation table in 1-degree increments in terms of EMF vs. T90. Recommended for high quality thermocouple standards. Order 1918-A for Au/Pt thermocouple standards, 1918-B for Type S and Type R standards.

Order No.	Temperature	Fixed Points Used	Uncertainty (k=2)	Extrapolated Uncertainty (k=2)
1918-A	0°C to 1000°C	FPSn, FPZn, FPAl, FPAg (Gold/pt)	0.02°C	0.025°C
1918-B	0°C to 1450°C	FPSn, FPZn, FPAl, FPAg (Type S–R)	0.15°C	2°C

Requirements for thermocouples: Must have very clean, unbroken (even uncracked) sheaths, have at least 20" long sheath length, and have at least 36" lead length. Please call our customer service department for clarification if needed.

Precision Digital Thermometer System Calibration by Comparison — NVLAP Accredited

All calibrations in this section include as-found data, as-left system data, and adjustments. Systems are calibrated as systems and not as individual components (probe and readout). Uncertainties are similar to those listed on the opposite page, depending on the system being calibrated. Consult Hart's customer service group for temperature ranges not listed here. An additional fee is charged for non-standard temperature points requested.

Order No.	Temperature	Comparison Points Used
1930-4-R	–200°C to 500°C	–197.0°C, –38.8°C, 0.01°C, 231.9°C, 419.5°C, 500.0°C
1930-4-8	–200°C to 420°C	–197.0°C, –38.8°C, 0.01°C, 231.9°C, 419.5°C
1930-D-8	–100°C to 420°C	–100.0°C, –38.8°C, 0.01°C, 231.9°C, 419.5°C
1930-5-8	–40°C to 420°C	–38.8°C, 0.01°C, 231.9°C, 419.5°C
1930-5-9	–40°C to 232°C	–38.8°C, 0.01°C, 156.6°C, 231.9°C
1930-8	0°C to 420°C	0.01°C, 231.9°C, 419.5°C
1935-A	100°C span	6 points over span
1935-B	60°C span	7 points over span
1935-C	100°C span	11 points over span

Fixed Point Cell Direct Comparison — NVLAP Accredited

Comparison to a Hart working standard fixed-point cell. A comprehensive calibration report is included. (For Best Measurement Capability comparisons, please call Hart.)

Order No.	ITS-90 Fixed Point Cell	Uncertainty (k=2)
1904-Hg	TPHg	0.25mK
1904-Tpw	TPW	0.10mK
1904-Ga	MPGa	0.10mK
1904-In	FPIn	0.70mK
1904-Sn	FPSn	0.80mK
1904-Zn	FPZn	1.00mK
1904-Al	FPAl	1.80mK
1904-Ag	FPAg	4.50mK

DC Resistance Calibration — NVLAP Accredited

Your DC resistors are compared to Hart's standard resistors. A comprehensive calibration report is included.

Order No.	Resistance Range	Uncertainty (k=2)
1960	1 - 10 Ohm	0.35 ppm
1960	10 - 100 Ohm	0.45 ppm
1960	100 - 1000 Ohm	0.60 ppm
1960	1000 - 10000 Ohm	0.70 ppm

Humidity Sensor Calibration

All calibrations in this section are traceable to NIST and include certificates compliant with ANSI/NCSL Z540-1 and ISO Guide 17025. As-found data, as-left data, and adjustments are included.

Order No.	Temp. Points	RH Points
1980-A	1	3
1980-B	1	5
1980-C	3	5
1980-D	5	5

Instrument Calibration

For recalibration of Hart Scientific thermometer readouts and dry-wells please call Hart Customer service. If you are calling from within the USA, please call toll free (800) 438-4278 or (888) 538-4278. If you are calling from outside of the USA please call (801) 763-1600. Calibration of Hart thermometer readouts fall within Hart's scope of accreditation.

Technical Tip

ISO 17025 Triggers Changes in Calibration Interval Management

The ISO 17025 views calibration interval management as the responsibility of the customer rather than the calibration supplier. As a result, when you contact us to arrange for recalibration of your instruments, our customer service representative will ask you what interval you wish to set. If no interval is selected, the calibration report will show the due date as "Not Defined."

In the case of new instruments, we will set the initial interval based on manufacturer's recommendations (including our own if Hart is the manufacturer) unless we are instructed otherwise. Remember, although manufacturers may provide advice regarding calibration intervals, cal labs accredited under ISO 17025 may not. You have the choice and responsibility to determine the calibration cycle for your instruments.

Technical Tip

Should I Get a "System" Cal?

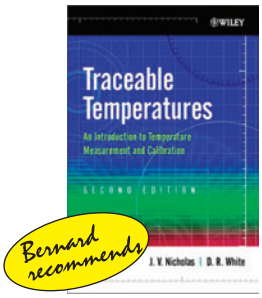
Traditionally, readouts and probes are calibrated individually. This is generally best because the instruments are specified individually, traceability is straightforward, and it permits interchangeability.

However, in some circumstances system calibrations can prove beneficial. For example, if the probe and readout are "married" and are both stable performers, it is often faster and cheaper to have them calibrated as a system rather than individually. As-found data is obtained in temperature units and traceability is established through the system. As long as interchangeability is not required, this approach can prove beneficial when used judiciously.

PUBLICATIONS

Have you read a good book lately? Would you like something to relax with after work? We've got a few books for you that will answer your most demanding questions, whether you need to be introduced to temperature metrology or you're ready to challenge its deepest theories.

Don't let other calibration professionals get ahead of you, and don't wait until the movie comes out—read these books now! If you aren't going to read any of these, you need them on your bookshelf so everybody will think you read them. There's no better way to make others think you're ahead of the game. And yes, we take VISA!



Traceable Temperatures: An Introduction to Temperature Measurement and Calibration

J. V. Nicholas and D. R. White; John Wiley & Sons, 2nd Edition, 2001, 400 pages.

Order No. 9393-008

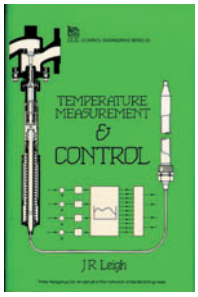
This book is a 1994 edition written by two New Zealand metrologists. It covers traceability, uncertainties, the temperature scale, calibration, PRTs, LIGs, thermocouples, and radiation. While easy to read, this book is thorough and contains many small bits of information that are useful. If you're learning calibration for the first time or refreshing your memory, *Traceable Temperatures* will work for you.

Temperature Measurement

Bela G. Laptak, editor; Chilton Book Company, 1993, 131 pages.

Order No. 9393-003

The chapters in this book were provided by a number of authors and edited by Laptak. This is basically an entry-level text that covers basic theory without rigorous math. It's suitable for industrial technicians and managers needing a solid but elementary understanding of different devices for temperature measurement.

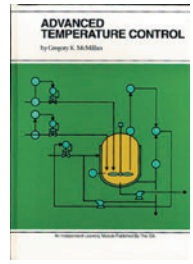


Temperature Measurement and Control

J. R. Leigh; IEE Control Engineering Series 33, 1988, 189 pages.

Order No. 9393-009

This book has several elementary chapters on temperature, thermocouples, thermistors, and other common industrial sensor types. It also looks at heat sources and gives basic information on the differences and uses of heat sources. Half of the text is devoted to temperature control thermometry and tends to be more in-depth than the other chapters.

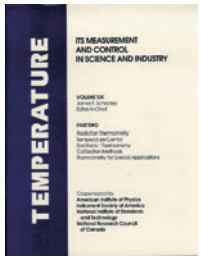


Advanced Temperature Control

Gregory K. McMillan; Instrument Society of America, 1995, 218 pages.

Order No. 9393-012

If you're looking for elementary information in process control involving temperature, this book has it. It explains the basics on measurement, temperature loop analysis, controllers, exchangers, and reactors. The book is easy to read and has reasonable illustrations, along with the elementary math of temperature control systems. While it does not discuss sensor types or techniques, it does help illustrate the use and purposes of sensors in a temperature control environment.



Temperature: Its Measurement and Control in Science and Industry

James F. Schooley, editor; American Institute of Physics, 1993, Volume 6, Parts 1 and 2, 1269 pages.

Order No. 9393-001 2-Volume Set

This two-part set is made of many in-depth papers written at the expert level. Part 1 covers thermodynamic temperature determinants, temperature scales, fixed points, resistance thermometry, and thermocouples. Part 2 covers radiation thermometry, temperature control, electronic thermometry, and calibration methods.

Techniques for Approximating the International Temperature Scale of 1990

Published by the Bureau International des Poids et Mesures, July 1990, 205 pages, reprinted 1997.

Order No. 9393-004

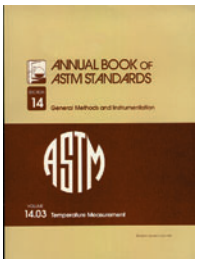
Maybe you've heard of the Blue and Red Books. This is the Blue Book. It's a simple, practical guide to producing accurate measurements that comply with ITS-90. The key word is *approximating*. Most labs don't need to reach the absolute highest levels of accuracy defined and directed by ITS-90. A more modest level of uncertainty is acceptable if ITS-90 compliance is met. This monograph shows you how to do that.

Supplementary Information for the International Temperature Scale of 1990

Published by the Bureau International des Poids et Mesures, December 1990, 185 pages, reprinted 1997.

Order No. 9393-005

This is the Red Book. It supplies all of the Blue Book's supplemental information you need to reach the maximum levels of ITS-90 calibrations. It covers fixed points, platinum resistance thermometry, gas thermometry, and radiation thermometry.

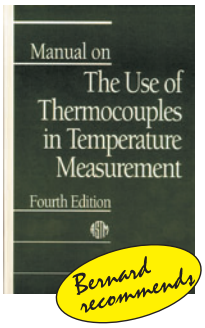


Annual Book of ASTM Standards

Vol. 14.03, Sec. 14 Temperature Measurement, ASTM, 570 pages.

Order No. 9393-013

The *Annual Book of ASTM Standards* consists of 72 volumes divided among 16 sections. This one is volume 14.03, *Temperature Measurement.* While this book may not be the first book on temperature measurement, it's really, really close. There are too many tables and too many papers to list. What else needs to be said? Join the club and get your copy today.



Manual on the Use of Thermocouples in Temperature Measurement

PCN 28-012093-40, ASTM Manual 12, fourth edition, 1993, 290 pages.

Order No. 9393-010

If you want to know about thermocouples, you'll find it in this book. It's sponsored by the ASTM Committee E-20 on temperature measurement. It covers thermocouples from A to Z. In addition to theoretical information, it covers temperature uncertainty and supplies a number of reference tables for key thermocouple information.

Guidelines for Realizing the International Temperature Scale of 1990 (ITS-90), NIST Technical Note 1265

B. W. Mangum and G. T. Furukawa; NIST, 1990, 176 pages.

Order No. 9399

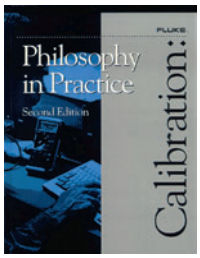
This publication includes, in detail, everything you need to know about the ITS-90. From 0.65 K upward, the authors explain how to realize the scale and offer measurement procedures for all the various subranges within the scale. For the portion of the scale relating to platinum resistance thermometers, computational examples are included for determining thermometer coefficients. If you're serious about realizing points within the ITS-90, this technical note is a must.

ISO/IEC 17025, 1999, General Requirements for the Competence of Testing and Calibration Laboratories

Order No. 9399-015

A must have! The new 17025 Standard is now required by worldwide accreditation bodies. It replaces the ISO Guide 25. Your lab's calibration certificates will be more widely accepted when you adopt the 17025 standard.

The ISO/IEC 17025 covers both technical competence and the operation of a quality management system (ISO 9001, 9002).

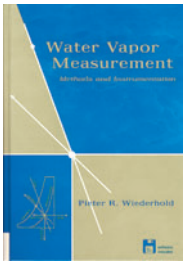


Calibration: Philosophy in Practice

Second Edition, Fluke Corporation, 1994.

Order No. 9393-002

This is not a temperature calibration book. It primarily discusses DC and low-frequency measurements, and it describes primary and secondary standards as they apply to electrical measurements. The book also has chapters on lab management. While there's no discussion of temperature calibration, the chapters on DC ratios and AC lore might be interesting to metrologists working with resistance bridges. However, these chapters are not for beginners.

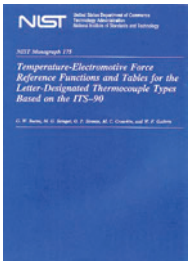


Water Vapor Measurement: Methods and Instrumentation

Pieter R. Wiederhold; Marcel Dekker, 1997, 357 pages.

Order No. 9393-017

Recommended by Thunder Scientific and including a floppy disk with General Eastern's Humidity Units Conversion Program, this text is well organized, well illustrated, and an excellent read. It discusses all aspects of humidity measurement and instrumentation, including rudiments and theory, common applications, advantages and limitations of frequently used sensors and techniques, and guidelines for installation, maintenance, and calibration. A must-read if you're new to humidity calibrations!

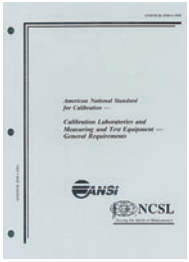


Temperature-Electromotive Force Reference Functions and Tables for the Letter-Designated Thermocouple Types Based on the ITS-90, NIST Monograph 175

G. W. Burns, M. G. Scroger, and G. F. Strouse; NIST 1993, 630 pages.

Order No. 9399-002

If you work with thermocouples, you rely on published reference functions and temperature-EMF tables. Are you using the right ones? When the International Temperature Scale of 1990 and the new representation of the volt came into effect in 1990, it became necessary to restate all thermocouple reference functions and tables to match the new definitions.



ANSI/NCSL Z540 (three-volume set)

Published by the National Conference of Standards Laboratories, 214 pages.

Order No. 9399-003

This three-volume set is an absolute must. Based on ISO Guide 25 and only 13 pages long, the Z540-1, *Calibration Laboratories and Measuring and Test Equipment—General Requirements,* establishes quality standards for calibration labs. The accompanying *Handbook for the Interpretation and Application of Z540-1* is an invaluable companion text. And the Z540-2, *U.S. Guide to the Expression of Uncertainty in Measurement,* explains all the rules for evaluating uncertainties.

GUIDELINES FOR HART PRODUCT SPECIFICATIONS

Not all manufacturers list the same specifications for similar products. Worse, not all manufacturers mean the same thing when they do. To help explain our specs, we offer the following guidelines. (Since these are "guidelines" and not complete explanations, please contact us if you'd like any additional explanation.)

Thermometer Probes

Calibration Uncertainty - This is the uncertainty with which a thermometer was calibrated and does not include all aspects of a thermometer's performance. This specification can sometimes be improved by limiting the calibration of the thermometer to a narrower range or by calibrating it with fixed-point devices.

Stability or Repeatability - Many thermometers include a stability spec separate from calibration uncertainty and long-term drift. This value includes all the uncertainties other than calibration uncertainty and long-term drift.

Probe Accuracy - For some probes, calibration uncertainty and short-term stability have been combined. This is the uncertainty of the thermometer without considering long-term drift effects.

Drift Rate - With use, particularly at high temperatures, resistance thermometers drift. Oxidation and handling are two of the biggest causes. Some drift effects can be reversed through annealing. Drift specs are usually limited by a given amount of time at high temperatures. With proper handling and less exposure to extreme temperatures, drift can be much less than the specification.

Immersion - The immersion requirement of a thermometer is difficult to state. The requirement changes with the medium in which the thermometer is immersed, the amount of thermal contact with the medium, and the difference between the medium's temperature and ambient temperature. Our specifications are therefore general guidelines assuming use in a typical fluid bath or in a dry-well with excellent thermal contact in typical ambient conditions.

Thermometer Readouts

Temperature Range - Because thermometer readouts are really ohm- or voltmeters, their "temperature" range is limited to their resistance or voltage range. The temperature ranges provided are guidelines. In most cases, the temperature range of the probe becomes the real limiting factor.

Resistance (Voltage) Accuracy - The "accuracy" of a readout is best stated by the accuracy with which it reads resistance or voltage. This is because all measurements are made in resistance or voltage and then translated into temperature using a user-selected conversion method. (The conversion algorithms in Hart readouts have been validated; no significant errors result from the mathematics in the conversion.) Readouts typically have different accuracies for different resistance or voltage ranges. The temperature and type of probe being used must be considered when computing the accuracy of the readout. Our spec is for one year, based on a rectangular probability distribution.

Temperature Accuracy - These numbers are guidelines only and do not include the accuracy of the probe. Because readouts do not measure temperature directly, their true accuracy can only be stated in terms of resistance or voltage. To determine temperature accuracy, the type and temperature of the probe must be considered.

Operating Temperature Range - The accuracy of a resistance device depends on ambient temperatures. Accuracy specifications assume the unit is within its operating temperature range. A readout operating in the center of this range is more accurate than one operating on the edge, but both will meet the given specifications. Readouts will function outside the range but with less accuracy.

Baths

Stability - All stability numbers are "2-sigma" figures. This means that two times the standard deviation of a bath's temperature (over at least 30 minutes) will fall within the stated specification. Because bath stability varies with temperature and the fluid being used, these variables are also specified.

Uniformity - This is defined as the largest two-minute-average temperature difference found between two locations within the bath's working area (which is defined as 1 inch from the bottom and sides of the bath and 3 inches below the fluid's surface). Limiting work to an even smaller area can further reduce the temperature differences experienced during calibration. Uniformity is heavily dependent on the fluid being used. Our specs reference fluids that might commonly be used at the temperatures in question.

Digital Setting Accuracy - The control probes used in fluid baths are not calibrated and are accurate to 0.5°C or 1.0°C. (External references are preferred for determining a bath's temperature.) Most baths, however, include set-point resolution to less than 0.001°C.

Dry-Wells

Accuracy - The control sensors—and therefore the displays—of industrial calibrators are calibrated using a calibrated reference thermometer. Reliance on this accuracy depends on using the calibrator in a similar fashion to how it was calibrated—using 1/4" (in most cases) probes inserted snugly to the bottom of the well.

Stability - Stability numbers are "2-sigma" figures. This means that two times the standard deviation of a dry-well's temperature (over at least 30 minutes) will fall within the specification.

Well-to-Well Uniformity - This is the maximum temperature difference between two wells, assuming probes of similar size (less than 1/4") and construction are inserted to the full immersion depth of the dry-well.

Certificates and Reports

Calibrated thermometer probes come with a report of calibration including data at various temperatures, depending on the instrument. Whether or not the report of calibration comes from Hart (and was therefore an accredited calibration under Hart's NVLAP scope) or from the thermometer's manufacturer (and therefore may not have been an accredited cal) depends on the model of the probe and whether it is being purchased new or being sent to Hart for recalibration. Consult this catalog, and if you have remaining questions, contact Hart's service group.

All Hart thermometer readouts, whether new instruments or recalibrated instruments, come with a Hart NVLAP report of calibration with data at a number of resistance or millivolt values, depending on the instrument. All Hart dry-wells and Micro-Baths, new or recalibrated, come with a Hart report of calibration that does not fall within Hart's NVLAP scope and includes data at a number of temperatures, depending on the instrument. All Hart fluid baths come with a report of test that does not fall within Hart's NVLAP scope and includes stability data.

HOW TO ORDER (800) 438-4278

Contacting Hart

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Outside the U.S., please contact your local representative. If you're not sure who that is, contact us directly (see list above) and we'll be happy to point you in the right direction.

Application Assistance

We know how to measure temperature and we know how to calibrate thermometers, so put our knowledge to work for you! Call us, email us, fax us… whatever. No matter how strange your application, our applications specialists are ready to discuss your needs and provide recommendations.

Pricing, Delivery, and Quotes

Current price lists are available on request. Depending on the product, you should allow anywhere from one week to 90 days for delivery. Custom orders may take longer. Your local distributor (outside the U.S.) or our Applications Specialists in American Fork can provide quotes with pricing and delivery for specific requests.

Specifications

We reserve the right to change any specification published in this catalog without notice. Since the catalog is published at infrequent intervals, these changes are reflected in current product user manuals. All products will conform to specifications effective at the time of order.

Purchase Orders

We require written purchase orders prior to shipment, but can schedule production for some items as soon as we have a PO number. Note: due to ISO/IEC Guide 17025 requirements, we do not begin any calibration that falls within the scope of our NVLAP accreditation without a written PO in hand, which we can review in its entirety. Please mail, email, or fax your PO to the above address or number.

Shipping

We quote and ship F.O.B. American Fork, Utah, so shipping charges are prepaid by us and added to your invoice. We also use the carrier of our choice, which may be UPS, Fed Ex, an air express carrier, or anyone else we believe handles our product well. If you wish to specify a carrier or wish to have the shipping charges billed direct to you through your carrier, that's fine—just send us all the appropriate information before we ship.

Some fixed-point cells must be hand-carried and cannot be shipped. You may pick these up yourself or we will deliver them and bill you for the cost of delivery. These arrangements need to be made at the time of ordering.

Along with shipping charges, we prepay and add insurance unless you specifically request us not to—but then you accept all risk of shipping damage. (When Hart is paying for shipping charges and not billing the customer—such as for in-warranty service returns—we self-insure against shipping damage.)

Items returned to Hart from outside the U.S. for service should not be subject to import duties when we return them to you—provided you returned them to us correctly. Consequently, if we are billed for duties, we will pass the charge through to you.

Warranty

All products are warranted for parts and labor for one year, except where longer warranties are indicated by our warranty symbols:

Please be careful with your temperature instruments. Metal-sheathed thermometers can be as susceptible to mechanical shock as are quartz-sheathed thermometers. And even dry-wells, which include embedded control PRTs, are susceptible to mechanical shock. It doesn't have to look damaged to be damaged.

Here's what our warranty does not include. We don't include consequential damage or damage from abuse, misuse, or neglect. We don't include shipping charges (except the cost of returning a warranty to you). And we don't warrant calibrations once an instrument has left our control. Remember—particularly with thermometers!—we warrant parts and labor. We do not warrant calibrations.

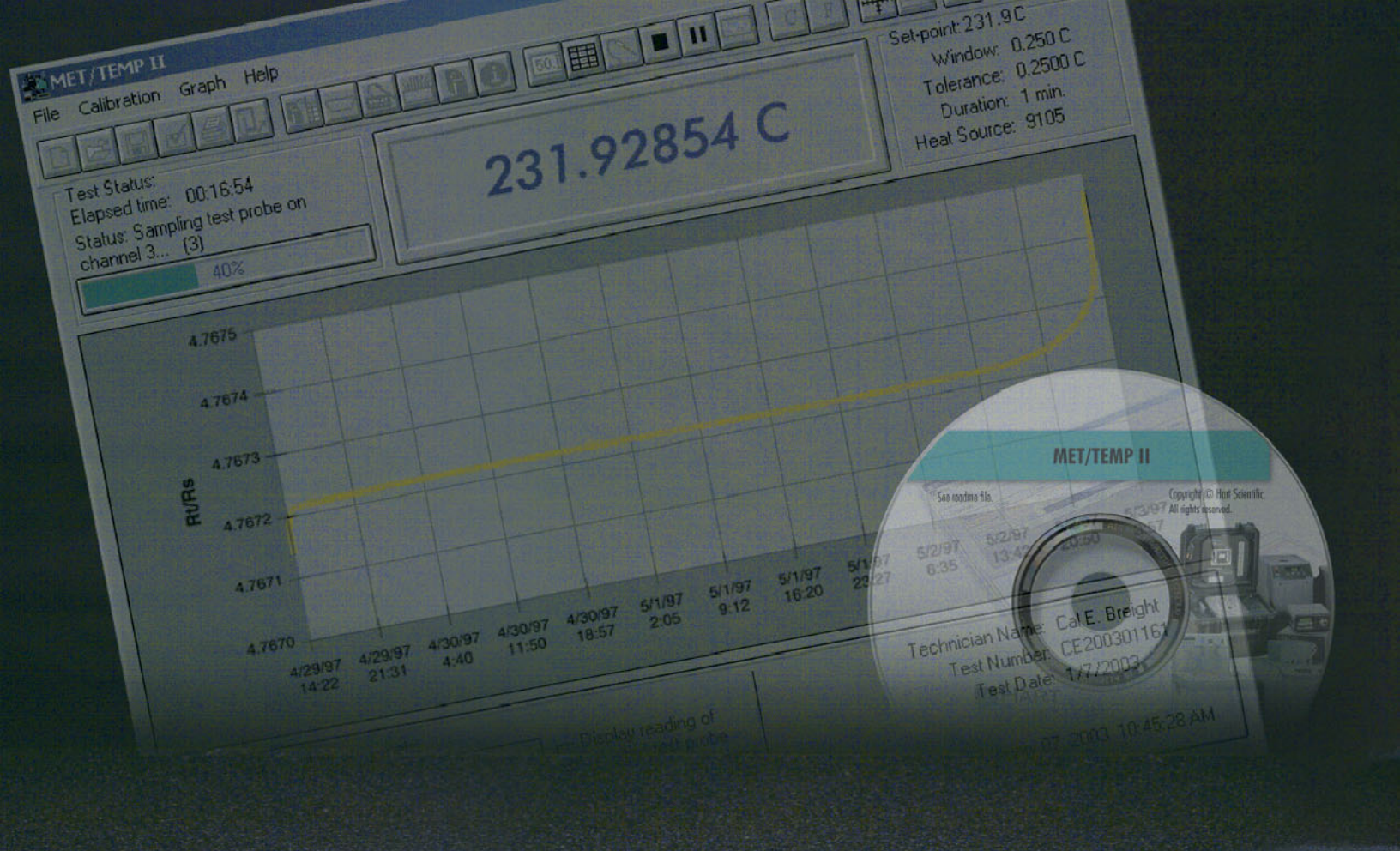
HART SERVICE

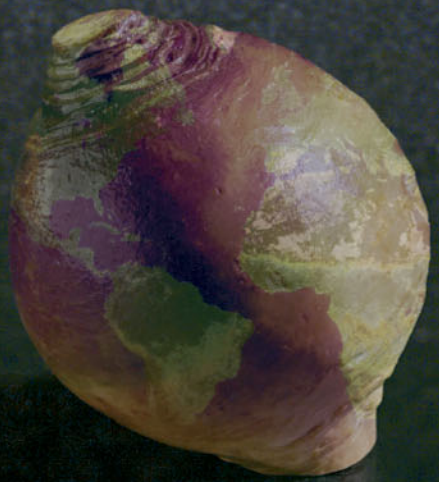
There are three requirements for working in Hart's service organization. First, you have to be technically competent and have a thorough understanding of Hart products, how they work, and the applications they're used in. Second, you have to be exceptionally reasonable and have a sense of fairness. And third, you have to be a customer champion (without violating point #2).

Our simple "policy" of treating people fairly, admitting when we've erred, and always maintaining the highest integrity is what guides us. I hope this is what you experience when you deal with Hart Scientific. (And if you feel otherwise, don't hesitate to let us know. You can reach me at chris.juchau@hartscientific.com, and you can reach our worldwide service manager at bryan.cowley@hartscientific.com.)

If you need calibration or repair services—or just have questions about how to use your Hart products—don't hesitate to contact us. We can be reached at (800) 438-4278 (in the U.S.), (801) 763-1600 (from anywhere), support@hartscientific.com, or by fax at (801) 763-1010.

For those of you outside the U.S., we are bringing this world-class service to you. We have established Hart service centers in Europe (one in Eindhoven, Netherlands, and one in Norwich, UK), in Singapore, and in China. We are also working on more extensive training for local service desks. Your local Hart representative will have more information on who in your region you should contact for Hart service. You are also welcome to contact us directly (see above) and we'll get you to the right people.





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