Hart Scientific's UKAS-Accredited European Primary Temperature Laboratory

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When Hart Scientific became a Fluke company in 2001, it gained immediate opportunities and abilities to better reach and serve its customers overseas. Offices around the world became staffed with technical experts, and Hart service centers were established in multiple countries in both Europe and Asia. Perhaps the most exciting opportunity was the chance to establish a world-class commercial temperature calibration laboratory in Norwich, England.

The city of Norwich is the home of Fluke's United Kingdom operations (formerly Wavetek and Datron) and a Fluke center of excellence for electrical metrology. (By the way, the first thing we had to learn was that the "w" *in Norwich is silent* — not to mention "laboratory" is pronounced "la-BOR-a-tree"!) In addition to providing technical consulting through local sales offices and instrument repair and recalibration services through local service centers, the Norwich facility presented an opportunity to provide European customers with the same exceptional level of temperature calibration services provided by Hart's U.S. laboratories in Utah.

Building a world-class temperature metrology laboratory, however, is no small task. It takes success with each of the "Four P's"— people, process, products (equipment), and place (environment). Hart's Norwich lab opened for business in June of 2003 and became accredited by the United Kingdom Accreditation Service (UKAS) four months later. This is the story of how Hart and Fluke were able to combine all the necessary ingredients to create what we believe to be the finest commercial temperature laboratory in Europe (outside of Europe's various national laboratories).

The Need

The need for low-uncertainty, accredited temperature calibration services is already well established, but it continues to grow. Temperature has long been the most measured physical parameter throughout process industries, but thermometer users in general are still developing their awareness and understanding of the errors inherent in most thermometry applications. While many ISO-driven quality systems (historically a major driver of metrology demand) are reaching maturity, users themselves are driving the need for precise temperature calibrations as they come to appreciate the costs associated with thermometry errors.

Lab manager Peter Crisp removes an SPRT from a Hart 9117 Annealing Furnace.

Likewise, process quality technicians are increasingly recognizing the need to calibrate temperature sensors and not just the electronics used to read them. This explains, in part, why demand for temperature calibration products and services has continued to grow, despite the recent recessions in the U.S. and elsewhere.

Beyond the general growth of temperature metrology, Hart's European customers have sought the low-uncertainty, accredited calibrations available to them through Hart's Utah laboratory. Through the new Norwich lab, Hart is able to serve a rapidly increasing customer base with similar (in some cases better) uncertainties and with a European accreditation (UKAS) without requiring the time it takes to send product "across the pond."

Marrying Electrical and Temperature Metrology

Norwich, in many ways, is the perfect place to establish a world-class temperature laboratory. Most importantly, it is already a world-class electrical metrology center. Is there overlap between electrical and temperature metrology? Absolutely! Aside from a simple (but somewhat true) generalization that "metrology is metrology," temperature measurements at the SPRT level really consist of low-resistance, low-noise electrical measurements at low currents. Any reduction of electrical noise improves the uncertainty of the temperature measurements. The bridge being used for SPRT measurements in Norwich, a Measurements International (MI) automated DC current-reversing model 6010, achieves standard errors as low as 0.001 ppm.

The People

Peter Crisp, manager and designer of the Norwich lab, has more than 25 years of experience in electrical metrology. He has designed five metrology labs both in the UK and overseas and has lectured on laboratory design. He has published extensively over his career on a wide variety of metrology subjects and enjoys an outstanding reputation throughout the metrology community. His expertise in low-noise electrical measurements has resulted in a significant reduction in the laboratory's uncertainty for SPRT calibrations.

Of course, Peter is not the first Hart metrologist to create an accredited world-class temperature laboratory. Hart's U.S. laboratory, led by Tom Wiandt, became accredited in September of 2000 and Tom played a major role in the creation of the Norwich lab. At Hart for the past eight years, Tom is Hart's Director of Metrology and has been working in temperature metrology (among other metrology disciplines) for 22 years, including seven at Southern California Edison. Some stir was created when Hart's NVLAP uncertainty schedule was first published, as the uncertainties were significantly lower than any other commercial laboratory in the world had ever had accredited (and even now continue to improve). Much of the work done to establish the Utah laboratory was directly transferable to creating the Norwich laboratory.

Both labs also relied on the work done by other expert metrologists and equipment designers. All of the standard platinum resistance thermometers (SPRTs) and fixed-point cells used in both labs (except mercury cells) were designed and manufactured by Xumo Li, Mingjian Zhao, and the primary standards team at Hart. The furnaces and baths were designed by Mike Hirst, an expert in temperature source design and founder of Hart Scientific. And the DC resistance thermometer readouts (excluding the MI bridge) were designed by Rick Walker, a 15-year veteran of low-noise readout design work at Hart.

Obviously, it takes a team of people to create the capabilities found in a lab like the one in Norwich. Even the best equipment, facilities, and processes can't ultimately succeed without experienced, highly competent metrologists who understand how those three things interact with the instruments being measured and who are able to deal with the myriad details and nuances of precision thermometry measurements.

The Processes

Because the capabilities of the Norwich lab largely mirror those of Hart's Utah lab, and because both facilities' first priority is the servicing of the same Hart thermometers, the procedures used in both labs are essentially identical.

Perhaps the most notable difference between the two labs is that they're each accredited by different bodies, the Utah lab by the U.S.'s National Voluntary Laboratory Accreditation Program (NVLAP lab code 200348) and the Norwich lab by UKAS (lab number 0775). UKAS was chosen by Norwich because of their previous experience together, the convenience of their proximity, and because of the outstanding reputation UKAS enjoys throughout Europe and around the world.

One important issue that arose during the accreditation process was traceability. To save time and money — and, more importantly, to take advantage of the low uncertainties provided by the National Institute of Standards and Technology (NIST) in the United States — all of the primary standards used in Norwich were certified either through the Utah lab or directly at NIST. This ensured very low uncertainties for the primary standards as a starting point and also proved the accuracy of the fixed-point cells being used. The triple point of water cells used in Norwich, for example, have been certified by NIST with an uncertainty of 0.05 mK (which increases to 0.07 mK after combining with the laboratory's contributions for the triple point of water measurement process).

Of course, a great deal of statistical data has been gathered on each of the standards used in support of their stated contributions toward total uncertainties.

The acceptance by UKAS of traceability to NIST was a key element of the total success of the accreditation, as was the willingness of UKAS to accept NIST "process metrology" methods of quantifying certain components of uncertainty. Process metrology relies on statistical data to accumulate and quantify uncertainties. For example, a dedicated "check standard" SPRT is used with each individual fixed-point cell to monitor plateau flatness and repeatability each time a fixed point is realized. As this data becomes adequately robust, it provides key statistical inputs (in terms of plateau flatness and reproducibility data) to the uncertainty component provided by certification of the fixed-point cells.

Traceability to NIST and recognition of NVLAP-accredited certifications from the Utah lab were largely made possible because both the U.S. and U.K. are signatories to the current ILAC (International Laboratory Accreditation Cooperation) Arrangement. The issue was discussed and agreed upon between ILAC, UKAS, the European Accreditation body (EA), and Hart Europe prior to formal assessment of the Norwich lab by UKAS.

Category	Model	Device	Qty
SPRTs	Hart 5681	25-ohm Quartz SPRT	2
	Hart 5683	25-ohm Quartz SPRT	6
	Hart 5684	0.25-ohm Quartz SPRT	1
	Hart 5698	25-ohm Metal-Cased Working Standard SPRT	1
	Hart 5699	25-ohom Extended Range Metal-Cased SPRT	2
Fixed-Point Cells	Hart 5900	Triple point of Mercury Cell	1
	Hart 5901	Triple Point of Water Cell	4
	Hart 5904	Freezing Point of Indium Cell	1
	Hart 5905	Freezing Point of Tin Cell	1
	Hart 5906	Freezing Point of Zinc Cell	1
	Hart 5907	Freezing Point of Aluminium Cell	1
	Hart 5908	Freezing Point of Silver Cell	1
	Hart 5917A	Mini Fixed-Point Aluminimum Cell	1
	Hart 5943	Melting Point of Gallium Cell	1
Maintenance Furnaces	Hart 9114	Freeze Point Furnace	4
	Hart 9115	Freeze Point Furnace (silver)	1
	Hart 9117	Annealing Furnace	1
	Hart 9230	Gallium Maintenance System	1
	Hart 9260	Mini Fixed-Point Furnace	1
Baths	Hart 6022	Hot Bath (oil)	3
	Hart 6050	Very Hot Bath (salt)	1
	Hart 6055	Deep Very Hot Bath (salt)	1
	Hart 7008	Resistor Bath	1
	Hart 7012	Cold Bath	1
	Hart 7030	Cold Thermistor Bath	1
	Hart 7037	Deep Cold Bath	1
	Hart 7060	Very Cold Bath	1
	Hart 7312	TPW Maintenance Bath	1
	Hart 7380	Compact Very Cold Bath	1
Measurement Devices	Datron 1271	Digital Multimeter	1
	Hart 1504	Tweener Thermometer	1
	Hart 1560	Blackstack Thermometer	1
	Hart 1590	Superthermometer II (1ppm)	1
	Keithley 2182	Digital Nanovoltmeter	1
	Hart 2560	SPRT Module	1
	Hart 2565	Thermocouple Module	1
	Hart 2590	Mighty-Mux II 10 Channel Scanner	1
	Fluke 2640A	NetDAQ Networked Data Acquisition Unit	1
	MI 4220A	Low Thermal Matrix Scanner	1
	MI 6010T	Automatic CC Thermometry Bridge	1
	Guildline 9145A	Low-Thermal Switch	1
Resistance Standards	Tinsley 5685A	1 Ohm Wilkins AC/DC Standard Resistor	1
	Tinsley 5685A	10 Ohm Wilkins AC/DC Standard Resistor	1
	Tinsley 5685A	25 Ohm Wilkins AC/DC Standard Resistor	1
	Tinsley 5685A	100 Ohm Wilkins AC/DC Standard Resistor	1
	Tinsley 5685B	1k Ohm Wilkins AC/DC Standard Resistor	1
	Tinsley 5685B	10k Ohm Wilkins AC/DC Standard Resistor	1
Other Reference Thermometers	Hart 5610	Reference Thermistor Probe	1
	Hart 5613	PRT Comparison Check Standard (6")	1
	Hart 5626	PRT Comparison Check Standard (12")	1
	Hart 5626	PRT Comparison Check Standard (15")	1
	Hart 5629	Au/Pt Thermocouple Realisation Standard	1
	Hart 5650	Pt/Rh/Pt Thermocouple Realisation Standard	1
Other	Hart 2028	Deep LN2 Comparator/Ice Bath Dewar	1
	Hart 2031	Quick-Stick Immersion Freezer	1
	Hart 7196	LN2 Comparator/Ice Bath Dewar	1

Temperature standards and sources used in Hart Scientific's Norwich Lab.

The Products (Equipment)

As already mentioned, the temperature standards and temperature sources used in the Norwich facility were designed and manufactured by Hart Scientific, a Fluke company. Each piece was certified, calibrated, or tested by Hart or by NIST. The resistance bridge used in ratiometric resistance measurements during SPRT calibrations was supplied by MI and the resistance standards were provided by Tinsley. A few other switches and source/measurement instruments came from a variety of other manufacturers. A complete list of all the key products used in the Norwich lab is shown at left.

The Place (Environment)

As with most metrology disciplines, ambient conditions can have a significant effect on measurements. Besides the need for stable temperature and humidity, clean electrical supply, clean air, and even lighting are particularly important for temperature laboratories.

The HVAC system in the Norwich laboratory is capable of dissipating 22 kW of heat via constant cooling in two 11 kW stages. The two stages are normally alternated to extend their lives (the typical load is currently less than 10 kW), but can operate together if necessary. Variable electric heating (up to 7.5 kW) and a proportional control system provide a nominal temperature of 23°C ±1°C, though short-term control is better than ±0.5°C. The air handling system provides twelve complete and quiet air changes per hour in the main laboratory with no localized drafts to upset sensitive instruments.

In the comparison calibration area, separated from the main lab by a wall with double doors (see lab floor plan p. 26), constant temperature baths using

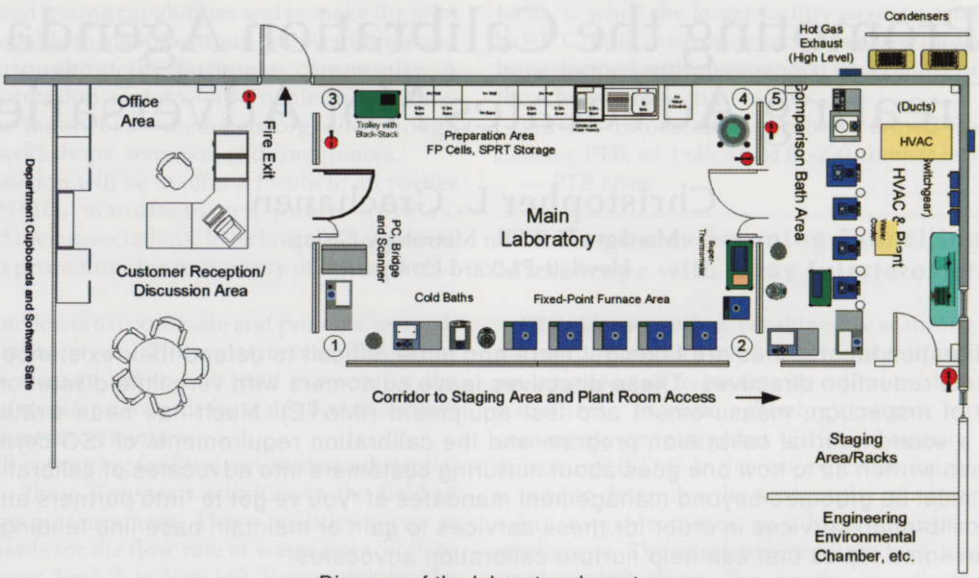

Diagram of the laboratory layout.

oils, alcohols, and salt are used. A high-volume, high-velocity air extraction system constantly replaces laboratory air with conditioned fresh air from outside and is supported by a fail-safe backup system. Variable-volume dampers and specially designed extraction nozzles (rather than the more conventional "hoods" often seen in temperature laboratories) make the air extraction system more reliable.

As already mentioned, the electrical power systems supplying the lab have been designed to thoroughly filter out noise. This has been achieved by designing the laboratory's electrical power system using experience drawn from sensitive DMM design. The principle is very simple — measurement instrumentation such as the Hart Super-Thermometer, *Black Stack* and MI 6010T Bridge are run from separate clean supplies that cannot be modulated by the varying loads from equipment with heaters and compressors (such as baths and furnaces), or those that have switch-mode supplies (computers). Only LCD computer monitors are used inside the laboratory to reduce electrical interference that would normally radiate from conventional CRT monitors. High-efficiency, high-frequency fluorescent lighting is used to give good overall lighting levels (essential for the inspection of delicate glassware) but with very low electrical noise levels and minimal electric field. The risk of "light piping" effects on the SPRTs being used is minimal because of their design.

The Result

Combine all these things and you get one of the world's most capable temperature laboratories, unique in its combination of electrical and temperature metrology as well as in its UKAS accreditation leveraging NVLAP and NIST. The accredited uncertainty schedule of the laboratory is as follows:

SPRT by ITS-90 Fixed Point		*Reference PRT by Comparison*	
Point	±U (mK) k=2	Temp.°C	±U (mK) k=2
LN^2	1.6	-196	9.3
Hg	0.27	-80	5.0
H_20	0.07	-40	4.0
Ga	0.27	0	2.6
In	0.58	30	2.8
Sn	0.72	100	5.6
Zn	1.01	156	6.5
Al	2.06	232	6.1
Ag	8.83	420	8.8
		500	12.3

Precision Thermistor by Comparison

Temp. °C	±U (mK) k=2
0	2.1
10	2.3
20	2.3
30	2.3
40	2.4
50	2.4
60	2.5
70	2.5
80	2.6
90	2.6
100	2.7

It took three months to plan the lab, three months to build it and install most of the equipment, six months to establish historical and statistical data such that the uncertainty budget could be produced and the lab could open for business, and eight months in total for the accreditation process. Accreditation involved assessments of technical capabilities and uncertainties as well as assessment of the lab's quality system and operating procedures, compliant with ISO/IEC 17025.

By appointment, the Norwich laboratory is available to visitors. To pay a visit or for more information, please send email to ukservicedesk@fluke.com. Andy Eddy, Fluke's UK service manager, and Peter Crisp would love to hear from you — as would we all!