After a historical review and the basic theory of heat transfer, it is time to start measuring temperature in Lesson 3.

LESSON 3 TRACEABLE TEMPERATURE MEASUREMENT

In order to be able to measure a temperature you must also know what measurement uncertainty you have. Without that, the temperature measurement is basically worthless.

THE TRACEABILITY CHAIN FOR TEMPERATURE

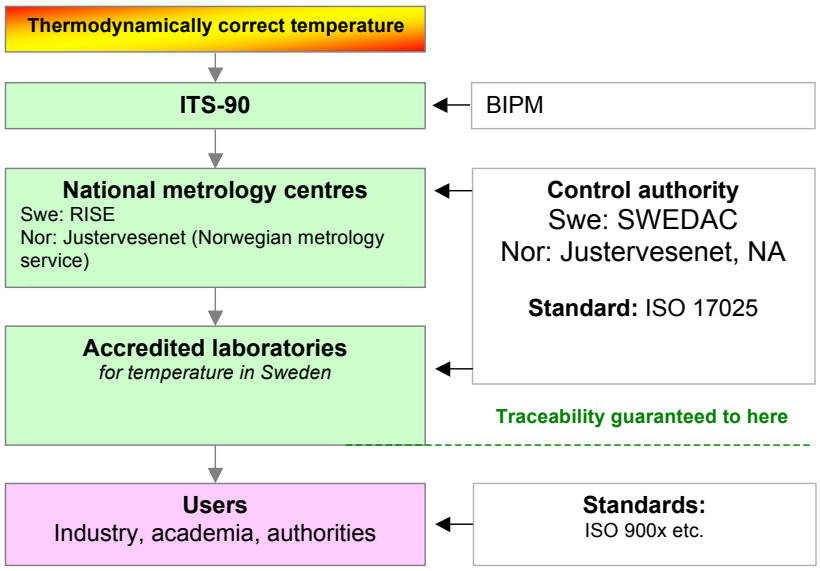
The start of an unbroken chain to the correct temperature begins with ITS-90 (the international temperature scale, set in 1990 by the International Bureau of Weights and Measures, BIPM). In Sweden, RISE (formerly SP) is the national metrology centre for temperature. There accredited laboratories can get their equipment calibrated. The national accreditation body for Sweden, Swedac, ensures that the right equipment, routines and skills exist to maintain the accreditation.

The user then decides how to ensure the traceability to the sensors being used.

GLOSSARY:

Calibration: is a comparison of two measurements made by sensors or measurement systems. One of them has a known uncertainty and the other (made by the sensor or measurement system you want to calibrate) has an unknown uncertainty. Adjusting the sensor or measurement system is not part of the calibration process.

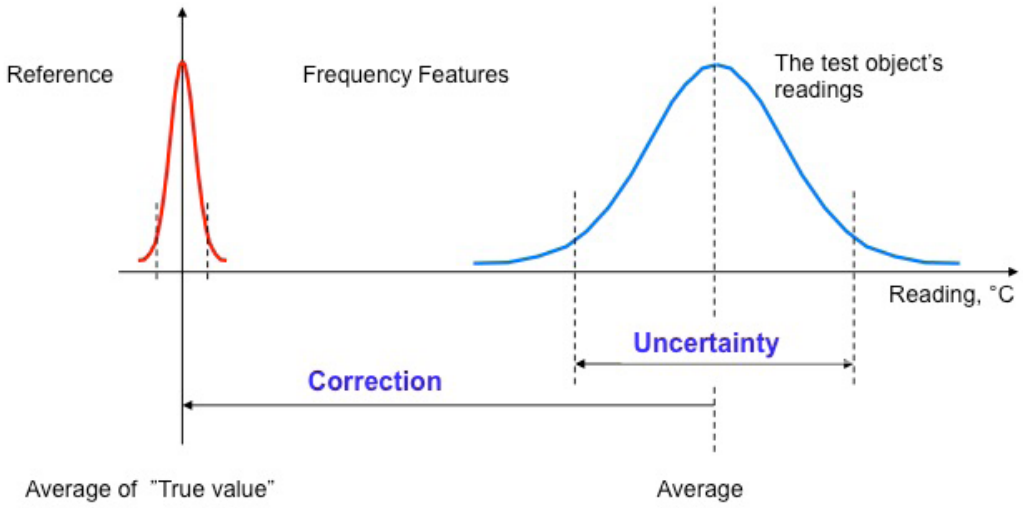
Traceability: means that the measurement result can be traced back to a known temperature via an unbroken chain of comparisons, all with known uncertainties.



This figure shows how temperature is made traceable to ITS-90 via various calibration bodies. The link to the thermodynamic temperature is via BIPM's research project.

REQUIREMENTS FOR TRACEABILITY AND MEASUREMENT UNCERTAINTY

When doing accredited work in accordance with ISO 17025, the demands for traceability and for the accounting of measurement uncertainty are absolute requirements. ISO 9001 and 9002 require a calibration chain to recognised standards, and that the measurement capability is sufficient. The latter means in practice that the measurement uncertainty must be both known and small in order for the accuracy of the measurements to be sufficiently good for the



The figure shows the concepts of correction and measurement uncertainty in a comparative calibration. You obtain the spread around the mean values by repeating the readings a large number of times. The spread is caused by the chance measurement errors that are introduced with every reading.

measurement task. Thus ISO 9001 and 9002 do not make any specified demands on the laboratory operations other than that the measurement devices used for the products must be traceably calibrated, where traceability is available.

CALIBRATION METHODS

There are two main calibration methods:

- Fixed point calibration
- Comparative calibration

where fixed point calibration consists of a direct link to the applicable definition of the temperature scale, ITS-90. Other calibrations are done by comparison in a stable medium between a reference measurement system and a calibration object.

FIXED POINT CALIBRATION

The sensor is inserted into a fixed point cell such as the triple point of water or the freezing point of tin or zinc. No reference system is required because these well-defined natural phenomena have been assigned a temperature figure in accordance with the ITS-90 temperature scale. See the table to the right.

Fixed point calibration is done at national metrology centres, accredited calibration laboratories and certain corporate laboratories. In a laboratory environment extremely small measurement uncertainties are possible, often < 0.01 °C. The small fixed point cells that are on the market provide excellent reference temperatures for the occasions when careful monitoring is needed of both thermocouples and Pt100 sensors.

COMPARATIVE CALIBRATION

Comparative calibration is the most common calibration method in industry. The measurement uncertainty achieved is often sufficient for the calibration of equipment in industrial processes. There are two main ways to do a comparative calibration:

- In situ (on site)
- In a separate furnace/bath

No	Temperature (°C)	Temperature (K)	Element	Phase shift
16	1064.18	1337.33	Gold	Freezing point
15	961.78	1234.93	Silver	Freezing point
14	660.323	933.473	Aluminium	Freezing point
13	419.527	692.677	Zinc	Freezing point
12	231.928	505.078	Tin	Freezing point
11	156.5985	429.7485	Indium	Freezing point
10	29.7646	302.9146	Gallium	Melting point
9	0.01	273.16	Water (TP)	Triple point
8	-38.8344	234.3156	Mercury	Triple point
7	-189.3442	83.8058	Argon	Triple point
6	-218.7916	54.3584	Oxygen	Triple point
5	-248.5939	24.5561	Neon	Triple point
4	=-252.85	=20.3	e-H_2/He	Boiling point
3	=-256.15	=17.0	e-H_2	Boiling point
2	-259.3467	13.8033	e-H_2	Triple point
1	-270.15/-268.15	3 / 5	Helium	Boiling point

The ITS-90 primary fixed points. Platinum resistance standards (SPRT) are used from phase transition 2 up to and including 15 in the table. Within accreditation, AKL 0076 at Pentronic uses the fixed points marked in green (8-15), which cover the most common calibration intervals. The more intense green shade indicates the temperature scale's fundamental fixed point. The temperature 0 K or –273.15 °C cannot be realised.

IN SITU

In situ means on the spot or on site. The advantage of the in situ method is that it preserves the sensor's normal working environment. The sensor arrangement is thereby exposed to the same protective tube losses, radiation exchanges and other similar factors as during normal operation. No deviating factors affect the calibration. Whether the temperature of the sensor's position is representative of what you really want to measure is another question to be considered later.

IN A SEPARATE FURNACE/BATH

In this type of calibration you place the sensor being compared in a separate bath or furnace or similar device that is constructed to give stable temperatures. This method is characterised by good control over the heat source's stability and absolute temperature. This method must be used if it is not possible to do an in situ calibration.

If you would like to discover even more about temperature measurement, Pentronic offers courses in "Traceable temperature measurement" in Västervik or at your own premises if required. For more information visit www.pentronic.se

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