CRITERIA FOR LABORATORY ACCREDITATION IN TEMPERATURE METROLOGY

Prepared by: SADCAS Advisory Committee – CLAS	**Approved by**: Chief Executive Officer	**Approval Date**: 2022-03-29 **Effective Date**: 2022-03-29

TABLE OF CONTENTS

1 PURPOSE AND SCOPE 3
2 ABBREVIATIONS 3
3 DEFINITIONS 3
4 ENVIRONMENTAL REQUIREMENTS 8
5 GENERAL REQUIREMENTS 8
6 TECHNICAL REQUIREMENTS 9
6.1 Thermocouple Calibration 9
6.2 Compensation and Extension TC Calibration 10
6.3 Surface Temperature Probes 10
6.4 Ice Point Reference 11
6.5 Resistance Thermometer Calibration 11
6.6 Liquid-in-Glass Thermometer Calibration 11
6.7 Digital Thermometer Calibration 12
6.8 Mechanical Dial Thermometer Calibration 12
6.9 Electrical Simulation 13
6.10 CJC Calibration 14
6.11 Radiation Thermometer Calibration 14
6.12 Isothermal Evaluation – Steam Sterilizers (Autoclaves) 14
6.13 Isothermal Evaluation - Sterilizers 15
6.14 Environmental Chamber Evaluation 15
6.15 Temperature Installations 15
6.16 Heat Stress Monitor Calibration 15
6.17 Temperature Recorder Calibration 15
6.18 Hotplate Calibration 16
6.19 Temperature Block Calibrator Calibration 16
6.20 Preparation and Evaluation of Liquid Baths 16
6.21 On-Site Calibration 17
7 REFERENCES 17
APPENDIX A: SAMPLE OF SCHEDULE OF ACCREDITATION 18
APPENDIX B - AMENDMENT RECORD 20

1. PURPOSE AND SCOPE

The purpose of this document is to define the specific environmental, general and technical requirements to be met by accredited laboratories in the field of temperature measurement and calibration and includes those DC/LF electrical laboratories accredited to perform electrical simulation of temperature instrumentation.

This document is applicable to Southern African Development Community Accreditation System (SADCAS) accredited Laboratories.

2 ABBREVIATIONS

CJC	Cold Junction Compensation
CMC	Calibration and Measurement Capability
DC/LF	Direct Current/Low Frequency
ELC	Emergent Liquid Column
K	Kelvin
LIG	Liquid-in-Glass
mA	Milliamp
MSDS	Material Safety Data Sheets
Pt 100	Platinum Resistance Thermometer with R(0°C) = 100Ω
UoM	Uncertainty of Measurement
UUT	Unit under Test
RJ	Reference (cold) Junction
RTD	Resistance Temperature Device
SADCAS	SADC Accreditation Service
SANAS	South African National Accreditation System
SI	International System of Units
TC	Thermocouple
WBGT	Wet Bulb Globe Temperature

3 DEFINITIONS

Annealing or heat treatment is the process whereby a thermocouple or resistance thermometer is relieved of internal stresses by heating at a fixed temperature for a specified time period.

Blackbody
A blackbody is an entity that absorbs all electromagnetic radiation falling upon it. As a perfect absorber, it neither reflects nor transmits, and has an emissivity of 1. [15] The perfect or ideal source of thermal radiant power having a spectral distribution described by the Planck equation.

The term blackbody is often used to describe a furnace or other source of radiant power which approximates the ideal. [4]

A reference source of infrared radiation made in the shape of a cavity and characterised by precisely known temperature of the cavity walls and having effective emissivity at the cavity opening arbitrarily considered equal to unity.

Base Metal Thermocouple
Thermocouple whose thermo-elements are composed primarily of base metals and their alloys. [4]

Cold Junction Compensation
Internal cold junction compensation is applied in thermocouple measuring instruments. It determines the temperature at the input junctions of the instrument and applies a microvolt correction for the deviation of the temperature from 0 °C for the specific type of thermocouple measured.

Compensating TC Cable
Compensating cable is made of different alloys to that of the thermocouple, but manufactured to match the emf/temperature characteristic of the thermocouple, but over a restricted temperature range. [8]

Contact Thermometer
An instrument that is adapted for measuring temperature by means of thermal conductivity by determining the temperature at the moment when negligible thermal energy flows between the thermometer and the object of measurement. [4]

Electrical Simulation
In this application, simulation is the process of replacing a temperature sensor (thermocouple or resistance thermometer) by an equivalent electrical device in order to calibrate a temperature indicator or transducer. [5] Electrical simulation may also include the calibration of temperature indicator using a current or voltage input such as 4-20mA, or 1-5 volts respectively.

International System of Units, SI
The coherent system of units adopted and recommended by the General Conference on Weights and Measures (CGPM) based on seven base units, namely meter (m), kilogram (kg), second (s), ampere (A), kelvin (K), mole (mol) and candela (cd). [13]

Thermocouple.
A thermocouple is a pair of conductors of dissimilar materials joined at one end forming part of an arrangement using the Seebeck thermoelectric effect for temperature measurement. [7]

Kelvin, K
Base unit of the temperature in the International System of Units (SI). [4]

Liquid-in-glass Thermometer
A temperature measuring instrument whose indications are based on the temperature coefficient of expansion of a liquid relative to that of its containing glass bulb. [4]

Measuring Junction
That junction of a thermocouple which is subjected to the temperature to be measured, sometimes referred to as the hot junction.

Radiation Thermometer
A radiometer calibrated to indicate the temperature of a blackbody. [4] This thermometer is a non-contact type.

Ice Point
A secondary fixed point, 0.0 °C, on the International Temperature Scale of 1990 (ITS-90), that is a melting mixture of pure ice and water that realizes the temperature of 0.0 °C. Distilled water must be used as well as ice made with distilled water to realise the ice point.

Reference Junction
That junction of a thermocouple which is at a known temperature. [4]

Response Time
Time interval between when a stimulus is subjected to a specified abrupt change and the instant when the response reaches and remains within specified limits around its final steady value. The response time for a sensor is the time taken to achieve 99.5% of the step change and is equal to approximately 5-time constants. (See time constant).

Spectral Emissivity
Spectral emissivity is a dimensionless number lying between 0 and 1, and is defined as the ratio of energy radiated from a surface to that of a blackbody at the same temperature, at the same wavelength and under the same viewing conditions. [15]

Temperature Block Calibrator
Temperature block calibrators comprise a solid block, with a temperature controller and indicator. The block has borings intended for the calibration of thermometers. [9]

Steam Sterilization
Steam sterilization involves the use of steam under pressure, delivered at a particular temperature for an appropriate time. Sterilization occurs as the latent heat of condensation is

transferred to the load causing it to heat rapidly. Heating denatures any microorganisms remaining following the cleaning process. Steam sterilizers are also known as autoclaves.

Temperature Mapping

Temperature mapping is the evaluation of the temperature uniformity and stability in the applicable volume by the use of several temperature probes.

Time Constant

The Time Constant, T, of a sensor is defined as the time taken for it to achieve 63.2% of a step change in temperature.

Repeatability

The ability of a measuring instrument to provide closely similar indications for repeated applications of the same measurands under the same conditions of measurement. [13]

Zone of Homogeneity

With reference to Temperature Block Calibrators the 'zone of homogeneity' is that zone of at least 40 mm in length, normally located at the lower end of the boring into which the thermometer to be calibrated is inserted. [9]

Compensating Extension Wires

Those extension wires fabricated from materials basically different in composition from the thermocouple. *They have similar thermoelectric properties and within a stated temperature range effectively transfer the reference junction to the other end of the wires*. [4]

Complete Immersion Thermometer

A liquid-in-glass thermometer designed to indicate temperatures correctly when the entire thermometer is exposed to the temperature being measured.[4]

Degree Celsius, ºC

Derived unit of temperature in the International System of Units (SI). (See Kelvin).
At any temperature, an interval of one degree Celsius is the same as an interval of one Kelvin, by definition.[4]

Extension Wires

Those having temperature emf characteristics that when connected to a thermocouple effectively transfers the reference junction to the other end of the wires. [4]

International Practical Temperature Scale of 1968 (IPTS-68)

The temperature scale adopted by the 13th General Conference on Weights and Measures in 1968. *The IPTS-68 was superseded by the International Temperature Scale of 1990*. [4]

International Temperature Scale of 1990 (ITS-90)
The temperature scale prepared in accordance with instructions of the 18th General Conference on Weights and Measures, and adopted on January 1, 1990.

Noble Metal Thermocouple
Thermocouple whose thermo elements are composed of primarily of noble metals and their alloys. [4]

Partial Immersion Thermometer
A liquid in glass thermometer designed to indicate temperature correctly when the bulb and a specified part of the stem are exposed to temperatures being measured. [4]

Radiometer
A device for measuring radiant power that has an output proportional to the intensity of the input power. [4]

Resistance Thermometer
A temperature measuring device comprised of a resistance thermometer element, internal connecting wires, a protective shell with or without means for mounting, a connection head, a connecting wire, or other fittings, or both. [4]

Self-heating
The increase in the temperature of the thermometer element caused by the electric power dissipated in the element, the magnitude depending upon the thermometer current and heat conduction from the thermometer element to the surrounding medium. [4]

Thermistor
A semiconductor, the primary function of which is to exhibit a monotonic decrease in electrical resistance with an increase in sensor temperature, that is, a semiconductor for which the temperature coefficient of resistance is negative and exhibits neither discontinuities nor changes in sign. [4]

Total Immersion Thermometer
A liquid in glass thermometer designed to indicate temperature correctly when just that portion of the thermometer containing the liquid is exposed to temperatures being measured.[4]

Triple Point of Water
Triple point of the liquid, solid, and vapor phases of water. [4]

4 ENVIRONMENTAL REQUIREMENTS

An accredited laboratory working in the field of temperature measurements shall operate under the following environmental conditions:

4.1 The laboratory shall be maintained at a temperature of 23°C ± 5°C. Where measurements are performed outside this specified limit, the laboratory must produce documented evidence that the results have been validated, for example when measurements are performed on-site.

4.2 Rates of change and gradients of the ambient temperature must be kept to below 2 ºC per hour.

4.3 A high degree of cleanliness shall be maintained in the laboratory and adequate lighting shall be provided. [1]

5 GENERAL REQUIREMENTS

5.1 Laboratories may be accredited for the calibration of:

- noble and base metal thermocouples;
- TC compensation and extension leads;
- surface temperature probes;
- ice point reference;
- triple point of water;
- platinum resistance thermometers;
- thermometers including liquid-in-glass, digital, and mechanical (bi-metal or filled systems);
- electrical simulation calibration of both TC and RTD temperature indicators, controllers, transmitters and temperature calibrators, including the calibration of CJC;
- radiation thermometers;
- tungsten ribbon lamps;
- Isothermal media evaluation, including autoclaves, sterilizers, and environmental chambers;
- temperature installations, including ovens, incubators, stirred water baths, fridges, and freezers;
- heat stress monitors;
- temperature recorders including thermo-hygrographs, and data loggers;
- surface temperature of hot plates;
- dry block temperature calibrators,
- on site accreditation for any of the above, but excluding triple point of water.

(Refer to the Scope of Accreditation – Temperature Metrology Appendix 2)

5.2 The laboratory shall measure the output of the UUT in the applicable units. Generally, the units will be °C, with certain exceptions such as thermocouples, the output being measured in microvolts (µV) or millivolts (mV), resistance thermometers, the output being measured in ohms (Ω), temperature transducers the output in milliamps (mA). In the case of temperature calibrators, the units may be degrees Celsius (°C), or the applicable electrical units.

5.3 Laboratories shall report the results accurately, clearly, unambiguously and objectively. [3] It is therefore preferable to report measurement results where applicable in both the electrical unit (mV, µV, mA or Ω) and the equivalent temperature in °C. Where results are reported in non-SI units, the equivalent SI unit shall be reported alongside and the applicable conversion factor shall be stated.

5.4 The laboratory is required to have MSDS for all standards fluids, chemicals and hazardous cleaning materials used within the laboratory, for example, but not limited to acids, organic solvents, salts, temperature bath fluids, etc. [2]

5.5 If the laboratory either uses or calibrates Liquid-in-Glass thermometers they shall have an MSDS for Mercury, and a procedure describing how mercury spills are to be cleaned up. [2]

5.6 The laboratory is required to have procedures in place for the storage and usage of standards in order to ensure their ongoing integrity.

5.7 The laboratory shall have and apply procedures for all calibrations, including the making up of an ice point reference.

5.8 The laboratory shall be equipped with suitable isothermal heat sources such as stirred liquid baths, furnaces, and/or block calibrators for the calibration of temperature sensors.

5.9 Where digital multimeters are used to measure the output of thermocouples, transmitters, thermistors, and RTD's, the specification of the digital multimeter shall be used in the estimation of the UoM, unless it can be shown that sufficient measurements over the applicable measurement range (mV, mA, Ω) have been made by the calibrating laboratory, allowing for interpolation and correction where applicable, and subsequently the use of the UoM specified by the calibrating laboratory.

6 TECHNICAL REQUIREMENTS

6.1 Thermocouple Calibration

6.1.1 The laboratory should have the appropriate reference junctions for each type of thermocouple as required, both base metal and noble metal, and shall use these as appropriate for the calibration of thermocouples.

6.1.2 TC reference junctions should be calibrated, and a calibration certificate issued for each RJ. The uncertainty of the RJ shall be taken into account in the uncertainty budget for any calibration where the RJ has been used.

6.1.3 In instances where the reference junctions have not been calibrated then the laboratory shall use the manufacturer's specification for the extension or compensating wire as the basis for the uncertainty of the reference junction.

6.1.4 The procedure for the calibration of thermocouples shall address as a minimum:

- depth of immersion;
- temperature variation of the thermal source;
- time and spatial temperature distribution of the thermal source;
- annealing;
- temperature variation of the cold (reference) junction;
- parasitic thermo-voltages;
- electromagnetic interference;
- Initial inspection (obvious defects, contamination, etc.)
- calibration of digital voltmeters or direct reading temperature indicators.[8]

6.1.5 The calibration procedure shall address possible calibration changes of type K thermocouples (and to a lesser extent other base metal thermocouples) when exposed to temperature cycling at 500 ºC or above. [8]

6.2 Compensation and Extension TC Calibration

6.2.1 The calibration of compensation or extension thermocouple cable will take place over a limited range, typically not exceeding 0 ºC to 70 ºC.

6.2.2 When a sample of TC cable or TC compensating or extension cable is calibrated and taken to be representative of a reel or length of cable, the laboratory shall address the requirements for sampling as specified in Clause 7.3 of ISO/IEC 17025:2017

6.2.3 Procedures for the calibration of compensation and extension thermocouple wire shall address those aspects identified in 6.1.4 above.

6.3 Surface Temperature Probes

6.3.1 The laboratory shall have procedures that describe how the thermocouple measuring tip is to make contact with the measuring (hot) surface, and the applicable settling time, necessary to produce repeatable measurements.

6.3.2 The laboratory shall have a suitable measurement source such as a hotplate, with a suitable surface finish together with a reference surface temperature thermometer.

6.4 **Ice Point Reference**

6.4.1 The procedure for the preparation of the ice point reference, shall include the method of preparation, the type and grade of water to be used, appearance, and expected uncertainty.

6.4.2 An ice point prepared with reasonable care should reproduce 0 ºC ± 0,05 ºC or better. [11]

6.5 **Resistance Thermometer Calibration**

6.5.1 The laboratories procedure for the calibration of resistance thermometers shall address as a minimum:

- depth of immersion;
- temperature variation of the thermal source;
- time and spatial temperature distribution of the thermal source;
- annealing;
- connection configuration and colour coding;
- self-heating;
- Initial inspection (obvious defects, contamination, etc.)
- calibration of digital multimeters or direct reading temperature indicators;
- possible loading effects when using a digital multimeter.

6.5.2 The annealing of a resistance thermometer shall only take place with the consent of the customer, and shall be recorded as part of the contract review process.

6.5.3 Where no other requirement has been specified by the customer the thermometer should be allowed to cool by:

- For thermometers used only up to approximately 450 °C, they may be removed from the heat source and allowed to cool down to ambient conditions;
- For thermometers used above that temperature, after annealing the thermometer should be allowed to cool down to 450 °C in the heat source, where-after it may be removed and allowed to cool down to ambient.

6.6 **Liquid-in-Glass Thermometer Calibration**

6.6.1 The procedure/s for calibration of LIG thermometers shall describe complete, partial or/and total-immersion of the thermometer, and shall include the method for the calculation of emergent liquid column corrections where appropriate.

6.6.2 Certificates issued for the calibration of LIG thermometers shall include all relevant information on the thermometer including details of the manufacturer, serial number, measuring range, type, scale interval, immersion type and depth, in addition to the measurement results.

6.6.3 The calibration procedure shall include a visual inspection of the thermometer for gross defects such as missing graduations, broken columns, and separations in the thermometric liquid. [11]

6.6.4 The calibration procedure shall include the method for handling, storage and transportation of LIG thermometers.

6.6.5 A magnifying eyepiece and suitable light source should be used to reduce parallax errors and increase readability. [11]

6.6.6 It must be noted that block calibrators, may not be suitable for the calibration of total immersion liquid-in-glass thermometers, since, in most cases, these cannot be immersed to the appropriate depth required over the full temperature range.

6.7 **Digital Thermometer Calibration**

6.7.1 The calibration of a digital thermometer may include electrical simulation. This is addressed separately in section 6.9 of this document.

6.7.2 The procedure for the calibration of digital thermometers shall address as a minimum:
- depth of immersion;
- temperature variation of the thermal source;
- time and spatial temperature distribution of the thermal source;
- temperature variation of the cold (reference) junction;
- electromagnetic interference;
- Initial inspection (obvious defects, contamination, etc.).

6.7.3 Typically handheld digital thermometers use either TC type K, RTD, Pt 100, or thermistor temperature sensors. Subsequently, range, stability and accuracy will differ between all of these types, and cognisance of these differences shall be considered when the UoM is estimated.

6.7.4 When a digital thermometer is calibrated with a temperature probe, both the thermometer and probe shall be uniquely identified. If the probe is detachable, or interchangeable the certificate shall include a disclaimer that the calibration is only valid when the digital thermometer is used with the specified temperature probe.

6.7.5 Digital thermometers that include an externally accessible ‘zero’ adjustment, shall have the adjustment screw sealed with a tamper proof sticker, after the calibration has been completed.

6.8 **Mechanical Dial Thermometer Calibration**

6.8.1 Mechanical dial thermometers can be separated into two distinctive types, those operating with a filled liquid capillary system, and those incorporating a bi-metallic strip, or bi-metallic helical coil.

6.8.2 Mechanical dial thermometers are generally less accurate than other types of thermometers and are typically used in industrial applications, rather than in a laboratory environment.

6.8.3 Mechanical effects due to friction in the transmission and indication may result in a difference in rising and falling temperatures (hysteresis) and this shall be considered during the estimation of the UoM. [12]

6.8.4 The procedure shall address the immersion depth.

6.8.5 In instances where the thermometer is provided with an external means of adjustment to offset changes in the calibration, such as an adjustable dial, or pointer, this adjustment shall be sealed with a tamper proof sticker after the calibration has been completed.

6.9 Electrical Simulation

6.9.1 The laboratory shall have and apply procedures for the calibration of temperature indicators and controllers by electrical simulation. Temperature indicators and controllers are instruments that convert an electrical signal to a reading in temperature units. Temperature simulators and calibrators are also typically capable of producing an electrical signal equivalent to the output setting in temperature units on the device.

6.9.2 Procedures shall address the interconnections for calibration purposes of the standard and the UUT. For RTD devices this shall include 2, 3 or 4 wire connections. For TC devices the procedure shall address the use of compensating leads, including their polarity, and the use of reference junctions. The calibration certificate shall indicate whether the calibration was performed using 2, 3 or 4 wire connections.

6.9.3 The laboratory shall have copies of all reference tables for all thermocouple types, and resistance thermometers that they are accredited to calibrate. [5] The laboratory should also have TC colour charts available.

6.9.4 The temperature scale used to express temperature values in the calibration certificate shall be clearly stated. Unless requested by the customer the International Temperature Scale of 1990 (ITS-90) shall be used. [5]

6.9.5 The standard reference tables used to convert the electrical signals to temperature values together with their reference/identification numbers shall be stated on the calibration certificate. [5]

6.9.6 For calibrators or simulators capable of measuring and simulating several different type of temperature sensors, the calibration certificate shall clearly indicate the sensor types, and range covered by the calibration, and this should have been agreed with the customer.[5]

6.9.7 Certain temperature calibrators or simulators have a selectable CJC feature, allowing the CJC to be enabled or disabled, or manually set to a temperature such as 0 ºC or ambient. These instruments may be calibrated using either method. The calibration certificate shall clearly indicate if the results were obtained with the CJC enabled, disabled or manually set. [5]

6.10 CJC Calibration

6.10.1 The laboratory shall have procedures for the calibration of the CJC when this is performed separately to the TC output or input function of the UUT.

6.10.2 The procedure shall take cognizance of the fact that the CJC temperature is measured, usually with a sensor bonded to one of the terminals, and therefore the temperature stability of the UUT is as critical as the stability of an ice point that may be used as part of the calibration.

6.11 Radiation Thermometer Calibration

6.1.1 The laboratory procedures for the calibration of Radiation Thermometers shall address:

- Spectral emissivity,
- Alignment with the target,
- Size of the source.

6.12 Isothermal Evaluation – Steam Sterilizers (Autoclaves)

6.12.1 The calibration / performance evaluation of a steam sterilizer shall be conducted in accordance with the requirements as agreed during the contract review.

6.12.2 The requirements for the calibration / evaluation of a steam sterilizer may be superseded by regulatory requirements.

6.12.3 A multipoint calibration / evaluation shall be performed (Minimum of 3 points).

6.12.4 Care must be taken to ensure that the pressure seal of the lid of the steam sterilizer is not damaged, should it be necessary for temperature sensor wires be fed into the chamber via the lid. Individual temperature loggers can be used instead of conventional temperature sensors (TCs or RTDs) to overcome the problem of gaining access to the chamber.

6.12.5 Since the evaluation of steam sterilizers is done over elapsed time, the laboratory shall have and maintain a suitable time standard to calibrate the timer of the steam sterilizer. Similarly, a calibrated pressure gauge with manifold and pressure pump can be used for the calibration of the pressure gauge of the steam sterilizer.

6.12.6 A temperature laboratory may apply for limited Time Interval and Pressure accreditation for the calibration of steam sterilizers only. This accreditation may not be used for any other purpose. The calibration certificate must include an exclusion if either the pressure indicating device or timer were not included in the calibration / evaluation.

6.12.7 The certificate / report shall include a disclaimer that the calibration / evaluation does not cover the inspection of the steam sterilizer as a pressure vessel that may be required in terms of legislation.

6.12.8 The calibration certificate must indicate if the calibration / evaluation was performed with, or without a load.

6.13 **Isothermal Evaluation - Sterilizers**

6.13.1 The evaluation of non-pressurized sterilizers is achieved by temperature mapping alone.

6.14 Environmental Chamber Evaluation

6.14.1 The calibration of environmental chambers necessitates the following measurements:

- Variations in space for temperature and % relative humidity
- Variations in time for temperature and % relative humidity

6.14.2 It is recommended that the humidity is measured at the same point in the chamber where the temperature is measured. Applying humidity calculations to humidity measured in the center of the chamber, based on the spatial temperature measurements, may provide incorrect humidity spatial values.

6.15 **Temperature Installations**

6.15.1 Laboratories performing the calibration of temperature indicators, controllers and recorders excluding the temperature probes shall be accredited for electrical simulation.

6.15.2 The calibration may include temperature mapping for large volumes.

6.16 **Heat Stress Monitor Calibration**

6.16.1 The requirements for the calibration of Heat Stress Monitors, otherwise known as WBGT monitors is addressed in SANAS document TR46 ‘Calibration of Heat Stress Monitors’. [14]

6.17 **Temperature Recorder Calibration**

6.17.1 Laboratories performing the calibration of temperature recorders such as thermohygrographs or data loggers shall be equipped with a suitable chamber.

6.18 **Hotplate Calibration**

6.18.1 The laboratory shall have suitable reference surface temperature thermometers in order to perform these calibrations.

6.18.2 The laboratory shall have procedures that describe how the thermocouple measuring tip is to make contact with the measuring surface of the hotplate, and the applicable settling time, necessary to produce repeatable measurements.

6.19 **Temperature Block Calibrator Calibration**

6.19.1 The calibration of a Temperature Block Calibrator includes an evaluation of performance of the calibrator.

6.19.2 The calibration procedure shall therefore cover the following measurements as a minimum:

- An evaluation of the zone of homogeneity, in the central boring or a specifically identified marked boring;
- The greatest temperature difference between the borings at a specified temperature;
- Stability over a 30-minute period, after stability has been reached;
- Calibration against the indicated temperature at a minimum of 3 different temperatures, distributed uniformly over the temperature range excluding ambient. If one of the desired temperatures is near ambient the temperature shall be increased or decreased by approximately 20ºC from ambient. [9]

6.19.3 Where any of the above measurements have not been performed this shall be specified on the calibration certificate.

6.19.4 In addition, the calibration procedure shall address:

- The outside diameter of the thermometer used to perform the calibration relative to the inside diameter of the boring or bushing;
- The minimum immersion length;
- The use of insulation materials on the top of the block;
- The location of the thermometer in the zone of homogeneity during calibration;
- Heat conduction when using a standard thermometer with a diameter ≥6mm. [9]

6.20 **Preparation and Evaluation of Liquid Baths**

Preparation and Evaluation of Liquid Baths shall be carried out in accordance with [16].

6.21 **On-Site Calibration**

6.21.1 Laboratories wishing to be accredited for on-site work shall have procedures that describe how equipment including standards are to be transported, how measurement standards are validated (intermediate checks performed) to ensure the on-going integrity and accuracy of the measurement standards.

7 REFERENCES

[1] Lighting at work, Free to download, web friendly version of HSB38, 2nd Edition published 1997, ISBN 978 0 7176 1232-1

[2] ISO 45001:2018 Occupational health and safety management systems - Requirements with guidance for use

[3] ISO/IEC 17025:2017 General requirements for the competence of testing and calibration laboratories

[4] ASTM E 344-00 Terminology relating to Thermometry and Hygrometry.

[5] EURAMET cg-11 Calibration of Temperature Indicators and Simulators by Electrical Simulation and Measurement Version 2.0 (03/2011)

[6] IEC-584-1 International Electrotechnical Commission Thermocouples – Part 1 Reference Tables

[7] IEC-584-2 International Electrotechnical Commission Thermocouples – Part 2 Tolerances

[8] EURAMET cg-08 Calibration of Thermocouples. Version 2.1 (10/2011)

[9] EURAMET cg-13 Calibration of Temperature Block Calibrators Version 2.0 (03/2011)

[10] OIML R133 International Organization of Legal Metrology Liquid-in-glass thermometers, Ed. 2002(E)

[11] AS TG 3 IANZ Technical Guide Working Thermometers Calibration Procedures, March 2002. ISBN: 0908611 58 7

[12] WIKA – Handbook Pressure and Temperature Measurement, 1995

[13] ISO/IEC Guide 99 (JCGM 200:2012), International vocabulary of metrology — basic and general concepts and associated terms (VIM), issued by BIPM, IEC, IFCC, ILAC, ISO, IUPAC, IUPAP and OIML.

[14] ISO 7243: 2017 Ergonomics of the thermal environment — Assessment of heat stress using the WBGT (wet bulb globe temperature) index

[15] Guide to the realization of the ITS-90: Radiation Thermometry

[16] ASTM E2488-09(2014) Standard Guide for the Preparation and Evaluation of Liquid Baths Used for Temperature Calibration by Comparison.

APPENDIX A: SAMPLE OF SCHEDULE OF ACCREDITATION

SCHEDULE OF ACCREDITATION

TEMPERATURE METROLOGY

Laboratory Accreditation Number: CAL-14 00x

Permanent Address of Laboratory: … … … …… **Postal Address:** … … … **Tel** : … **Cell** : … **Fax** : … **Email** : …		**Technical Signatories** : … **Nominated Representative** : … **Issue No**. : … **Date of issue** : … **Expiry Date** : …

ITEM	MEASURED QUANTITY OR TYPE OF GAUGE OR INSTRUMENT	METHOD	RANGE OF MEASURED QUANTITY	CALIBRATION AND MEASUREMENT CAPABILITY EXPRESSED AS AN UNCERTAINTY (±)
				At CAB and On-site
1	Thermocouples: Noble Metal	Internal: e.g. *P-NMI-XYZ*	0 ºC to 70ºC 70ºC to 650 ºC 650 ºC to 1820 ºC	0,3 °C 2,0 °C 4,0 °C
	Base Metal	Reference: e.g. *EURAMET cg-08*	-50 ºC to 0ºC 0ºC to 70ºC 70ºC to 150 ºC 150 ºC to 650 ºC 650 °C to 1370 °C	1,0 °C 0,2 °C 1,0 °C 2,5 °C 4,0 °C
	Compensation and Extension Lead	Internal: Reference	0 ºC to 70 ºC	0,3 °C
	Surface Temperature Probes	Internal: Reference	50 ºC to 150 ºC 150 ºC to 350 ºC	1,5 °C 5,0 °C

				At CAB	
2	Ice Point Reference	Internal: Reference	0,0 ºC	0,1 °C	
3	Water Triple Point Cell	Internal: Reference	0,01 °C	0,001 °C	
4	Platinum Resistance Thermometers	Internal: Reference	-60 ºC to 180 ºC 180 ºC to 650 ºC 650 °C to 850 °C	0,3 °C 0,6 °C 1,5 °C	
				At CAB	**On-site**
5	Thermometers Liquid–in-glass	 Internal: Reference:	 -20 ºC to 50 ºC 50 ºC to 180 ºC 180 ºC to 450 ºC	 0,2 °C 0,6 °C 1,5 °C	 0,5 °C 1,0 °C 2.0 °C
	Digital Thermometers		-40 ºC to 200 ºC 200 ºC to 800 ºC	0,2 °C 0,6 °C	0,5 °C 1.0 °C
	Mechanical (Dial) Thermometers		-50 ºC to 50 ºC 50 ºC to 200 ºC 200 ºC to 500 ºC	1,5 °C 2,5 °C 5,0 °C	2,0 °C 3,0 °C 6,0 °C

Original date of accreditation: … Page 1 of 2

Page 1 of 1

The CMC, expressed as an expanded uncertainty of measurement, is stated as the standard uncertainty of measurement multiplied by a coverage factor k = 2, corresponding to a confidence level of approximately 95%.

APPENDIX B - AMENDMENT RECORD

Revision Status	Change			Approved by	Effective Date
	Page	Clause/ Sub-clause	Description of Change		
Issue 1	-	-	-	CEO	2022-03-29