Proceso selectivo convocado para el acceso, por promoción interna, en la Escala de Científicos Superiores de la Defensa. Resolución 400/38504/2024, de 25 de noviembre (B.O.E. núm. 293 de 05.12.2024).

TRIBUNAL CALIFICADOR Nº 2

Segundo Ejercicio: Supuesto práctico

Programa: METROLOGÍA Y CALIBRACIÓN EN EL ÁMBITO DE DEFENSA AEROESPACIAL

- No de la vuelta a esta hoja del EJERCICIO ni empiece el examen hasta que se le indique.
- Cumplimente y firme la HOJA DE DATOS PERSONALES. Al finalizar el ejercicio, esta hoja, será guardada en un sobre y precintado.
- El EJERCICIO consiste en resolver un supuesto práctico relacionado con el temario específico que figura en el Anexo II de la convocatoria.
- El tiempo máximo de realización de este ejercicio es de **ciento ochenta (180) minutos.**
- El SUPUESTO PRÁCTICO, deberá entregarlo el opositor al finalizar el tiempo.

PÁGINA EN BLANCO

Supuesto práctico 1: intercomparación

Un grupo de veintiséis laboratorios de calibración acreditados conforme a la norma UNE ISO/IEC 17025:2017 necesita participar en una intercomparación para cumplir el requisito 7.7 de Aseguramiento de la validez de los resultados, de dicha Norma y los requisitos de ENAC al respecto.

Para ello, ha identificado una intercomparación ofrecida por un proveedor de Intercomparaciones acreditado por ENAC conforme a la norma UNE-EN ISO/IEC 17043 "Evaluación de la conformidad. Requisitos generales para los ensayos de aptitud". El proveedor anuncia que la evaluación de los laboratorios participantes se realizará mediante la obtención del valor del Error Normalizado (En) para cada uno de los resultados.

La intercomparación consiste en la caracterización de un termómetro de lectura directa con sensor de resistencia termométrica. Los valores nominales de temperatura empleados para la caracterización del patrón viajero se detallan más adelante. Como parámetro bajo prueba se solicita la corrección o diferencia (con signo) entre la temperatura nominal aplicada al termómetro y la lectura obtenida con el patrón viajero.

Como Patrón Viajero se empleará en esta Intercomparación el siguiente equipo: Termómetro de Lectura Directa (TLD) con sensor de resistencia, termométrica, Marca: ASL, Modelo: F100, Escala: -200 °C a 850 °C, Resolución: 0,001 °C.

Los valores nominales de los puntos de medida a realizar para esta Intercomparación son los siguientes: -40, -20, 0, 20, 50, 100, 150, 200 y 250) °C.

1) Defina el proceso a seguir para organizar este ejercicio de intercomparación, enumerando en un diagrama de flujo las distintas fases y desarrollando su contenido. ***[10 puntos]***

2) Defina en detalle la operativa para la gestión del patrón viajero, desde su elección, desarrollando las distintas actuaciones y las medidas a adoptar para asegurar la integridad del mismo. ***[10 puntos]***

3) Defina la sistemática, apoyado en un diagrama de flujo, desde el punto de vista del auditor, de la auditoría vertical de los registros de una comparación de este tipo. ***[10 puntos]***

Nótese que en este ejercicio se evaluará el razonamiento empleado en la aplicación de los conocimientos del temario de "METROLOGÍA Y CALIBRACIÓN EN EL ÁMBITO DE DEFENSA AEROESPACIAL", enumerados al dorso, a un ejercicio de intercomparación en el ámbito de la acreditación.

Conocimientos aplicables del temario:

Tema 6. La Entidad Nacional de Acreditación. Acreditación de laboratorios de ensayo y calibración.

Tema 13. Confirmación metrológica. Patrones primarios y secundarios.

Tema 15. Medida y calibración. Transferencia de unidades y obtención de la trazabilidad metrológica

Tema 16. Fases generales en la calibración de un instrumento de medida. Cumplimiento de especificaciones.

Tema 29. Expresión de la incertidumbre en un certificado de calibración. Interpretación de resultados. Cumplimiento de especificaciones de los instrumentos de medida.

Tema 31. Competencia de los laboratorios de ensayo y calibración. Precisión y exactitud de la medida.

Tema 32. Competencia de los laboratorios de ensayo y calibración. Aseguramiento de la validez de los resultados.

Tema 36. La gestión de laboratorios de calibración acreditados. Plan de calibración.

Tema 38. La acreditación de laboratorios de calibración y ensayo.

Tema 40. La auditoría interna en los laboratorios de calibración acreditados.

Tema 41. Fases del proceso de evaluación en las auditorías externas. Aplicación a laboratorios de calibración.

Proceso selectivo convocado para el acceso, por promoción interna, en la Escala de Científicos Superiores de la Defensa. Resolución 400/38504/2024, de 25 de noviembre (B.O.E. núm. 293 de 05.12.2024).

TRIBUNAL CALIFICADOR Nº 2

Segundo Ejercicio: Supuesto práctico

Programa: METROLOGÍA Y CALIBRACIÓN EN EL ÁMBITO DE DEFENSA AEROESPACIAL

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- El tiempo máximo de realización de este ejercicio es de **ciento ochenta (180) minutos.**
- El SUPUESTO PRÁCTICO, deberá entregarlo el opositor al finalizar el tiempo.

PÁGINA EN BLANCO

<u>Supuesto práctico 2 (Queja)</u>

El Laboratorio de calibración de temperatura y humedad del centro de metrología y calibración del INTA (**CMYC**)[1] ha recibido una queja de un cliente, **DOSCAL**[2], que alega que las incertidumbres reflejadas en el certificado de calibración del termómetro **MILIKELVIN**, que le acaban de calibrar, son mucho mayores que la capacidad de medida y calibración (CMC) acreditada del CMYC y las incertidumbres reflejadas en los certificados de las calibraciones del mismo equipo que le ha realizado en los tres últimos años. Esto supone que los criterios metrológicos establecidos por **DOSCAL** para este termómetro se incumplirían. Como consecuencia de ello, su plan de calibración se vería afectado y no podría asegurar su CMC acreditada para las calibraciones “in situ” de termómetros de lectura directa con sensor de resistencia.

(Nota 1): CMYC *está acreditado por ENAC. conforme a la norma UNE-EN ISO/IEC 17025:2017, para la calibración de termómetros de lectura directa con incertidumbres lo suficientemente bajas para asegurar el cumplimiento de las especificaciones del termómetro, compatibles con los criterios metrológicos establecidos por* ***DOSCAL*** *y que se han cumplido en las calibraciones realizadas en los tres años precedentes.*

(Nota 2): DOSCAL *está acreditado por ENAC conforme a la norma UNE-EN ISO/IEC 17025:2017 para la calibración en la magnitud, rango, capacidad de medida y calibración y categoría correspondiente del equipo termómetro* ***MILIKELVIN****, tales que le permiten utilizar el termómetro como patrón para sus calibraciones in situ.*

1) Indique el diagrama de flujo del proceso de gestión de quejas a aplicar, e investigue los posibles escenarios, la causa raíz de la queja, si es que esta aplica, en cada caso. ***[10 puntos]***.

2) ¿Qué acciones correctivas y, en el caso que pudiera plantear un riesgo no identificado, qué acciones se aplicarían en cada caso del apartado anterior? ***[10 puntos]***.

3) Diseñe un proceso de auditoría para la evaluación del proceso de calibración del laboratorio afectado. ***[10 puntos]***.

Conocimientos aplicables del temario:

Tema 6. La Entidad Nacional de Acreditación. Acreditación de laboratorios de ensayo y calibración.

Tema 13. Confirmación metrológica. Patrones primarios y secundarios.

Tema 14. Métodos de calibración. Fases generales del proceso de calibración por comparación.

Tema 15. Medida y calibración. Transferencia de unidades y obtención de la trazabilidad metrológica.

Tema 16. Fases generales en la calibración de un instrumento de medida. Cumplimiento de especificaciones.

Tema 18. Requisitos relativos a los recursos. Instrumentación de los laboratorios de calibración.

Tema 19. Requisitos relativos a los recursos. Criterios de aceptación y rechazo.

Tema 29. Expresión de la incertidumbre en un certificado de calibración. Interpretación de resultados. Cumplimiento de especificaciones de los instrumentos de medida.

Tema 34. La gestión de laboratorios de calibración acreditados. Revisión de los pedidos, ofertas y contratos.

Tema 36. La gestión de laboratorios de calibración acreditados. Plan de calibración.

Tema 37. La gestión de laboratorios de calibración acreditados. Control de trabajo no conforme.

Tema 38. La acreditación de laboratorios de calibración y ensayo.

Tema 39. Requisitos relativos a los recursos en un laboratorio de calibración acreditado.

Tema 40. La auditoría interna en los laboratorios de calibración acreditados.

Tema 41. Fases del proceso de evaluación en las auditorías externas. Aplicación a laboratorios de calibración.

Tema 42. Estructura documental de un sistema de gestión de la calidad en un laboratorio de calibración.

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TRIBUNAL CALIFICADOR Nº 2

Segundo Ejercicio: Supuesto práctico

Programa: METROLOGÍA Y CALIBRACIÓN EN EL ÁMBITO DE DEFENSA AEROESPACIAL

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PÁGINA EN BLANCO

Supuesto práctico 3 (Calibración por comparación)

Un laboratorio de calibración está acreditado por ENAC, conforme a la norma UNE-EN ISO/IEC 17025:2017, para la calibración de termómetros de resistencia de platino (TRP), con una capacidad de medida y calibración (CMC) acreditada en el margen de -30 ºC a 250 ºC de 0,005 ºC en el punto triple del agua, 0,01 ºC en el punto de fusión del hielo y 0,02 ºC en el resto del margen, para un nivel de confianza del 95 % (k=2).

Un cliente de la industria le solicita la calibración de un TRP de 400 mm de longitud terminado en un cabezal de conexiones industrial con cuatro terminales. El termómetro, según el fabricante, cumple con las tolerancias de clase W 0,6 de la Norma UNE-EN IEC 60751:2022 "Termómetros industriales de resistencia de platino y sensores de temperatura de platino"(Ver nota 1). Está interesado en la calibración en el margen de -25 ºC a 200 ºC.

Para la calibración, el laboratorio dispone de los siguientes equipos de ensayo y medida (EEM):

- Dos termómetros de resistencia de platino de 100 Ω, calibrados en el margen de -80 ºC a +290 ºC por comparación, con una incertidumbre de 3 mK en el punto triple del agua y de 10 mK en el resto del margen y que cumplen la clase W 0,1 de la citada norma. Su calentamiento propio a 1 mA < 3 mK.
- Un puente de resistencia de diez canales, con relación de 0 a 4, con resolución 0,000 001 Ω/Ω, con una incertidumbre de 2,0 x 10^{-6} Ω/Ω e intensidad de medida de 1 mA (± 10 %).
- Una resistencia patrón de 100 Ω con su recinto termostático, con una incertidumbre de 1,0 x 10^{-6} Ω/Ω y deriva anual -1,0 x 10^{-6} Ω/Ω.
- Una célula de punto triple del agua, con una incertidumbre de 0,2 mK
- Un baño de temperatura con margen de -30 ºC a 100 ºC, con estabilidad de ± 3 mK y uniformidad ± 10 mK.
- Un baño de temperatura con margen de 100 ºC a 290 ºC, con estabilidad de ± 3 mK y uniformidad ± 10 mK.

1) Realice un diagrama de flujo del proceso de verificación o confirmación metrológica y detalle el procedimiento de calibración a emplear, utilizando los EEM enumerados. ***[10 puntos]***.

2) Realice un diagrama de flujo del proceso de cálculo de incertidumbre y desarrolle el cálculo de incertidumbre para la medida realizada a la temperatura máxima, describiendo y justificando las contribuciones de incertidumbre empleadas. ***[10 puntos]***.

3) Confeccione el certificado de calibración ENAC, incluyendo entre los resultados (a) un punto con una desviación con respecto a la norma menor de la tolerancia de clase W0,6 con una incertidumbre que solapa con la tolerancia permitida y (b) otro con una desviación mayor que la tolerancia y cuya incertidumbre no solapa con la tolerancia permitida. ***[10 puntos]***.

Nota 1: Se adjunta copia de trabajo de la Norma UNE-EN IEC 60751:2022 "Termómetros industriales de resistencia de platino y sensores de temperatura de platino"

Conocimientos aplicables del temario:

Tema 6. La Entidad Nacional de Acreditación. Acreditación de laboratorios de ensayo y calibración.

Tema 13. Confirmación metrológica. Patrones primarios y secundarios.

Tema 14. Métodos de calibración. Fases generales del proceso de calibración por comparación.

Tema 15. Medida y calibración. Transferencia de unidades y obtención de la trazabilidad metrológica.

Tema 16. Fases generales en la calibración de un instrumento de medida. Cumplimiento de especificaciones.

Tema 17. Registro e informe de resultados. Contenido mínimo según la Norma ISO/IEC 17025.

Tema 18. Requisitos relativos a los recursos. Instrumentación de los laboratorios de calibración.

Tema 19. Requisitos relativos a los recursos. Criterios de aceptación y rechazo.

Tema 21. Método GUM. Estimación de incertidumbre de medida, incertidumbre típica, incertidumbre combinada, incertidumbre expandida.

Tema 22. Evaluación de la incertidumbre de medida en las calibraciones.

Tema 23. Requisitos del proceso. Evaluaciones tipo A y tipo B de la incertidumbre típica.

Tema 24. Evaluación de la incertidumbre de medida. Magnitudes de entrada. Estimación de contribuciones.

Tema 25. Determinación de la incertidumbre de medida. Expresión en informe de resultados.

Tema 26. Definición y cálculo de los grados efectivos de libertad. Aplicación en laboratorios de calibración.

Tema 27. Incertidumbre expandida. Determinación de factores de cobertura. Aplicación en laboratorios de calibración.

Tema 28. Cálculo y determinación de la incertidumbre expandida de medida en la calibración de un patrón de trabajo. Informe de resultados.

Tema 29. Expresión de la incertidumbre en un certificado de calibración. Interpretación de resultados. Cumplimiento de especificaciones de los instrumentos de medida.

Norma Española

UNE-EN IEC 60751:2022

Idioma: Inglés

Termómetros industriales de resistencia de platino y sensores de temperatura de platino. (Ratificada por la Asociación Española de Normalización en abril de 2022.)

Asociación Española
de Normalización
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UNE-EN IEC 60751:2022

Termómetros industriales de resistencia de platino y sensores de temperatura de platino. (Ratificada por la Asociación Española de Normalización en abril de 2022.)

Industrial platinum resistance thermometers and platinum temperature sensors (Endorsed by Asociación Española de Normalización in April of 2022.)

Thermomètres à résistance de platine et capteurs thermométriques de platine industriels (Entérinée par l'Asociación Española de Normalización en avril 2022.)

En cumplimiento del punto 11.2.5.4 de las Reglas Internas de CEN/CENELEC Parte 2, se ha otorgado el rango de documento normativo español UNE al documento normativo europeo EN IEC 60751:2022 (Fecha de disponibilidad 2022-03-04)

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Este anuncio causará efecto a partir del primer día del mes siguiente al de su publicación en la revista UNE.

La correspondiente versión oficial de este documento se encuentra disponible en la Asociación Española de Normalización (Génova 6 28004 MADRID, www.une.org).

Las observaciones a este documento han de dirigirse a:

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www.une.org

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN IEC 60751

March 2022

ICS 17.200.20

Supersedes EN 60751:2008 and all of its amendments and corrigenda (if any)

English Version

Industrial platinum resistance thermometers and platinum temperature sensors (IEC 60751:2022)

Thermomètres à résistance de platine et capteurs thermométriques de platine industriels (IEC 60751:2022)

Industrielle Platin-Widerstandsthermometer und Platin-Temperatursensoren (IEC 60751:2022)

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European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

Ref. No. EN IEC 60751:2022 E

European foreword

The text of document 65B/1210/FDIS, future edition 3 of IEC 60751, prepared by SC 65B "Measurement and control devices" of IEC/TC 65 "Industrial-process measurement, control and automation" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN IEC 60751:2022.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2022-12-03
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2025-03-03

This document supersedes EN 60751:2008 and all of its amendments and corrigenda (if any).

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Any feedback and questions on this document should be directed to the users' national committee. A complete listing of these bodies can be found on the CENELEC website.

Endorsement notice

The text of the International Standard IEC 60751:2022 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following note has to be added for the standard indicated:

IEC 61298-1 NOTE Harmonized as EN 61298-1

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE 1 Where an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

Publication	Year	Title	EN/HD	Year
IEC 60068-2-6	-	Environmental testing - Part 2-6: Tests - Test Fc: Vibration (sinusoidal)	EN 60068-2-6	-
IEC 61152	-	Dimensions of metal-sheathed thermometer elements	EN 61152	-
IEC 61515	2016	Mineral insulated metal-sheathed thermocouple cables and thermocouples	EN 61515	2016

IEC 60751

Edition 3.0 2022-01

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Industrial platinum resistance thermometers and platinum temperature sensors

Thermomètres à résistance de platine et capteurs hermométriques de platine industriels

IEC 60751:2022-01(en-fr)

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www.iec.ch

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IEC 60751

Edition 3.0 2022-01

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Industrial platinum resistance thermometers and platinum temperature sensors

Thermomètres à résistance de platine et capteurs hermométriques de platine industriels

INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

ICS 17.200.20

ISBN 978-2-8322-1069-2

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INDUSTRIAL PLATINUM RESISTANCE THERMOMETERS AND PLATINUM TEMPERATURE SENSORS

FOREWORD

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IEC 60751 has been prepared by subcommittee 65B: Measurement and control devices, of IEC technical committee 65: Industrial-process measurement, control and automation. It is an International Standard.

This third edition cancels and replaces the second edition published in 2008. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) formula of resistance versus temperature relationship become the standard specification and the numerical table ceases to be the standard,
b) new clause "Compliance and requirement" is introduced,
c) tolerance acceptance test is modified,
d) an expanded marking system is introduced to accommodate special valid temperature range,
e) vibration test method is revised,
f) cold seal is introduced as an additional type test,

g) numerical table of resistance versus temperature is included in Annex A as information.

The text of this International Standard is based on the following documents:

Draft	Report on voting
65B/1210/FDIS	65B/1214/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INDUSTRIAL PLATINUM RESISTANCE THERMOMETERS AND PLATINUM TEMPERATURE SENSORS

1 Scope

This International Standard specifies the requirements, in addition to the resistance versus temperature relationship, for both industrial platinum resistance thermometers (later referred to as "thermometers") and industrial platinum resistance temperature sensors (later referred to as "platinum resistors") whose electrical resistance is derived from defined functions of temperature.

Values of temperature in this document are in terms of the International Temperature Scale of 1990, ITS-90. A temperature in the unit °C of this scale is denoted by the symbol t, except in Table A.1 where the full nomenclature t_{90} /°C is used.

This document applies to platinum resistors whose temperature coefficient α, defined as

$$\alpha = \frac{R_{100} - R_0}{R_0 \cdot 100\,°\text{C}},$$

is conventionally written as $\alpha = 3{,}851 \cdot 10^{-3}\ °\text{C}^{-1}$, where R_{100} is the resistance at t = 100 °C and R_0 is the resistance at t = 0 °C.

This document covers platinum resistors and thermometers for the temperature range −200 °C to +850 °C with different tolerance classes. It can also cover particular platinum resistors or thermometers for a part of this temperature range.

For resistance versus temperature relationships with uncertainties less than 0,1 °C, which are possible only for platinum resistors or thermometers with exceptionally high stability and individual calibration, a more complex interpolation equation than is presented in this document can be necessary. The specification of such equations is outside the scope of this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60068-2-6, *Environmental testing – Part 2-6: Tests – Test Fc: Vibration (sinusoidal)*

IEC 61152, *Dimensions of metal-sheathed thermometer elements*

IEC 61515:2016, *Mineral insulated metal-sheathed thermocouple cables and thermocouples*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1
platinum resistor
resistor made from a platinum wire or film with defined electrical characteristics, embedded in an insulator (in most cases glass or ceramic), designed to be assembled into a platinum resistance thermometer or into an integrated circuit

3.2
platinum resistance thermometer
thermometer
PRT
temperature-responsive device consisting of one or more sensing platinum resistors within a protective sheath, internal connecting wires, and external terminals to permit connection of electrical measurement instruments

Note 1 to entry: Mounting means and connection heads can be included. Not included is any separable protection tube or thermowell.

3.3
nominal resistance
expected resistance R_0 of a platinum resistor or thermometer at 0 °C, declared by the supplier and shown in the thermometer marking, usually rounded to the nearest ohm

Note 1 to entry: Platinum resistors are often characterized by their nominal resistance. For example, a platinum resistor with R_0 = 100 Ω is often referred to as a Pt100

3.4
terminals
termination of the connections supplied with the platinum resistance thermometer

Note 1 to entry: Typical types of terminals are:

- screws or clamps on the terminal socket,
- pins of fixed connectors,
- open ends of fixed cables or equivalents.

3.5
temperature-sensitive length
length of the thermometer whose temperature directly influences the resistance measured

Note 1 to entry: Usually, the temperature-sensitive length is related to the length of the platinum resistor.

3.6
minimum immersion depth
immersion depth at which the change from the calibration at full immersion does not exceed 0,1 °C

3.7
tolerance
maximum allowable deviation of $R(t)$ measured at temperature t from the nominal resistance versus temperature relationship expressed as $\Delta t(t)$ in °C

3.8
dielectric strength
maximum voltage between all parts of the electric circuit and the sheath of the thermometer or, in the case of a thermometer with two or more sensing circuits, between two individual circuits that the thermometer can withstand without damage

3.9
insulation resistance
electrical resistance measured between any part of the electric circuit and the sheath at ambient or elevated temperatures and with a specified measuring voltage (AC or DC)

3.10
self-heating
increase of the temperature of the platinum resistor or of the platinum resistor in a thermometer caused by the dissipated energy of the measuring current

3.11
self-heating coefficient
temperature rise due to dissipated energy by measuring current in a resistor expressed with the unit °C/mW

3.12
thermal response time
time a thermometer takes to reach a specified percentage of a step change in temperature

3.13
thermoelectric effect
effect of inducing electro-motive force (abbreviated by e.m.f hereafter) caused by different metals used in the electric circuit of the thermometer and by thermoelectric inhomogeneity of the internal leads at the conditions of temperature gradients along the leads

3.14
hysteresis
resistance difference at the middle of the temperature range between before and after exposing the thermometer to the lower and upper limit of the temperature range

3.15
expanded uncertainty
quantity defining an interval about the result of a measurement that can be expected to encompass a large fraction of the distribution of values that could reasonably be attributed to the measurand

Note 1 to entry: For reference, see 3.16.

3.16
coverage factor
numerical factor used as a multiplier of the combined standard uncertainty in order to obtain an expanded uncertainty

Note 1 to entry: Coverage factor, k, is typically in the range 2 to 3. In this document, $k = 2$ is chosen, the confidence level of which is 95 %. Refer to Bibliography [1].

4 Characteristics

4.1 General

The nominal resistance versus temperature relationship for platinum resistors and thermometers and their tolerance class are standardized. This specification is applied to a sensing platinum resistor at its connecting points and to a complete thermometer at its terminals.

In the case of two-wire connections (see 5.5), the resistance values of the leads between the connecting point of the platinum resistor and the terminals shall be considered. They shall be subtracted from measured resistances. In some cases, it is also advisable to consider the temperature coefficient of the lead wires, the geometrical characteristics of the wires, and the temperature distribution along their length. This information may be supplied to users as additional information (refer to Clause 7).

4.2 Nominal resistance versus temperature relationship

The resistance versus temperature relationships used in this document are as follows:

For the range −200 °C to 0 °C:

$$R_t = R_0\,[1 + \mathrm{A}t + \mathrm{B}t^2 + \mathrm{C}(t - 100\ °\mathrm{C})\,t^3]$$

For the range of 0 °C to 850 °C:

$$R_t = R_0\,(1 + \mathrm{A}t + \mathrm{B}t^2)$$

where

R_t is the resistance at the temperature t,

R_0 is the resistance at t = 0 °C.

The constants in these equations are,

A = 3,908 3 × 10^{-3} $°\mathrm{C}^{-1}$

B = −5,775 × 10^{-7} $°\mathrm{C}^{-2}$

C = −4,183 × 10^{-12} $°\mathrm{C}^{-4}$.

4.3 Numerical table of resistance values

Table A.1 and Table A.2 are derived from the equations and coefficients specified in 4.2 for a thermometer or platinum resistor of nominal resistance R_0 of 100 Ω.

Table A.1 and Table A.2 are applicable to any thermometer and platinum resistor having any value of R_0.

In this case, the resistance values in Table A.1 and Table A.2 shall be multiplied by the factor R_0 / 100 Ω.

NOTE 1 In this edition, the numerical tables given in Annex A cease to be normative; they are now informative. The specification of this document is the formula described in 4.2 with which user can calculate numerical value of R_t.

NOTE 2 The most frequently used device has R_0 of 100 Ω. Devices with R_0 of 10 Ω, 500 Ω or 1000 Ω are used frequently as well.

5 Compliance and requirements

5.1 Compliance

In order for a thermometer to be compliant with this document, it shall be made from a platinum resistor which is compliant with this document.

Platinum resistors and thermometers shall be tested to prove that the device meets all the applicable requirements specified in this document. Suppliers shall be responsible for conducting the tests and for proving that the device conforms to this document before transferring the device to the user. The test method and evaluation are specified in this document.

5.2 Tolerance classes

5.2.1 Tolerance class and its temperature range of validity

Tolerance classes are given in Table 1 for a platinum resistor and in Table 2 for a thermometer for any value of R_0.

These tolerance classes are closely related to the operable temperature range. Therefore, the temperature ranges of validity of a tolerance class are shown in the adjacent column in the table. Temperature ranges of validity are based on the working experience with film and wire platinum resistors.

A thermometer that has a modified tolerance or temperature range of validity can still be compliant with this document provided it satisfies all the applicable requirements, other than the tolerance or the temperature range of validity, and the modification is notified to the user. Details on this are described in 5.2.3.2.

Thermometers or platinum resistors without the specified temperature range of validity for the tolerance are not permitted in this document.

5.2.2 Tolerance class of platinum resistors

Table 1 specifies the tolerance class for platinum resistors. Tolerances and ranges of validity that differ from values given in Table 1 shall be agreed between the supplier and the user.

Table 1 – Tolerance class of platinum resistors

Wire wound platinum resistors		**Film platinum resistors**		**Tolerance** (°C)
Tolerance class	**Temperature range of validity** (°C)	**Tolerance class**	**Temperature range of validity** (°C)	
W 0,1	−100 to +350	F 0,1	0 to +150	±(0,1 + 0,001 7 | *t* |)
W 0,15	−100 to +450	F 0,15	−30 to +300	±(0,15 + 0,002 | *t* |)
W 0,3	−196 to +660	F 0,3	−50 to +500	±(0,3 + 0,005 | *t* |)
W 0,6	−196 to +660	F 0,6	−50 to +600	±(0,6 + 0,01 | *t* |)
NOTE The symbol | *t* | denotes modulus of temperature in °C without regard to the sign.				

5.2.3 Tolerance classes and marking of thermometers

5.2.3.1 Tolerance classes of thermometers

Table 2 specifies the tolerance class for thermometers.

Table 2 – Tolerance class of thermometers

Tolerance class	Temperature range of validity (°C) for thermometers made using		Tolerance (°C)
	Wire wound platinum resistors	Film platinum resistors	
AA	−50 to +250	0 to +150	±(0,1 + 0,0017 | *t* |)
A	−100 to +450	−30 to +300	±(0,15 + 0,002 | *t* |)
B	−196 to +600	−50 to +500	±(0,3 + 0,005 | *t* |)
C	−196 to +600	−50 to +600	±(0,6 + 0,01 | *t* |)

NOTE The symbol | *t* | denotes modulus of temperature in °C without regard to the sign.

5.2.3.2 Special tolerance classes of thermometers

Tolerances and ranges of validity that differ from the values given in Table 2 shall be agreed between the supplier and the user. These special thermometers shall be clearly distinguished from a standard device by the "-sp" marking as is specified in 5.2.3.3. Recommended special tolerance classes may be constructed as multiples or fractions of class B tolerance. Example 1 in 5.2.3.3 demonstrates this case.

It is also left to the suppliers and the users to establish a special class for their thermometers with a temperature range different from the ranges in Table 2. Special temperature ranges of validity may be defined for restricted or extended temperature ranges. Example 2 in 5.2.3.3 demonstrates this case.

5.2.3.3 Marking of thermometers

Each thermometer shall be marked or labelled accordingly so that the user can confirm, either directly or indirectly, the number of platinum resistors, connecting wire configuration, tolerance class, and its temperature range of validity.

Marking Example1: 2 × Pt100 / (2/3B) –F-sp / 3 / −50 / +250

This means:

- Two platinum resistor construction,
- Nominal resistance: R_0 = 100 Ω,
- Tolerance class: 2/3B [Tolerance value ±(0,2 + 0,0033 | *t* |)],
- Platinum resistor type: F (film),
- Special tolerance class [(2/3)B]: suffix –sp of F is the notification. It means that the tolerance class is different from Table 2 and range of validity differs also,
- Wire configuration: 3 wire configuration (see Figure 1),
- Range of validity: −50 °C to +250 °C,
- Lower temperature limit of the thermometer: −50 °C,
- Upper temperature limit of the thermometer: +250 °C.

Marking Example 2: 1 × Pt100 / AA-W-sp / 4 / −50 / +300

This means:

- One platinum resistor construction,
- Nominal resistance: R_0 = 100 Ω,

- Tolerance class: AA,
- Platinum resistor type: W (wire wound),
- Special range of validity; suffix -sp of W means that range of validity is different from Table 2,
- Wire configuration: 4 wire configuration (see Figure 1),
- Range of validity: −50 °C to +300 °C,
- Lower temperature limit of the thermometer: −50 °C,
- Upper temperature limit of the thermometer: +300 °C.

5.3 Measuring current

The measuring current of a platinum resistor or thermometer shall be limited to a value at which the self-heating of the thermometer under conditions specified in 6.4.3 does not exceed 25 % of the tolerance value of the declared tolerance class. The measuring current is usually not more than 1 mA for a 100 Ω wire wound platinum resistor.

5.4 Electrical supply

Platinum resistors and thermometers shall be constructed so that they are suitable for use in measuring systems using direct current or alternating current at frequencies up to 100 Hz. Some measuring systems may require operation at higher frequencies.

5.5 Connecting wire configuration

Thermometers of tolerance class better than class B shall have 3-wire or 4-wire configuration with 4-wire configuration being recommended.

Thermometers may be constructed with one or more platinum resistors and a variety of internal connecting wire configurations. A typical example of identification and designation of the terminals is shown in Figure 1.

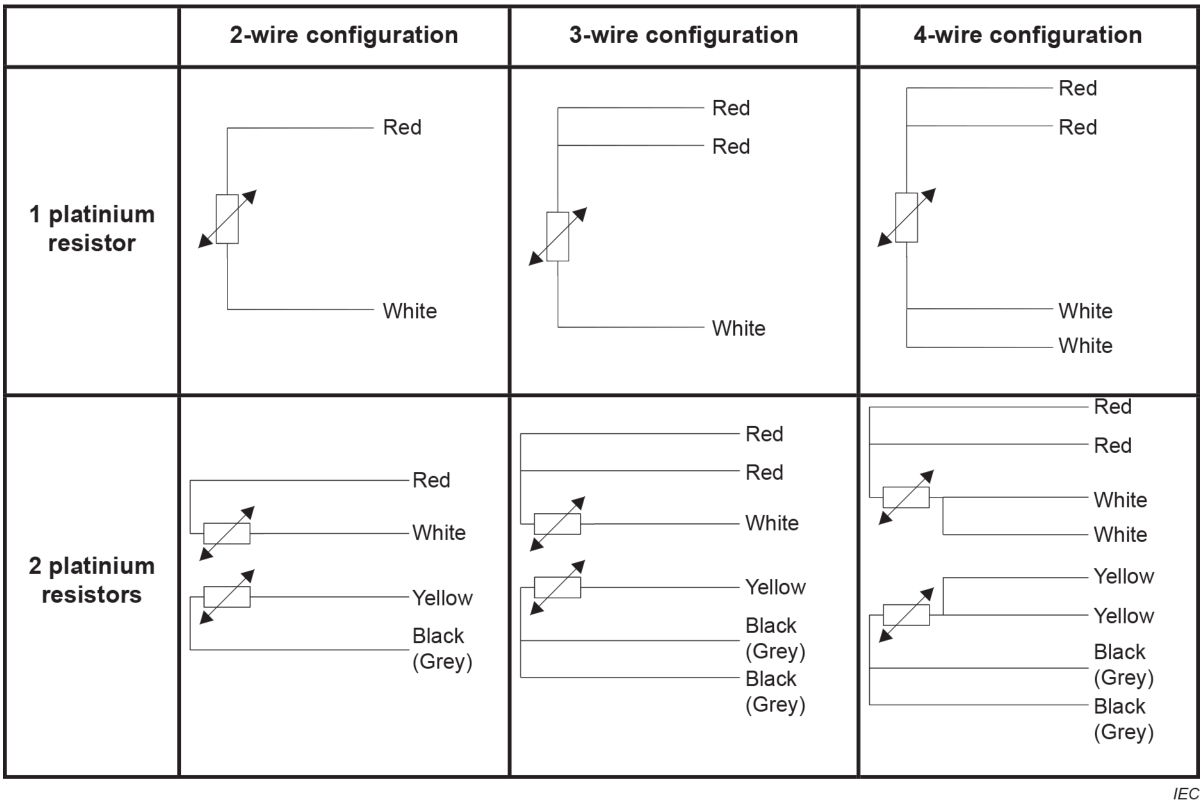


Figure 1 – Example of connecting configurations

6 Tests

6.1 General

6.1.1 Test categories

Tests shall be performed to prove that platinum resistors or thermometers conform to the requirements of this document. The tests are categorised as routine production test, type test, and additional type test. It is not intended or recommended that all tests be performed on every platinum resistor or thermometer supplied. Different kinds of tests are therefore described from 6.1.2 to 6.1.5.

6.1.2 Routine production tests

The routine production test shall be performed on every platinum resistor or thermometer manufactured in accordance with this document. This routine production test can be replaced by a sampling test provided that technically established control procedures are in place to demonstrate that the statistical sampling test is sufficient. If the routine production test is replaced by a sampling test, the user shall be informed.

6.1.3 Type tests

Type tests shall be carried out on a platinum resistor or a thermometer of each particular design and temperature range of operation. The routine production test items shall also be performed on the type tests. These tests are subdivided into tests for all forms of platinum resistors or thermometers.

6.1.4 Additional type tests for thermometers

Additional type tests may be required by other regulations or by agreement between the supplier and the user for special applications. If not stated otherwise, there are no fixed specifications for these test items. The results of the tests shall be made available on request.

6.1.5 Summary of the tests

All the tests specified in this document are summarized in Table 3 with reference to the clause in which details of the test are given.

Table 3 – Table of tests specified in this document

	Routine production tests		Type tests		Additional type tests for thermometers
	Platinum resistors	Thermometers	Platinum resistors	Thermometers	
Tolerance acceptance test	6.2.1	6.3.1		6.3.1	
Insulation resistance at ambient temperature		6.3.2		6.3.2	
Sheath integrity test		6.3.3		6.3.3	
Dimensional test		6.3.4		6.3.4	
Tolerances			6.4.1	6.5.1	
Stability at upper temperature limit			6.4.2	6.5.2	
Self-heating			6.4.3	6.5.3	
Insulation resistance at elevated temperature				6.5.4	
Thermal response time				6.5.5	
Thermoelectric effect				6.5.6	
Effect of temperature cycling				6.5.7	
Effect of hysteresis				6.5.8	
Minimum immersion depth				6.5.9	
Capacitance					6.6.2
Inductance					6.6.3
Dielectric strength					6.6.4
Vibration test					6.6.5
Drop test					6.6.6
Cold seal					6.6.7

6.2 Routine production tests for platinum resistors

6.2.1 Tolerance acceptance test

All types of platinum resistors shall be tested at one temperature at least. The test temperature shall be in the range from −5 °C to +30 °C, preferably 0 °C. Estimation of measurement uncertainty for the test shall be done with coverage factor k = 2.

Platinum resistors of the tolerance classes W0,1, F0,1, W0,15 and F0,15 shall be tested at one additional temperature at least. This test temperature shall be the upper or lower temperature limit of the platinum resistor, or spaced from the first test temperature by 90 °C, whichever is less.

For selection of the platinum resistor, the supplier shall perform a measurement with expanded uncertainty of less than 1/3 of the tolerance band. However, the supplier shall also be allowed to select a measurement with an alternative expanded uncertainty to respond to demands, provided that the uncertainty is notified to the user.

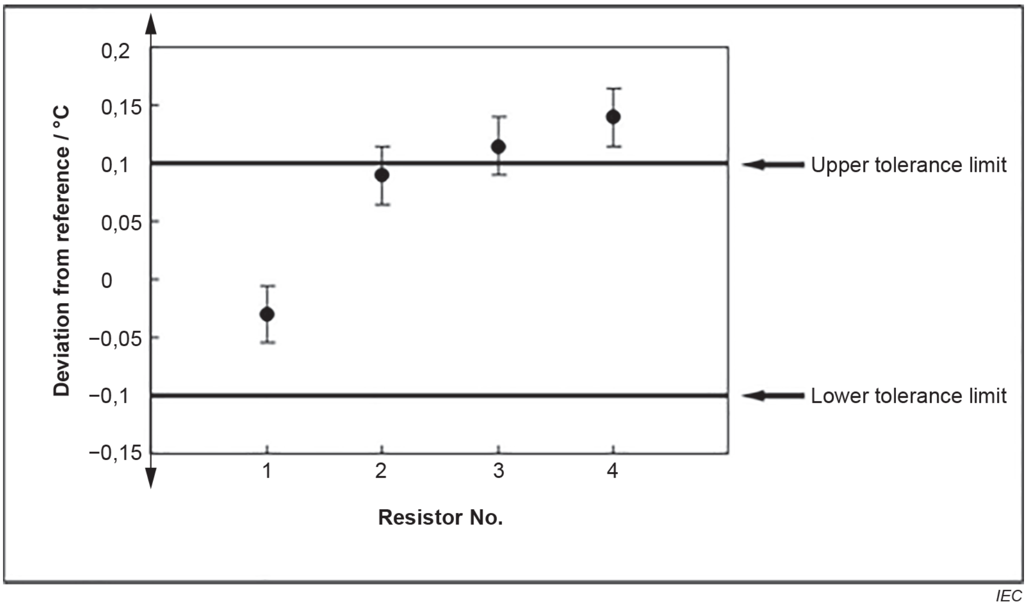
As a typical example, the resistors numbered 1 to 4 in Figure 2 illustrate resistance deviation of tolerance class 0,1 resistors.

The selection criteria for the supplier are: the equivalent temperature deviation calculated by resistance deviation from the nominal resistance versus the temperature function plus the expanded uncertainty of the measurement shall be completely within the corresponding tolerance band which is exemplified by resistor 1 in Figure 2.

The rejection criteria for the user are: at the entrance, check the tolerance value is not met. It is judged by the measurement result that the deviation plus expanded uncertainty of the measurement is completely outside the tolerance band which is exemplified by resistor 4 in Figure 2.

Regarding resistors 2 and 3, of which part of the expanded uncertainty interval lies outside the tolerance band, the user can ask the supplier for information about the test measurement of the particular platinum resistor.

NOTE For the selection guidelines, refer to the Bibliography [2].



The examples shown are for tolerance class 0,1. Limits are part of the tolerance band.

Figure 2 – Examples of test results for selecting or rejecting platinum resistors

6.3 Routine production tests for thermometers

6.3.1 Tolerance acceptance test

The suppliers shall ensure that platinum resistors of the appropriate tolerance class have been used for their thermometers. Thermometers of tolerance classes A and better (see 5.2) shall be tested for resistance accuracy at one temperature point in the range of −5 °C to +30 °C. All the selection criteria are the same as those described in 6.2.1.

6.3.2 Insulation resistance at ambient temperature

The insulation resistance between each terminal and the sheath shall be tested with a test voltage of a minimum of 100 V DC.

The insulation resistance shall be not less than 100 MΩ.

For thermometers with two or more measuring circuits, the same test shall be made between the individual circuits.

6.3.3 Sheath integrity test

6.3.3.1 General

The integrity of the sheath and all closure welding shall be tested in general by suitable means: either by a suitable test method not mentioned in this document, or with such a method given in this document. For particular applications, sheath integrity tests may be agreed between the user and the supplier. Examples of commonly accepted suitable integrity tests are given in 6.3.3.2 to 6.3.3.5.

6.3.3.2 Water quench test

The thermometer shall be subjected to a minimum temperature of 300 °C for a minimum time of 5 min and then immediately plunged into water at room temperature. Then the insulation resistance shall be measured while the thermometer is immersed. The insulation resistance shall meet the requirements of 6.3.2.

6.3.3.3 Nitrogen pressure test

The thermometer shall be externally pressurized for approximately 30 s at a minimum pressure of 2,5 MPa in a nitrogen gas, after which the thermometer shall be immediately immersed in water or alcohol. There shall be no bubbling from the weld.

6.3.3.4 Liquid nitrogen test

The thermometer shall be immersed in liquid nitrogen until the temperature is stabilized, after which the thermometer shall be immediately immersed in water or alcohol. There shall be no bubbling from the weld. This test is only recommended for thermometers that can be used at a temperature down to −196 °C or −200 °C.

6.3.3.5 Helium leakage test

The helium leakage test shall be mentioned as a further means of integrity test. The details of this test may be determined by agreement between the supplier and the user.

6.3.4 Dimensional test

If the manufactured thermometer is covered by the scope of IEC 61152, the outside diameter and the straightness shall be tested to be in accordance with the requirements of IEC 61152.

6.4 Type tests for platinum resistors

6.4.1 Tolerances

The tolerance values for the specified tolerance class shall be met for the whole temperature range of validity. The number of necessary measurements for this test depends on the temperature range and the tolerance class and shall include temperatures close to the upper and lower limits of the declared temperature range. To consider uncertainty, refer to 6.2.1.

6.4.2 Stability at upper temperature limit

The platinum resistor shall be subjected to its declared upper temperature limit in air for 1 000 hours. The drift in resistance ($R_{0,\text{ End of test}} - R_{0,\text{ Start of test}}$) shall be converted to temperature and it shall not be more than the tolerance value at 0 °C for the respective tolerance class.

6.4.3 Self-heating

The self-heating coefficient shall be evaluated at a temperature between 0 °C and 30 °C in flowing air with a velocity of (3 ± 0,3) m/s or in flowing water with a velocity (0,3 ± 0,1) m/s. The self-heating under the above mentioned conditions shall not exceed 25 % of the tolerance value of the declared tolerance class at the declared maximum measuring current. Applied test conditions shall be declared.

6.5 Type tests for thermometers

6.5.1 Tolerances

The tolerance values for the specified tolerance class shall be met for the whole temperature range of validity. The number of necessary measurements for this test depends on the temperature range and the tolerance class, and shall include temperatures close to the upper and lower limits of the declared temperature range.

NOTE Tolerance is closely related to the acceptance test. Acceptance criteria are described in 6.2.1 of this document.

6.5.2 Stability at upper temperature limit

The thermometer shall be subjected to its declared upper temperature limit in air for a minimum of 4 weeks (672 h) continuously. The drift in resistance ($R_{0,\text{ End of test}} - R_{0,\text{ Start of test}}$) is to be converted to temperature, and it shall be within the tolerance band of the declared tolerance class. The insulation resistance specification 6.5.4 shall be met after the exposure.

6.5.3 Self-heating

The same procedure shall be applied for this test as is specified for platinum resistors in 6.4.3, and the same evaluation condition shall be applied.

6.5.4 Insulation resistance at elevated temperature

The insulation resistance shall be tested with the thermometer being at the rated maximum temperature over at least the minimum immersion depth and a test voltage minimum of 10 V DC. The insulation resistance between each terminal and the sheath shall not be less than indicated in Table 4.

Table 4 – Minimum insulation resistance of thermometers at the maximum temperature

Rated maximum temperature	Minimum insulation resistance
°C	MΩ
Up to 250	20
251 to 450	2
451 to 650	0,5
651 to 850	0,2

6.5.5 Thermal response time

The thermal response time T in flowing water with a velocity (0,3 ± 0,1) m/s or in flowing air with a velocity (3 ± 0,3) m/s shall be recorded. To specify the response time it is necessary to declare the percentage of response, usually $T_{0,9}$, $T_{0,63}$, $T_{0,5}$, or $T_{0,1}$, which gives the time until the thermometer reading reaches 90 %, 63,2 %, 50 % or 10 % of the temperature step change, respectively. The test medium and its flow conditions shall be specified (usually flowing water or flowing air).

6.5.6 Thermoelectric effect

The thermometer shall be immersed in a uniform temperature environment of declared highest temperature of the thermometer class. The immersion where induced e.m.f. across the terminals of the thermometer attains its maximum shall be found. With this condition, the maximum permissible DC current shall be applied to obtain resistance R_n by measuring DC voltage across the terminals. The current shall then be reversed to obtain R_r. The equivalent temperature deviation calculated by the difference between R_n and R_r shall not exceed the tolerance value of the declared tolerance class in Table 2. The terminals shall be kept at ambient temperature throughout the process.

6.5.7 Effect of temperature cycling

The thermometer shall be brought carefully to the upper limit of its temperature range and then exposed to air at room temperature. It shall next be brought slowly to the lower limit of its temperature range and then exposed to air at room temperature. At each limit, the thermometer shall be immersed to at least its declared minimum immersion depth and shall be maintained at the temperature for sufficient time to reach equilibrium. If the temperature range of the thermometer is outside of room temperature, the test cycle shall be performed without exposition to room temperature.

After 10 cycles between the upper and the lower temperature limit, measured drift in resistance ($R_{0,\text{ End of test}} - R_{0,\text{ Start of test}}$) shall be converted to temperature and it shall be within the respective tolerance band of the class.

6.5.8 Effect of hysteresis

The resistance of the thermometer shall be measured in the middle of the temperature range after exposure to a temperature at the lower limit of the temperature range. Then the resistance shall be measured again at the same temperature in the middle of the temperature range after exposure of the thermometer to a temperature at the upper limit of the temperature range. The temperature difference between these two measurements shall not be larger than the tolerance value at the test temperature for the respective tolerance class. It is important for both measurements that the thermometer goes directly from the ends of the temperature range to the temperature in the middle of the range. Taking a thermometer of range 0 °C to 400 °C as an example, this test condition is interpreted as follows. The thermometer shall go from 0 °C to 200 °C, then from 200 °C to 400 °C, and finally from 400 °C to 200 °C without being cooled below 200 °C during this last step.

NOTE Hysteresis as defined in IEC 61298-1 can be applied to thermometers by the method described here.

6.5.9 Minimum immersion depth

The thermometer shall be immersed in water with a temperature of at least 85 °C to the same depth as is used for the tolerance acceptance test and with the thermometer terminals close to the ambient temperature. The thermometer shall then be extracted step by step out of the medium until the resistance changes by an amount which corresponds to a temperature change of 0,1 °C. This immersion depth shall be declared as the minimum immersion depth.

6.6 Additional type tests for thermometers

6.6.1 General

For particular applications, special type tests may be agreed between the user and the supplier. In 6.6.2 to 6.6.7, some of the typical examples are described.

6.6.2 Capacitance

The capacitance between one terminal and the sheath at a frequency of 1 kHz is to be reported.

6.6.3 Inductance

The inductance of each platinum resistor circuit at a frequency of 1 kHz is to be reported.

6.6.4 Dielectric strength

A test voltage of 500 V AC shall be applied between one measuring circuit and the sheath of the thermometer for a duration of 1 min. During this time, no breakdown shall occur. For thermometers with two or more measuring circuits, the same test shall be made between the individual circuits.

6.6.5 Vibration test

Vibration tests may be performed for the thermometers used in a specific environment with possible vibrations. The thermometer shall be mounted as it will be installed. Test methods shall comply with IEC 60068-2-6. The parameters such as frequency range and forcing acceleration of the vibration shall be determined by the agreement between the user and the supplier. The tested thermometer shall comply with all the electrical and mechanical requirements of this document.

6.6.6 Drop test

This test is intended to reveal any weakness of construction. The thermometer, complete with head, if any, shall be held with its longitudinal axis horizontal and then be dropped ten times from a height of 250 mm onto a 6 mm thick steel plate on a rigid floor. The thermometer shall be inspected for mechanical damage. It shall also be tested to ensure continued compliance with the insulation resistance requirements of 6.3.2 and the maintenance of electrical continuity.

6.6.7 Cold seal

The test shall be performed to ensure that the thermometer reading shall not be influenced by moisture in the environment where it is operated. The test method and validation shall follow in IEC 61515:2016, 5.3.1.5 (Cold seal immersion test). It is recommended to cycle the thermometers thermally according to the application range before applying the test. Thermometers with thermal blocks shall not be mounted for this test.

7 Information to be made available by the supplier

7.1 General

Suppliers shall keep information about their products so that users are able to access when it is needed. The items in 7.2 and 7.3 are typical information.

7.2 Applicable to resistors

- Results of all specified type tests,
- Length of the two leads,
- Linear resistance of the leads in Ω/mm,
- Temperature coefficient of resistance of the leads,
- Material of the leads.

7.3 Applicable to thermometers

- Results of all specified type tests,
- Temperature-sensitive length and position of platinum resistor,
- Ohmic resistance of internal connection wires and their temperature coefficient shall be available for 2-wire configurations where the resistance of internal connection wires is equal to or greater than the tolerance value at the maximum rated temperature in the respective tolerance class.

Annex A
(informative)

Numerical table

Table A.1 – Temperature versus resistance relationship below 0 °C; R_0 = 100,00 Ω

t_{90}/°C	Resistance in ohms at the temperature t_{90}/°C										t_{90}/°C
	0	−1	−2	−3	−4	−5	−6	−7	−8	−9	
−200	18,52										−200
−190	22,83	22,40	21,97	21,54	21,11	20,68	20,25	19,82	19,38	18,95	−190
−180	27,10	26,67	26,24	25,82	25,39	24,97	24,54	24,11	23,68	23,25	−180
−170	31,34	30,91	30,49	30,07	29,64	29,22	28,80	28,37	27,95	27,52	−170
−160	35,54	35,12	34,70	34,28	33,86	33,44	33,02	32,60	32,18	31,76	−160
−150	39,72	39,31	38,89	38,47	38,05	37,64	37,22	36,80	36,38	35,96	−150
−140	43,88	43,46	43,05	42,63	42,22	41,80	41,39	40,97	40,56	40,14	−140
−130	48,00	47,59	47,18	46,77	46,36	45,94	45,53	45,12	44,70	44,29	−130
−120	52,11	51,70	51,29	50,88	50,47	50,06	49,65	49,24	48,83	48,42	−120
−110	56,19	55,79	55,38	54,97	54,56	54,15	53,75	53,34	52,93	52,52	−110
−100	60,26	59,85	59,44	59,04	58,63	58,23	57,82	57,41	57,01	56,60	−100
−90	64,30	63,90	63,49	63,09	62,68	62,28	61,88	61,47	61,07	60,66	−90
−80	68,33	67,92	67,52	67,12	66,72	66,31	65,91	65,51	65,11	64,70	−80
−70	72,33	71,93	71,53	71,13	70,73	70,33	69,93	69,53	69,13	68,73	−70
−60	76,33	75,93	75,53	75,13	74,73	74,33	73,93	73,53	73,13	72,73	−60
−50	80,31	79,91	79,51	79,11	78,72	78,32	77,92	77,52	77,12	76,73	−50
−40	84,27	83,87	83,48	83,08	82,69	82,29	81,89	81,50	81,10	80,70	−40
−30	88,22	87,83	87,43	87,04	86,64	86,25	85,85	85,46	85,06	84,67	−30
−20	92,16	91,77	91,37	90,98	90,59	90,19	89,80	89,40	89,01	88,62	−20
−10	96,09	95,69	95,30	94,91	94,52	94,12	93,73	93,34	92,95	92,55	−10
0	100,00	99,61	99,22	98,83	98,44	98,04	97,65	97,26	96,87	96,48	0

Table A.2 – Temperature versus resistance relationship above 0 °C; R_0 = 100,00 Ω

t_{90}/°C	Resistance in ohms at the temperature t_{90}/°C										t_{90}/°C
	0	1	2	3	4	5	6	7	8	9	
0	100,00	100,39	100,78	101,17	101,56	101,95	102,34	102,73	103,12	103,51	0
10	103,90	104,29	104,68	105,07	105,46	105,85	106,24	106,63	107,02	107,40	10
20	107,79	108,18	108,57	108,96	109,35	109,73	110,12	110,51	110,90	111,29	20
30	111,67	112,06	112,45	112,83	113,22	113,61	114,00	114,38	114,77	115,15	30
40	115,54	115,93	116,31	116,70	117,08	117,47	117,86	118,24	118,63	119,01	40
50	119,40	119,78	120,17	120,55	120,94	121,32	121,71	122,09	122,47	122,86	50
60	123,24	123,63	124,01	124,39	124,78	125,16	125,54	125,93	126,31	126,69	60
70	127,08	127,46	127,84	128,22	128,61	128,99	129,37	129,75	130,13	130,52	70
80	130,90	131,28	131,66	132,04	132,42	132,80	133,18	133,57	133,95	134,33	80
90	134,71	135,09	135,47	135,85	136,23	136,61	136,99	137,37	137,75	138,13	90
100	138,51	138,88	139,26	139,64	140,02	140,40	140,78	141,16	141,54	141,91	100
110	142,29	142,67	143,05	143,43	143,80	144,18	144,56	144,94	145,31	145,69	110
120	146,07	146,44	146,82	147,20	147,57	147,95	148,33	148,70	149,08	149,46	120
130	149,83	150,21	150,58	150,96	151,33	151,71	152,08	152,46	152,83	153,21	130
140	153,58	153,96	154,33	154,71	155,08	155,46	155,83	156,20	156,58	156,95	140
150	157,33	157,70	158,07	158,45	158,82	159,19	159,56	159,94	160,31	160,68	150
160	161,05	161,43	161,80	162,17	162,54	162,91	163,29	163,66	164,03	164,40	160
170	164,77	165,14	165,51	165,89	166,26	166,63	167,00	167,37	167,74	168,11	170
180	168,48	168,85	169,22	169,59	169,96	170,33	170,70	171,07	171,43	171,80	180
190	172,17	172,54	172,91	173,28	173,65	174,02	174,38	174,75	175,12	175,49	190
200	175,86	176,22	176,59	176,96	177,33	177,69	178,06	178,43	178,79	179,16	200
210	179,53	179,89	180,26	180,63	180,99	181,36	181,72	182,09	182,46	182,82	210
220	183,19	183,55	183,92	184,28	184,65	185,01	185,38	185,74	186,11	186,47	220
230	186,84	187,20	187,56	187,93	188,29	188,66	189,02	189,38	189,75	190,11	230
240	190,47	190,84	191,20	191,56	191,92	192,29	192,65	193,01	193,37	193,74	240
250	194,10	194,46	194,82	195,18	195,55	195,91	196,27	196,63	196,99	197,35	250
260	197,71	198,07	198,43	198,79	199,15	199,51	199,87	200,23	200,59	200,95	260
270	201,31	201,67	202,03	202,39	202,75	203,11	203,47	203,83	204,19	204,55	270
280	204,90	205,26	205,62	205,98	206,34	206,70	207,05	207,41	207,77	208,13	280
290	208,48	208,84	209,20	209,56	209,91	210,27	210,63	210,98	211,34	211,70	290
300	212,05	212,41	212,76	213,12	213,48	213,83	214,19	214,54	214,90	215,25	300
310	215,61	215,96	216,32	216,67	217,03	217,38	217,74	218,09	218,44	218,80	310
320	219,15	219,51	219,86	220,21	220,57	220,92	221,27	221,63	221,98	222,33	320
330	222,68	223,04	223,39	223,74	224,09	224,45	224,80	225,15	225,50	225,85	330
340	226,21	226,56	226,91	227,26	227,61	227,96	228,31	228,66	229,02	229,37	340
350	229,72	230,07	230,42	230,77	231,12	231,47	231,82	232,17	232,52	232,87	350
360	233,21	233,56	233,91	234,26	234,61	234,96	235,31	235,66	236,00	236,35	360
370	236,70	237,05	237,40	237,74	238,09	238,44	238,79	239,13	239,48	239,83	370
380	240,18	240,52	240,87	241,22	241,56	241,91	242,26	242,60	242,95	243,29	380
390	243,64	243,99	244,33	244,68	245,02	245,37	245,71	246,06	246,40	246,75	390

t_{90}/°C	Resistance in ohms at the temperature t_{90}/°C										t_{90}/°C
	0	1	2	3	4	5	6	7	8	9	
400	247,09	247,44	247,78	248,13	248,47	248,81	249,16	249,50	249,85	250,19	400
410	250,53	250,88	251,22	251,56	251,91	252,25	252,59	252,93	253,28	253,62	410
420	253,96	254,30	254,65	254,99	255,33	255,67	256,01	256,35	256,70	257,04	420
430	257,38	257,72	258,06	258,40	258,74	259,08	259,42	259,76	260,10	260,44	430
440	260,78	261,12	261,46	261,80	262,14	262,48	262,82	263,16	263,50	263,84	440
450	264,18	264,52	264,86	265,20	265,53	265,87	266,21	266,55	266,89	267,22	450
460	267,56	267,90	268,24	268,57	268,91	269,25	269,59	269,92	270,26	270,60	460
470	270,93	271,27	271,61	271,94	272,28	272,61	272,95	273,29	273,62	273,96	470
480	274,29	274,63	274,96	275,30	275,63	275,97	276,30	276,64	276,97	277,31	480
490	277,64	277,98	278,31	278,64	278,98	279,31	279,64	279,98	280,31	280,64	490
500	280,98	281,31	281,64	281,98	282,31	282,64	282,97	283,31	283,64	283,97	500
510	284,30	284,63	284,97	285,30	285,63	285,96	286,29	286,62	286,95	287,29	510
520	287,62	287,95	288,28	288,61	288,94	289,27	289,60	289,93	290,26	290,59	520
530	290,92	291,25	291,58	291,91	292,24	292,56	292,89	293,22	293,55	293,88	530
540	294,21	294,54	294,86	295,19	295,52	295,85	296,18	296,50	296,83	297,16	540
550	297,49	297,81	298,14	298,47	298,80	299,12	299,45	299,78	300,10	300,43	550
560	300,75	301,08	301,41	301,73	302,06	302,38	302,71	303,03	303,36	303,69	560
570	304,01	304,34	304,66	304,98	305,31	305,63	305,96	306,28	306,61	306,93	570
580	307,25	307,58	307,90	308,23	308,55	308,87	309,20	309,52	309,84	310,16	580
590	310,49	310,81	311,13	311,45	311,78	312,10	312,42	312,74	313,06	313,39	590
600	313,71	314,03	314,35	314,67	314,99	315,31	315,64	315,96	316,28	316,60	600
610	316,92	317,24	317,56	317,88	318,20	318,52	318,84	319,16	319,48	319,80	610
620	320,12	320,43	320,75	321,07	321,39	321,71	322,03	322,35	322,67	322,98	620
630	323,30	323,62	323,94	324,26	324,57	324,89	325,21	325,53	325,84	326,16	630
640	326,48	326,79	327,11	327,43	327,74	328,06	328,38	328,69	329,01	329,32	640
650	329,64	329,96	330,27	330,59	330,90	331,22	331,53	331,85	332,16	332,48	650
660	332,79	333,11	333,42	333,74	334,05	334,36	334,68	334,99	335,31	335,62	660
670	335,93	336,25	336,56	336,87	337,18	337,50	337,81	338,12	338,44	338,75	670
680	339,06	339,37	339,69	340,00	340,31	340,62	340,93	341,24	341,56	341,87	680
690	342,18	342,49	342,80	343,11	343,42	343,73	344,04	344,35	344,66	344,97	690
700	345,28	345,59	345,90	346,21	346,52	346,83	347,14	347,45	347,76	348,07	700
710	348,38	348,69	348,99	349,30	349,61	349,92	350,23	350,54	350,84	351,15	710
720	351,46	351,77	352,08	352,38	352,69	353,00	353,30	353,61	353,92	354,22	720
730	354,53	354,84	355,14	355,45	355,76	356,06	356,37	356,67	356,98	357,28	730
740	357,59	357,90	358,20	358,51	358,81	359,12	359,42	359,72	360,03	360,33	740
750	360,64	360,94	361,25	361,55	361,85	362,16	362,46	362,76	363,07	363,37	750
760	363,67	363,98	364,28	364,58	364,89	365,19	365,49	365,79	366,10	366,40	760
770	366,70	367,00	367,30	367,60	367,91	368,21	368,51	368,81	369,11	369,41	770
780	369,71	370,01	370,31	370,61	370,91	371,21	371,51	371,81	372,11	372,41	780
790	372,71	373,01	373,31	373,61	373,91	374,21	374,51	374,81	375,11	375,41	790

t_{90}/°C	Resistance in ohms at the temperature t_{90}/°C										t_{90}/°C
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
800	375,70	376,00	376,30	376,60	376,90	377,19	377,49	377,79	378,09	378,39	800
810	378,68	378,98	379,28	379,57	379,87	380,17	380,46	380,76	381,06	381,35	810
820	381,65	381,95	382,24	382,54	382,83	383,13	383,42	383,72	384,01	384,31	820
830	384,60	384,90	385,19	385,49	385,78	386,08	386,37	386,67	386,96	387,25	830
840	387,55	387,84	388,14	388,43	388,72	389,02	389,31	389,60	389,90	390,19	840
850	390,48										850

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