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INTERNATIONAL STANDARD

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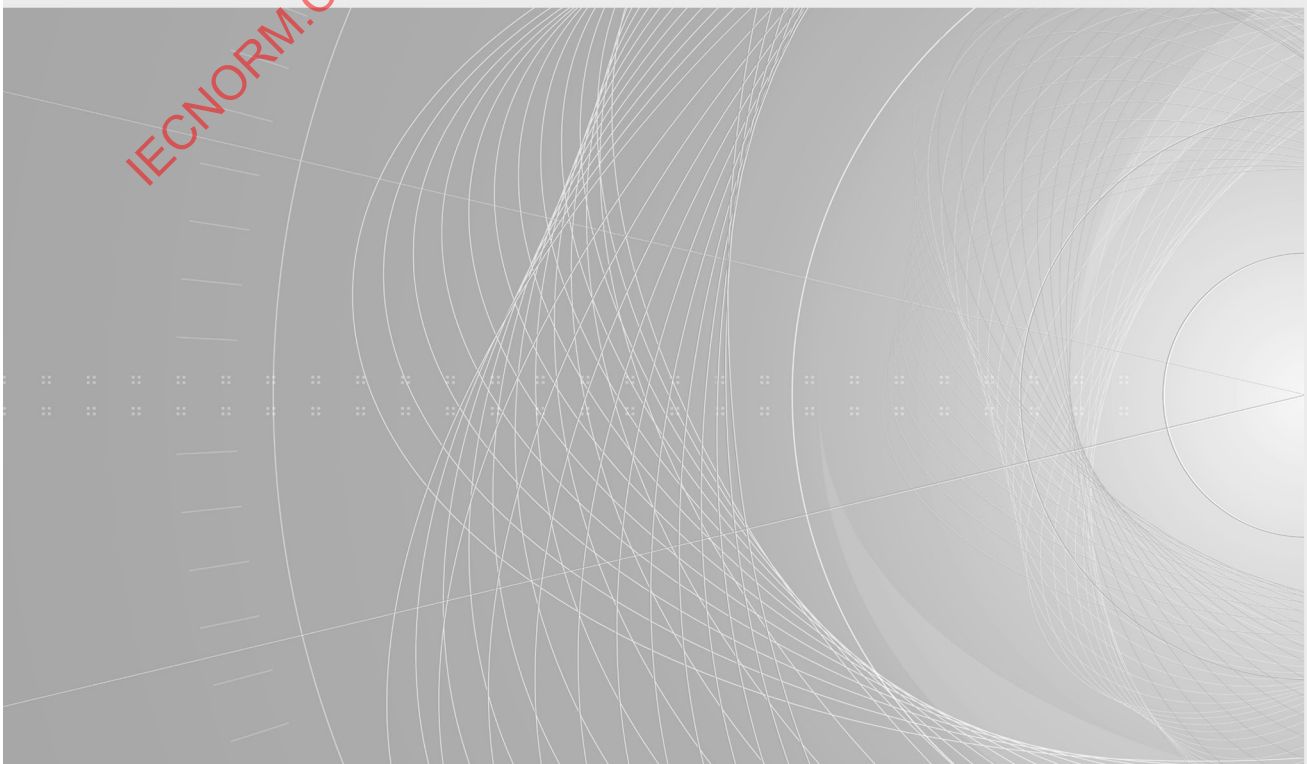
Electrical resistance trace heating systems for industrial and commercial applications –
Part 1: General and testing requirements



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CONTENTS

ELECTRICAL RESISTANCE TRACE HEATING SYSTEMS FOR INDUSTRIAL AND COMMERCIAL APPLICATIONS –

Part 1: General and testing requirements

FOREWORD

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IEC/IEEE 62395-1 has been prepared by IEC technical committee 27: Industrial electroheating and electromagnetic processing, in cooperation with Petroleum & Chemical Industry Committee of the IEEE Industrial Applications Society, under the IEC/IEEE Dual Logo Agreement between IEC and IEEE. It is an International Standard.

This document is published as an IEC/IEEE Dual Logo standard.

This first edition cancels and replaces the second edition published in 2013. This edition constitutes a technical revision.

This edition includes the following significant technical changes, apart from general revisions of IEC 62395-1 and harmonization with IEEE 515 [1][1] and IEEE 515.1 [2], with respect to the previous edition:

a) Added control and monitoring requirements for fire sprinkler systems and safety showers.

b) Provided a supplemental ice bath method for verification of rated output.

c) Provided constructional and type test requirements for glands used to terminate heating devices to an exposed enclosure.

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

Draft	Report on voting
27/1182A/FDIS	27/1186/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 the rules given in the ISO/IEC Directives, Part 2, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications/.

A list of all parts in the IEC 62395 series, published under the general title *Electrical resistance trace heating systems for industrial and commercial applications*, can be found on the IEC website.

The IEC Technical Committee and IEEE Technical Committee have 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, or
- revised.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

[1] Numbers in square brackets refer to the Bibliography.

INTRODUCTION

IEC/IEEE 62395-1 provides the essential requirements and testing appropriate to electrical resistance trace heating equipment used in industrial and commercial applications. While some of this work already exists in national or international standards, this document has collated much of this existing work and added considerably to it.

IEC/IEEE 62395-2 provides detailed recommendations for the system design, installation and maintenance of electric trace heating systems in industrial and commercial applications.

It is the objective of the IEC/IEEE 62395 series that, when in normal use, electrical trace heating systems operate safely under their defined conditions of use, by

a) employing heaters of the appropriate construction and meeting the test criteria detailed in IEC/IEEE 62395-1. The construction includes a metallic sheath, braid, screen or equivalent electrically conductive covering;

b) operating at safe temperatures when designed, installed, and maintained in accordance with IEC/IEEE 62395-2.

c) having at least the minimum levels of overcurrent and earth-fault protection required in IEC/IEEE 62395-1 and IEC/IEEE 62395-2.

ELECTRICAL RESISTANCE TRACE HEATING SYSTEMS FOR INDUSTRIAL AND COMMERCIAL APPLICATIONS –

Part 1: General and testing requirements

1 Scope

This part of IEC/IEEE 62395 specifies requirements for electrical resistance trace heating systems and includes general test requirements.

This document pertains to trace heating systems that can comprise either factory-fabricated or field-assembled (work-site) units, and which can be series and parallel trace heaters or surface heaters (heater pads and heater panels) that have been assembled and/or terminated in accordance with the manufacturer's instructions.

This document also includes requirements for termination assemblies and control methods used with trace heating systems.

This document provides the essential requirements and testing appropriate to electrical resistance trace heating equipment used in industrial and commercial applications. The products complying with this document are intended to be installed by persons who are suitably trained in the techniques required and that only trained personnel carry out especially critical work, such as the installation of connections and terminations. Installations are intended to be carried out under the supervision of a qualified person who has undergone supplementary training in electric trace heating systems.

This document does not include or provide for any applications in potentially explosive atmospheres.

This document does not cover induction, impedance or skin effect heating.

Trace heating systems are grouped into different types of applications and the different conditions found during and after installation necessitate different requirements for testing. Trace heating systems are usually for a specific type of installation or application. The product type grouping, applications and product attributes are indicated in Table 1.

NOTE Trace heating systems intended for use in explosive atmospheres are the subject of IEC/IEEE 60079-30-1 [3] and IEC/IEEE 60079-30-2 [4].

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 60519-1, *Safety in installations for electroheating and electromagnetic processing – Part 1: General requirements*

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

IEC 60695-11-3:2012, *Fire hazard testing – Part 11-3: Test flames – 500 W flames – Apparatus and confirmational test methods*

IEC/IEEE 62395-2:2024, *Electrical resistance trace heating systems for industrial and commercial applications – Part 2: Application guide for system design, installation and maintenance*

ISO 7240-2:2017, *Fire detection and alarm systems – Part 2: Fire detection control and indicating equipment*

ANSI/UL 864, *Standard for Control Units and Accessories for Fire Alarm Systems – Control and Indicating Equipment*

ASTM D 5025-20, *Standard Specification for Laboratory Burner Used for Small-Scale Burning Tests on Plastic Materials*

ASTM G155-21, *Standard practice for operating xenon arc light apparatus for exposure of non-metallic materials*

3 Terms and definitions

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

ISO, IEC and IEEE maintain terminology 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
- IEEE Standards Dictionary Online: available at http://dictionary.ieee.org

NOTE 1 General definitions are given in the International Electrotechnical Vocabulary, IEC 60050 (all parts) [5]. Terms relating to industrial electroheat are defined in IEC 60050-841 [6].

NOTE 2 The terms defined in this Clause 3 are used both in IEC/IEEE 62395-1 and IEC/IEEE 62395-2.

3.1
ambient temperature
temperature surrounding the object under consideration

Note 1 to entry: Where trace heaters or surface heaters are enclosed in thermal insulation, the ambient temperature is the temperature exterior to such thermal insulation.

3.1.1
maximum ambient temperature
highest specified ambient temperature

3.1.2
minimum ambient temperature
lowest specified ambient temperature

Note 1 to entry: Heat-loss calculations in IEC 62395-2 are based on the minimum ambient temperature.

3.2
branch circuit
portion of the wiring installation between the overcurrent device protecting the circuit and the trace heater(s) or surface heater(s)

3.3
cold lead
electrically insulated conductor or conductors used to connect a trace heater or surface heater to the branch circuit and designed so that it does not produce significant heat

3.4
connection
termination or splice used to attach trace heaters or surface heaters to power wiring or to connect sections of these devices

3.5
dead-leg
segment of process piping segregated from the normal flow pattern for the purpose of providing a heat loss reference

3.6
design loading
minimum power that meets the design requirements, in the specified adverse conditions (minimum ambient and maximum wind velocity), after voltage and resistance tolerances and appropriate safety factors have been considered

[SOURCE: IEC/IEEE 60079-30-1:2015, 3.6]

3.7
electrically conductive covering
metallic braid, metallic sheath, or alternative covering with sufficient conductivity so that, when bonded to ground, it will allow a ground fault protective device to operate under a fault condition

3.8
end termination
termination, which can be heat producing, applied to a trace heater at the end opposite to that where the power is supplied

3.9
factory-fabricated unit
trace heater unit or set or surface heater unit or set, including the necessary terminations and connections, assembled by the manufacturer

3.10
field-assembled unit
trace heaters or surface heaters supplied unterminated with terminating components to be assembled at the work site

3.11
heat loss
energy flow from a workpiece, pipe, vessel or equipment to its surroundings

3.12
heat sink
part that conducts and dissipates heat away from a workpiece

Note 1 to entry: Typical heat sinks are pipe shoes, pipe supports and items of large mass such as valve actuators or pump bodies.

3.13
heat transfer aids
thermally conductive materials, such as metallic foils or heat transfer compounds used to increase the heat-transfer efficiency from trace heaters or surface heaters to the workpiece

3.14
heater pad
surface heater, comprising series or parallel connected elements having sufficient flexibility to conform to the shape of the surface to be heated

3.15
heater panel
non-flexible surface heater, comprising series or parallel connected elements fabricated to conform to the general shape of the surface to be heated

3.16
heating device
trace heater or surface heater

3.17
heating device set
heating device assembled with the associated parts necessary to connect it to a source of electrical supply

3.18
integral component
component such as a heat shrink termination, a cold lead connection, a moulded end seal or a splice, which conforms to the general shape of the trace heater or surface heater and is exposed to the same environment as the trace heater or surface heater, which can be factory-fabricated or field-assembled, and which is not intended to be re-used in the event of a repair or modification

3.19
low risk of mechanical damage
installations and applications where only lower levels of impact and deformation are expected to occur

3.20
maximum continuous exposure temperature (trace heater de-energized)
highest allowable continuous temperature to which the trace heating system can be exposed as declared by the manufacturer

3.21
maximum intermittent exposure temperature
highest allowable intermittent temperature to which a trace heater can be exposed, as declared by the manufacturer

3.22
maximum maintain temperature
specified maximum workpiece or process temperature the trace heater can maintain as declared by the manufacture

3.23
maximum continuous operating temperature
specified maximum workpiece temperature, the trace heater, can operate continuously when energized as declared by the manufacturer

3.24
maintain temperature
specified temperature of a workpiece or process that the trace heaters shall be able to maintain

3.25
maximum sheath temperature
maximum temperature of the outermost continuous covering of the trace heater or surface heater

3.26
maximum withstand temperature
maximum continuous exposure temperature or the maximum intermittent exposure temperature (energized or de-energized) whichever is higher, as declared by the manufacturer

3.27
minimum installation temperature
minimum temperature at which the trace heating system can be handled and installed

3.28
MI trace heater
mineral insulated metal sheathed trace heater typically containing one or more heating conductors

3.29
operating voltage
actual voltage applied to the trace heater or surface heater when in service

3.30
outdoor exposure
exposure to outdoor conditions of ultraviolet light and moisture

3.31
overjacket
continuous layer of material applied over the trace heater or surface heater to provide mechanical or environmental protection

3.32
parallel trace heater
heating elements that are electrically connected in parallel, either continuously or in zones, so that the power output per lineal length is maintained, irrespective of any change in length for the continuous type or for any number of discrete zones

3.33
rated output
total power or the power per unit length or power per unit surface area of the trace heater or surface heater at rated voltage, temperature, and length or area

3.34
rated voltage
voltage assigned by the manufacturer to which operating and performance characteristics of trace heaters or surface heaters are referred

3.35
routine test
test that is carried out by the manufacturer of the trace heater or surface heater on all trace heaters or surface heaters during or after the production process

3.36
series trace heater
heating elements electrically connected in series with a single current path and with a specific resistance at a given temperature for a given length

3.37
sheath
uniform and continuous metallic or non-metallic covering enclosing components of the trace heater or surface heater to provide protection against influence from the surroundings (e.g., corrosion, moisture, abrasion, etc.)

Note 1 to entry: See overjacket (3.31).

3.38
sheath temperature
temperature of the outermost continuous covering (braid, sheath, or overjacket) that can be exposed to the surrounding environment

3.39
stabilized design
design method where the temperature of the trace heater or surface heater will, by design and use, stabilize below the limiting temperature, under the most unfavourable conditions, without the need for a protective system to limit the temperature

3.40
start-up current
current of a trace heater or surface heater following energization

3.41
surface heater
heater pad or heater panel

3.42
surface heater unit
surface heater suitably terminated in conformity with the manufacturer's instructions

3.43
system documentation
information provided by the trace heater manufacturer to allow satisfactory understanding, installation and safe use of the trace heating system

3.44
tee
electrical connection of trace heaters, in series or in parallel, to accommodate a branch or a branch circuit

3.45
temperature controller
device or combination of devices incorporating a means of sensing temperature and of controlling the energy supplied to the trace heater or surface heater

3.46
temperature sensor
device designed to respond to temperature providing an electrical signal or mechanical operation

3.47
thermal insulation
material having air- or gas-filled pockets, voids, or heat reflecting surfaces that, when properly applied, retards the transfer of heat

3.48
trace heater
device of linear geometry designed for the purpose of producing heat on the principle of electrical resistance

3.49
trace heater unit
trace heater suitably terminated in conformity with the manufacturer's instructions

3.50
trace heating
utilization of trace heaters or surface heaters as well as support components, designed for the purpose of producing heat through heating elements electrically connected in series or in parallel, used to maintain or raise temperatures of piping, tanks and other surfaces

3.51
type test
conformity test made on one or more items representative of the production

[SOURCE: IEC 60050-151:2001, 151-16-16]

3.52
weather barrier
material that, when installed on the outer surface of thermal insulation, protects the thermal insulation from water or other liquids, from physical damage caused by ice pellets, wind or mechanical abuse and from deterioration caused by solar radiation or atmospheric contamination

3.53
workpiece
object to which a trace heater or surface heater is applied

4 General requirements

4.1 General

Electrical resistance trace heating systems within the scope of this document shall be designed and constructed so as to help ensure electrical, thermal and mechanical durability and reliable performance such that, in normal use, they pose no danger to the user or the surroundings.

Trace heaters which are identified for use only in areas with a low risk of mechanical damage are subjected to a reduced load in the impact tests in 5.2.4 and 5.2.5 and a reduced force in the deformation test in 5.2.6 and shall be clearly marked as specified in Clause 7.

Trace heaters and surface heaters can be supplied with additional mechanical protection to meet the requirements of this document if they are supplied as an integral assembly (prefabricated) and shall be marked as required by Clause 7, item g).

Trace heating equipment intended for use in contact with potable water shall be constructed of materials that meet relevant toxicity requirements.

Trace heaters and surface heaters temperature ratings that are required to conduct the type test in this document, shall be stated and controlled by the trace heater manufacturer in their documentation and published in their literature. The trace heater manufacturer shall provide documentation of the specification of non-metallic materials on which the mechanical strength and the electrical insulation depend (between the heater and other conductive parts) which shall include identification of the material type.

4.2 Electrically conductive covering

Trace heaters and surface heaters shall be provided with an evenly distributed electrically conductive covering which shall cover at least 70 % of the surface. Surface heating units shall be constructed such that the electrically conductive covering shall be opposite the surface to be heated.

4.3 Electrical circuit protection requirements for branch circuits

The minimum requirements for trace heating systems are:

a) a means of isolating all live conductors from the supply;

b) over-current protection provided for each branch circuit;

c) a means of protecting against earth-faults by disconnecting all live conductors.

The trace heater or surface heater branch circuit electrical protection shall be capable of interrupting earth faults, as well as short-circuit faults. An earth-fault protective device or a controller with earth-fault interruption capability shall be used. The preferred trip level is nominal 30 mA or 30 mA above any inherent capacitive leakage characteristic of the heater as specified by the trace heater or surface heater supplier. These devices are intended for use in conjunction with circuit overcurrent protection. Where conditions of maintenance and supervision help ensure that only qualified persons will service the installed systems and continued circuit operation is necessary for the safe operation of the equipment or processes, earth-fault detection without interruption is acceptable if alarmed in a manner assuring an acknowledged response.

4.4 Temperature requirements

4.4.1 General

A trace heating system shall be designed so that under all conditions that can reasonably be foreseen, the surface temperature of the trace heater or surface heater does not exceed its maximum withstand temperature or any maximum system temperature ratings. This shall be achieved by a stabilized design or controlled design. In the design process of a system, the temperatures that occur have to be considered. All components, for example terminals or glands used with the trace heaters, have to resist the adjacent temperatures.

4.4.2 Stabilized design

Stabilized design applications, in which the maximum surface temperature of the trace heater or surface heater is determined without thermostatic control, shall employ either the systems approach specified in 5.2.13.2 or the product approach specified in 5.2.13.3.

4.4.3 Controlled design

The surface temperature obtained through controlled design is based on energy limitation by temperature controllers or high temperature limiters. There are no additional requirements for temperature controllers and high temperature limiters beyond those of the general industrial standards.

NOTE Typical general industrial requirements for temperature controllers and high temperature limiters can be found in the following documents. It is not a requirement of this document that conformity to those standards be verified.

a) IEC 61010-1, *Electrical Equipment for Measurement, Control, and Laboratory Use – Part 1: General requirements* [7];

b) IEC 60730-2-9, *Automatic electrical controls – Part 2-9: Particular requirements for temperature sensing control* [8];

c) UL 508, *Industrial Controls* [9];

d) CSA C22.2 No. 14, *Industrial control equipment* [10];

e) CSA C22.2 No. 24, *Temperature Indicating and Regulating Equipment* [11].

4.4.4 Controls and monitoring for fire sprinkler systems and safety showers

4.4.4.1 General

Temperature controllers and high temperature limiters for fire sprinkler systems and safety showers shall comply with 4.4.4.2 and 4.4.4.3.

Testing requirements for trace heaters and control systems for use with fire sprinkler systems are given in 5.6.

4.4.4.2 Control systems requirements

Temperature controllers and high temperature limiters for fire sprinkler systems and safety showers shall comply with the relevant parts of standards such as:

a) Additional design requirements as specified in ISO 7240-2, *Fire Detection and Alarm Systems – Control and Indicating Equipment*;

b) ANSI/UL 864, *Standard for Control Units and Accessories for Fire Alarm Systems – Control and Indicating Equipment*, which includes additional design requirements for software control and indicating equipment

4.4.4.3 Monitoring requirements

For safety showers, alarms are required to provide indication when ground fault circuit protection interrupts the circuit.

For fire sprinkler lines, the following are required:

Provisions for annunciating a local audible and visual alarm and providing a supervisory signal to a fire alarm system shall be provided for the following conditions depending upon the system design:

a) earth/Ground fault;

b) low sprinkler system temperature;

c) high sprinkler system temperature;

d) temperature sensor failure;

e) primary controller failure;

f) loss of continuity;

g) loss on incoming supply voltage;

h) any engagement of a secondary high temperature limiter, if provided.

5 Testing

5.1 Type tests – General

All trace heaters and surface heaters shall meet the requirements of the type tests given in 5.2. Trace heaters and surface heaters intended for applications described in Table 1 shall also meet the requirements specified in Table 2. The test samples needed for the type tests are summarized in Annex A.

Samples of trace heaters selected for testing shall be at least 3 m in length, unless otherwise specified.

Integral components shall be subjected to the same type test as the trace heater or surface heater unless otherwise noted.

System components, other than those identified as integral, shall be evaluated in accordance with standards relevant to their construction and use.

Tests shall be conducted at a room temperature between 10 ºC and 40 ºC unless otherwise specified.

Separate samples shall be used for each test unless otherwise specified. These shall be prepared in accordance with the manufacturer's recommendations.

Table 1 – Trace heater and surface heater types and related attributes

Trace heater type	Intended installations	Examples of installations	Required attributes
A	Insulated surfaces (including pipe)	Hot water lines Freeze protection Grease lines Fuel oil lines Pre-insulated pipe Below grade trace heating Sprinkler systems	Dielectric, thermal, mechanical, moisture exclusion, and performance characteristics verification Sprinkler system verification (if specified for use)
B	Outdoor exposed areas	Roof deicing Gutter and downspouts deicing Catch basins and drains Rail heating systems	Dielectric, thermal, mechanical, moisture exclusion, and performance characteristics verification Increased moisture resistance UV and condensation resistance Resistance to cutting Abrasion resistance Tension test Rail system tests (if specified for use)
C	Installations with embedded trace heating	Embedded snow melting Embedded frost heave protection Embedded floor warming Embedded energy storage systems Embedded door frames	Dielectric, thermal, mechanical, moisture exclusion, and performance characteristics verification Resistance to cutting Deformation test
D	Installations with trace heater inside conduit or piping	Embedded snow melting Embedded frost heave protection Embedded floor warming Embedded energy storage systems Embedded door frames Internal trace heating for freeze protection of potable water lines Enclosed drains and culverts	Dielectric, thermal, mechanical, moisture exclusion, and performance characteristics verification Increased moisture resistance (pressurized or non-pressurized) Pull-strength evaluation

Table 2 – Applicable tests for trace heaters, surface heaters, and integral components, by trace heater and surface heater type

Required test procedure	Subclause	Trace heater and surface heater type			
		Type A	Type B	Type C	Type D
Dielectric test	5.2.1	X	X	X	X
Electrical insulation resistance test	5.2.2	X	X	X	X
Flammability test	5.2.3	X	X	X	X
Room temperature impact test	5.2.4	X	X	X	X
Minimum temperature impact test	5.2.5	X	X	X	X
Deformation test	5.2.6	X	X	X	X
Cold bend test	5.2.7	X	X	X	X
Water resistance test	5.2.8	X	X	X	X
Integral components resistance to water test	5.2.9	X	X	X	X
Verification of rated output	5.2.10	X	X	X	X
Thermal stability of electrical insulating material	5.2.11	X	X	X	X
Thermal performance test	5.2.12	X	X	X	X
Maximum sheath temperature	5.2.13	X	X	X	X
Verification of start-up current	5.2.14	X	X	X	X
Verification of the electrical resistance of the electrically conductive covering	5.2.15	X	X	X	X
Test for heating device / heating device set glands - General	5.2.16	X	X	X	X
Connection integrity (integral components)	5.2.17	X	X	X	X
Verification of rated output – for outdoor exposed systems	5.3.1		X		
Determination of maximum sheath temperature – for outdoor exposed systems	5.3.2		X		
Increased moisture resistance test	5.3.3		X		
UV and condensation test	5.3.4		X		
Resistance to cutting test	5.3.5		X		
Abrasion test	5.3.6		X		
Tension test	5.3.7		X		
Rail system voltage spike test (if specified for rail heating)	5.3.8		X		
Rail system over-voltage test (if specified for rail heating)	5.3.9		X		
Verification of rated output – for embedded systems	5.4.1			X	
Determination of maximum sheath temperature – for embedded systems	5.4.2			X	
Resistance to cutting test	5.4.3			X	
Flammability test (exemption, if applicable)	5.4.4			X	
Verification of rated output – for systems internal to conduit and piping	5.5.1				X
Determination of maximum sheath temperature – for systems internal to conduit and piping	5.5.2				X

Required test procedure	Subclause	Trace heater and surface heater type			
		Type A	Type B	Type C	Type D
Increased moisture resistance test (for pressurized and non-pressurized systems)	5.5.3				X
Pull-strength test	5.5.4				X
Normal and abnormal operation test – for sprinkler systems (if applicable)	5.6.1	X			
Normal operation test – for sprinkler systems (if applicable)	5.6.2	X			
Abnormal operation test – for sprinkler systems (if applicable)	5.6.3	X			
Abnormal operation test without controller (if applicable)	5.6.4	X			

5.2 Type tests – All applications

5.2.1 Dielectric test

The dielectric test shall be performed on trace heaters or surface heaters in accordance with Table 3.

Table 3 – Test voltages for the dielectric test

Rated voltage U	Test voltage VAC. (RMS.)
< 30 VAC(RMS.)	500
< 60 VDC	500
≥ 30 VAC (RMS.)	$2U$ + 1 000[1]
≥ 60 VDC	$\sqrt{2}U$ + 1 000[1]

[1] For MI trace heaters, the required test voltage shall be reduced to $2U$ + 500 for products rated at or over 30 VAC., or to $\sqrt{2}U$ + 500 for products rated at or over 60 VDC.

For single conductor series trace heaters or surface heaters the voltage shall be applied between the conductor and the metallic sheath, braid, screen or equivalent electrically conductive covering.

For multi-conductor series trace heaters or surface heaters the voltage shall be applied between the conductors connected together and the metallic sheath, braid, screen or equivalent electrically conductive covering, and also between each conductor in turn with the remaining conductor(s) connected together.

For parallel trace heaters or surface heaters the voltage shall be applied between the conductors connected together and the metallic sheath, braid, screen or equivalent electrically conductive covering.

Alternatively, the dielectric test can be conducted by submerging the trace heaters or surface heaters in tap water at room temperature (resistivity typically 500 Ω·m). The test voltage shall be applied between the heating conductors and the water.

The rate of rise shall be neither less than 100 V/s nor more than 200 V/s and maintained for 1 min at the specified test voltage without dielectric breakdown. The test voltage waveform shall be essentially sinusoidal, with a frequency of 45 Hz to 65 Hz.

When determining U, the correct use of phase-to-phase or phase-to-neutral voltage levels shall be considered.

5.2.2 Electrical insulation resistance test

The electrical insulation resistance shall be measured on the test sample(s) prepared in accordance with 5.1 after the dielectric test specified in 5.2.1.

For single conductor series trace heaters or surface heaters the resistance of the electrical insulation shall be measured between the conductor and the metallic sheath, braid, screen or equivalent electrically conductive covering.

For multi-conductor series trace heaters or surface heaters where the conductors are electrically insulated from each other, the resistance of the electrical insulation shall be measured between the conductors connected together and the metallic sheath, braid, screen or equivalent electrically conductive covering, and also between each conductor in turn with the remaining conductor(s) connected together.

For parallel trace heaters or surface heaters the resistance of the electrical insulation shall be measured between the conductors connected together and the metallic sheath, braid, screen or equivalent electrically conductive covering.

The insulation resistance shall be measured by means of a DC voltage of at least 500 V. The measured value shall be not less than 50 MΩ.

5.2.3 Flammability test

A flammability test shall be performed on trace heaters and surface heaters and also on trace heaters and surface heaters with integral components. The full range of sizes shall be capable of complying with the test. The test shall be made in a room free from draughts and in a flame chamber or fume hood with a minimum volume of 0,5 cubic meters. For trace heaters, the sample shall be at least 450 mm in length, and shall be supported in a vertical position. For surface heaters the sample shall be as above with a width of 80 mm.

A gummed unbleached paper indicator shall be wrapped once around the sample so that it projects 20 mm from the sample. The paper indicator shall be positioned 250 mm above the point at which the inner blue cone of the flame contacts the sample. A layer of dry, pure surgical cotton not more than 6 mm in depth shall be placed underneath the sample so that the distance from the cotton to the point of the flame application is approximately 250 mm.

A laboratory burner as described in IEC 60695-11-3 or in ASTM D 5025-20 shall be used for the test. The fuel shall be methane, natural gas, propane, or butane with the following properties:

a) Methane or natural gas – For methane: technical grade, 98 % minimum purity; for methane or natural gas: a heating value of (37 ± 1) MJ/m^3 at 25 °C

b) Propane – Technical grade, 98 % minimum purity, a heating value of (94 ± 2) MJ/m^3 at 25 °C

c) Butane – CP grade, 99 % minimum purity, a heating value of (120 ± 3) MJ/m^3 at 25 °C

As shown in Figure 1, the flame shall be adjusted to a 130 mm height with a 40 mm inner blue cone. The burner shall be tilted to an angle of 20° from the vertical and the flame applied to the test sample so that the tip of inner blue cone of the flame touches the specimen at a point 250 mm below the unbleached paper indicator and approximately 150 mm from the bottom of the sample.

For integral components, the flame shall be set such that it contacts the component at the mid-point. Clamps used to support the sample shall be above the paper indicator and at least 80 mm below the point of flame application. If additional stability is needed for the testing of some integral components, then a steel wire and weight can be utilized to secure the component provided that the flame does not contact the steel wire or weight. Details of the test fixture required to achieve minimum influence on the test may vary based on heater and component properties and shall be agreed between manufacturer and test agency.

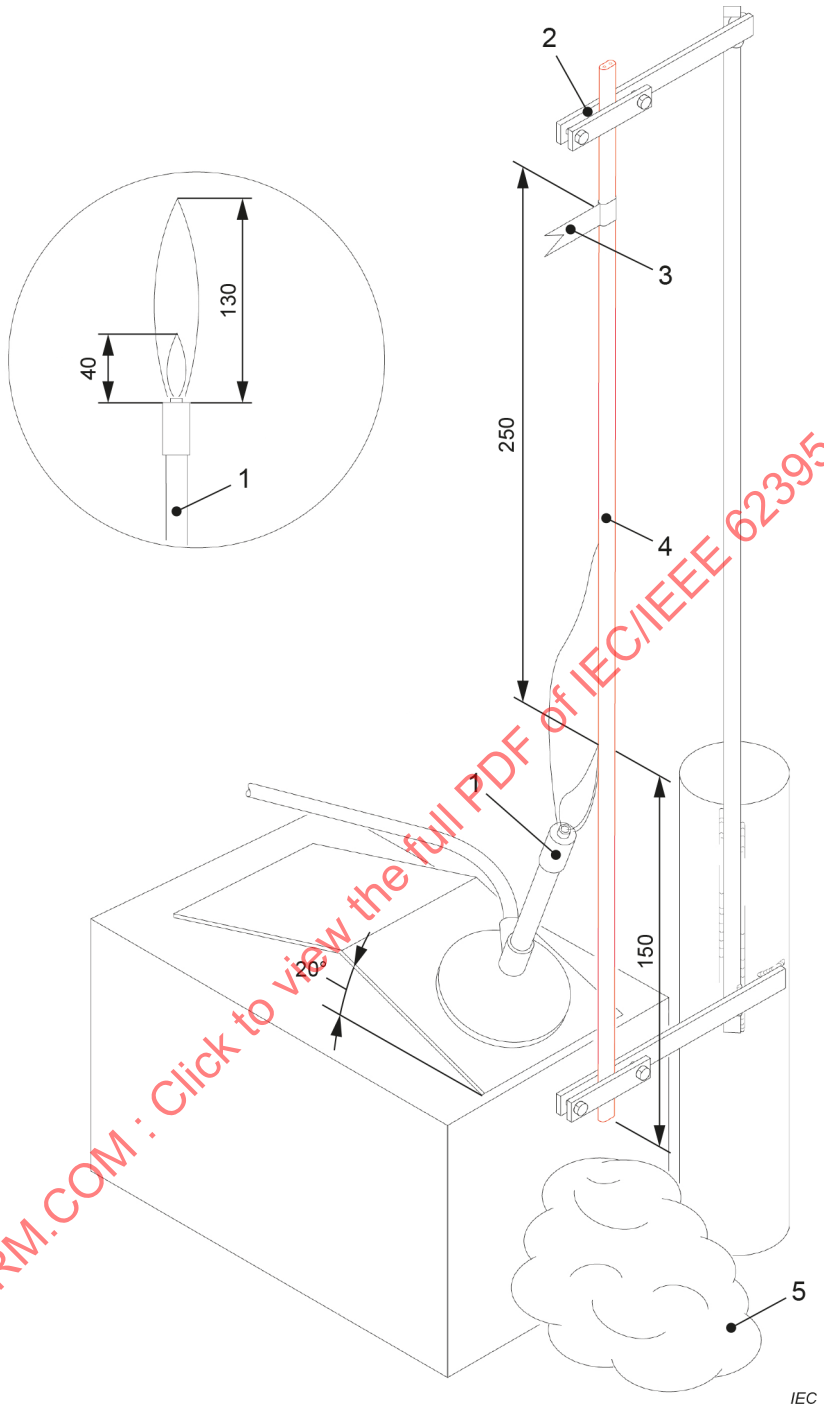
For surface heater samples, the flame is applied at the horizontal mid-point of the sample, with the unbleached paper indicator vertically above the flame using dimensions as shown in Figure 1.

The laboratory burner shall be moved towards the sample until the inner blue cone touches the sample; see Figure 1. The flame shall be applied for 15 s and then removed for 15 s, until five such applications have been made.

The test results shall be considered satisfactory if the sample does not support combustion for more than 1 min after the fifth application of the flame, does not burn more than 25 % of the extended unbleached paper indicator, and does not ignite the cotton from burning falling particles.

NOTE This specification is equivalent to the ignition sources specified in the IEC 60695-11-3 and ASTM D 5207 standards.

Dimensions in millimetres



Key

1 Burner
2 Support
3 Unbleached paper flag
4 Test sample
5 Dry pure surgical cotton

Figure 1 – Flammability test

5.2.4 Room temperature impact test

NOTE Electric trace heaters and surface heaters are, in the majority of applications, covered by thermal insulation and therefore afforded some mechanical protection. In some situations, however, trace heaters and surface heaters are not mechanically protected by thermal insulation. For example, during installation before the thermal insulation is applied or where the trace heater exits from the thermal insulation into a junction box or outdoor exposed area installations.

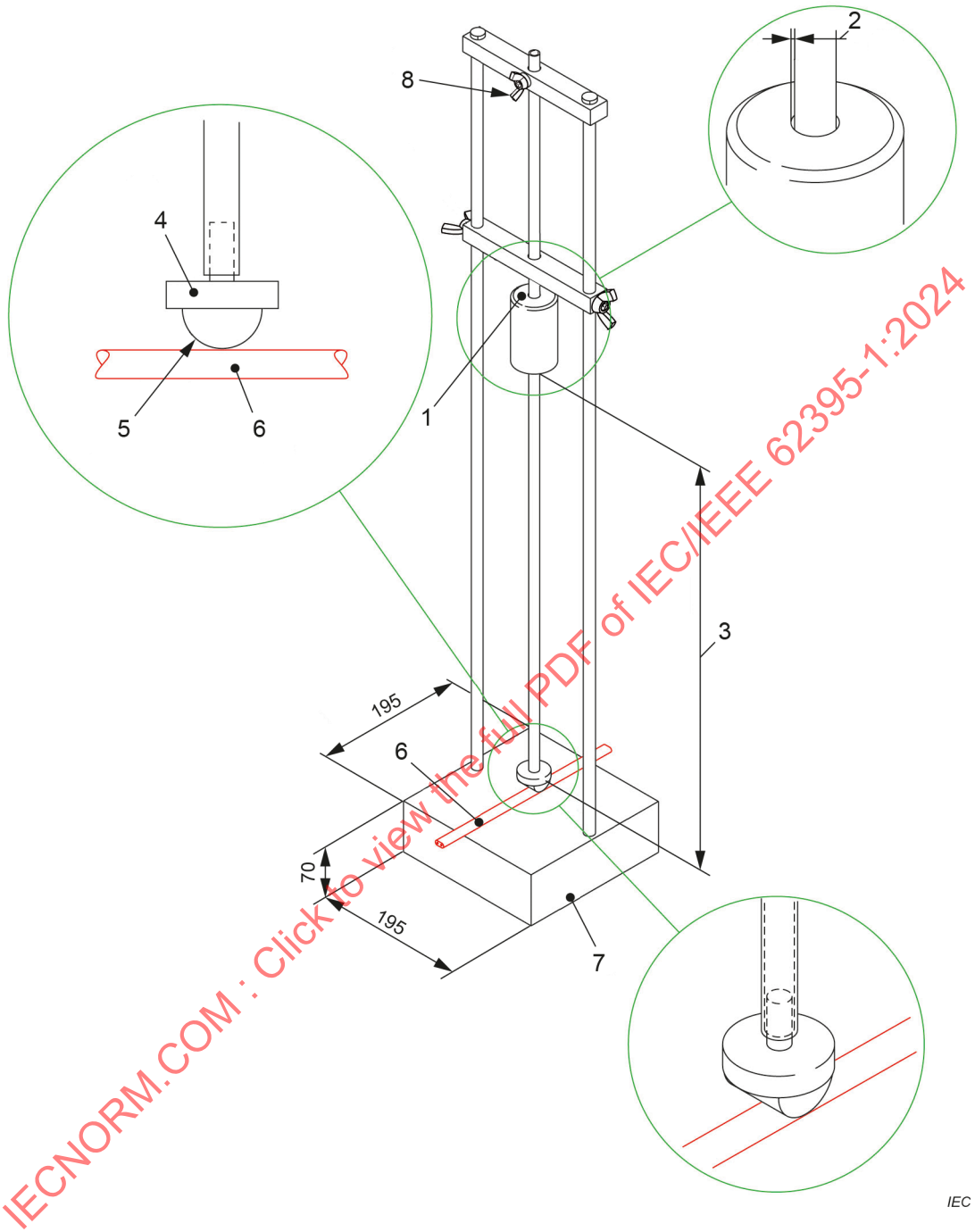
A sample approximately 450 mm in length is placed on a rigid flat steel plate (with a mass equal to or greater than 20 kg, approximately 195 mm × 195 mm × 70 mm). The plate is positioned on a rigid substrate such that the impact energy absorbed by the substrate is negligible. The sample is then positioned underneath an intermediate piece of hardened steel in the shape of a horizontal half-cylinder with a diameter of 25 mm. This cylinder shall have a length of 25 mm with smoothly rounded edges to a radius of approximately 5 mm when used to test surface heaters (see Figure 2). For the test, the cylinder is laid horizontally on the sample. A trace heater having a non-circular cross-section shall be so positioned that the impact is applied along the minor axis (i.e. the sample is positioned flat on the steel plate).

Other than in tests on electrical trace heaters intended for use in applications with low risk of mechanical damage, a hammer with a mass of $1{,}0\ ^{+0{,}01}_{0}$ kg shall be allowed to fall once onto the horizontal cylinder from a height of $0{,}7\ ^{+0{,}01}_{0}$ m.

For trace heaters and surface heaters intended for use in applications with low risk of mechanical damage in accordance with 4.1, the height can be reduced to $0{,}4\ ^{+0{,}01}_{0}$ m. Trace heaters or surface heaters submitted to such a test shall be examined by the testing body to verify that the manufacturer's installation instructions adequately caution the user as to its reduced mechanical capability [see Clause 7 item i)].

Immediately after impact, conformity is verified by testing the electrical insulation in accordance with 5.2.1 and 5.2.2 while the steel cylinder and hammer are still in place on the sample.

Dimensions in millimetres



Key

1	hammer with mass of 1 kg	5	half-cylinder with 25 mm overall length with 5 mm radius rounding on edges
2	sufficient clearance from guide tube to allow for free-fall	6	trace heater sample
3	height of fall of hammer: 0,7 m or 0,4 m	7	base with minimum 20 kg mass
4	impact plate (loosely inserted in guide tube)	8	set screw for guide tube – so guide tube does not rest on impact plate

Figure 2 – Example of room temperature impact test apparatus

5.2.5 Minimum temperature impact test

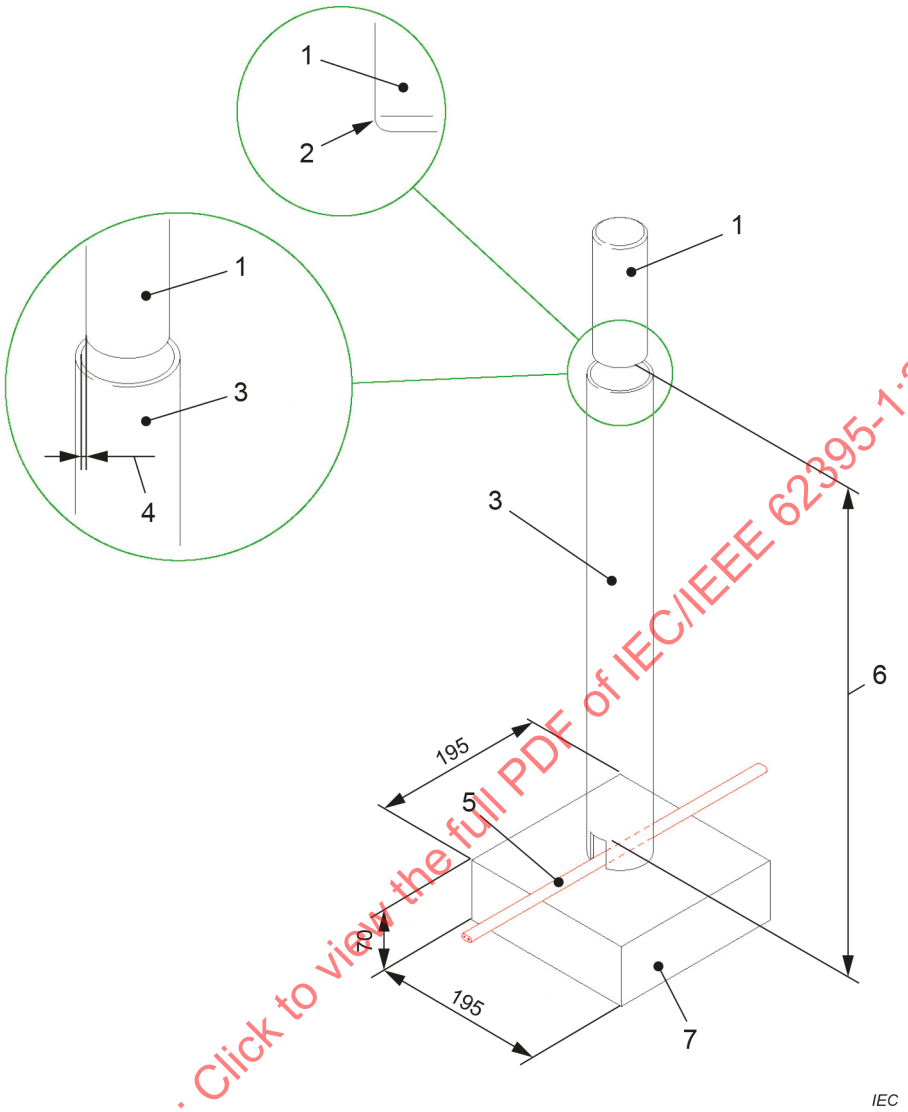
A sample approximately 450 mm in length is placed on a hardened steel plate (with a mass equal to or greater than 20 kg, 195 mm × 195 mm × 70 mm). The plate is positioned on a rigid substrate such that the impact energy absorbed by the substrate is negligible. The assembly is then conditioned for a minimum of 4 h at the manufacturer's minimum installation temperature. The apparatus used for this test is shown in Figure 3.

After conditioning, and other than in tests on trace heaters intended for use in applications with low risk of mechanical damage, a sample, while still at the minimum installation temperature, shall be subjected to a 50,8 mm diameter cylindrical steel plunger, with smoothly rounded edges to a radius of approximately 5 mm, having a mass of 1,8 $^{+0,02}_{0}$ kg and allowed to free fall from a height of 0,76 $^{+0,01}_{0}$ m.

For trace heaters intended for use in applications with a low risk of mechanical damage in accordance with 4.1, the height shall be reduced to 0,42 $^{+0,01}_{0}$ m. Trace heaters submitted to such a test shall have information in the installation instructions that adequately caution the user regarding the use of a trace heater with reduced mechanical capability. See Clause 7 item i).

The impacted portion of the sample shall then be immersed in tap water at room temperature for at least 5 min, and the dielectric test 5.2.1 and insulation resistance test 5.2.2 shall be conducted. For surface heaters, both the heating region and cold leads shall be impacted.

Dimensions in millimetres



Key

1	50,8 diameter hammer with mass of 1,8 kg	5	trace heater sample
2	smoothly rounded edges (~5 mm rounding)	6	height of fall of hammer: 0,76 m or 0,42 m
3	guide tube	7	base with minimum 20 kg mass
4	sufficient clearance to allow for free-fall		

Figure 3 – Example of minimum temperature impact test apparatus

5.2.6 Deformation test

A sample approximately 450 mm in length is placed on a rigid flat steel plate. A crushing force of at least 1 500 N is then applied for 30 s, without shock, by means of a 6 mm diameter steel rod with hemispherical ends and a total length of 25 mm. For the test, the rod is laid flat on the sample and in the case of a trace heater it is placed across a specimen at a right angle. In the case of a surface heater, it is necessary that the cylinder rests across an active element.

For trace heaters and surface heaters intended for use in applications with low risk of mechanical damage, the crushing force can be reduced to at least 800 N. Trace heaters or surface heaters submitted to such a test shall be examined by the testing body to verify that the manufacturer's installation instructions adequately caution the user regarding the use of a trace heater or surface heater with reduced mechanical capability. See Clause 7 item i).

After the deformation load is applied for at least 30 s, conformity is verified by testing the electrical insulation in accordance with 5.2.1 and 5.2.2 while the horizontal steel rod is still in place on the sample and the load applied.

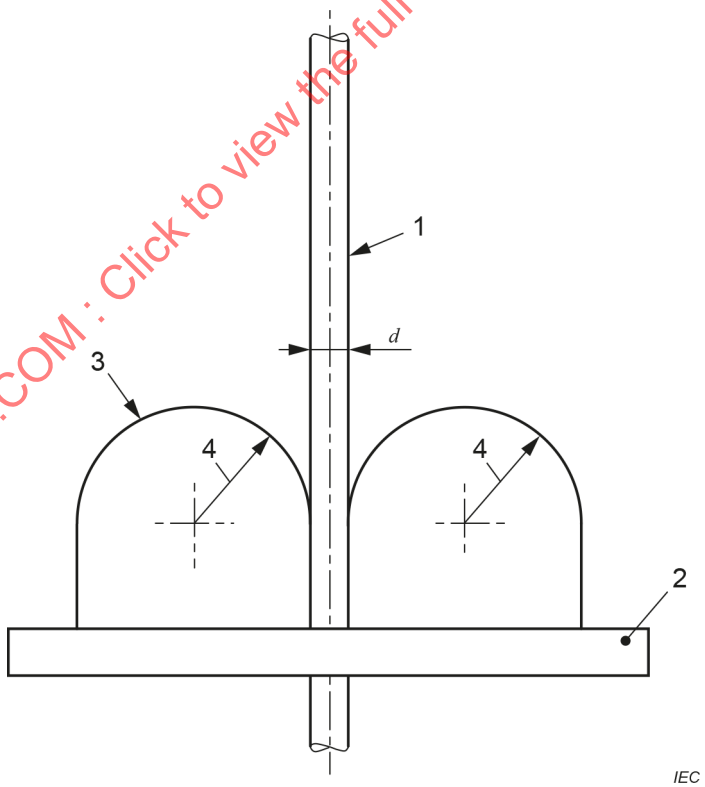
5.2.7 Cold bend test

This test applies only to trace heaters or surface heaters that have a stated minimum bending radius less than 300 mm.

The system documentation shall state the minimum installation temperature and the minimum bending radius.

The apparatus used for the cold bend test is shown in Figure 4, with the radius of the metal mandrel equal to the manufacturer's stated minimum bend radius. A sample at least 450 mm in length of trace heater or surface heater, without integral components, shall be fixed in the apparatus as shown. The apparatus and sample shall be placed in a refrigerated compartment and maintained at the manufacturer's specified minimum installation temperature for a period not less than 4 h. At the end of this period, while still at the manufacturer's specified minimum installation temperature, the sample shall be bent through at least 90° around one of the mandrels, then bent through at least 180° in the opposite direction over the second mandrel and then straightened to its original position. All the bending operations shall be carried out in the same plane. This cycle of operations shall be performed three times, and the rate of bend shall be approximately 5 s per cycle.

Conformity is verified by testing the electrical insulation in accordance with 5.2.1 and 5.2.2 and the sample shall have no visible cracks when examined with normal vision.



Key

1	trace heater or surface heater sample	4	manufacturer's stated minimum bend radius
2	steel base	d	trace heater diameter or primary bending plane
3	metal mandrel		

Figure 4 – Cold bend test

5.2.8 Water resistance test

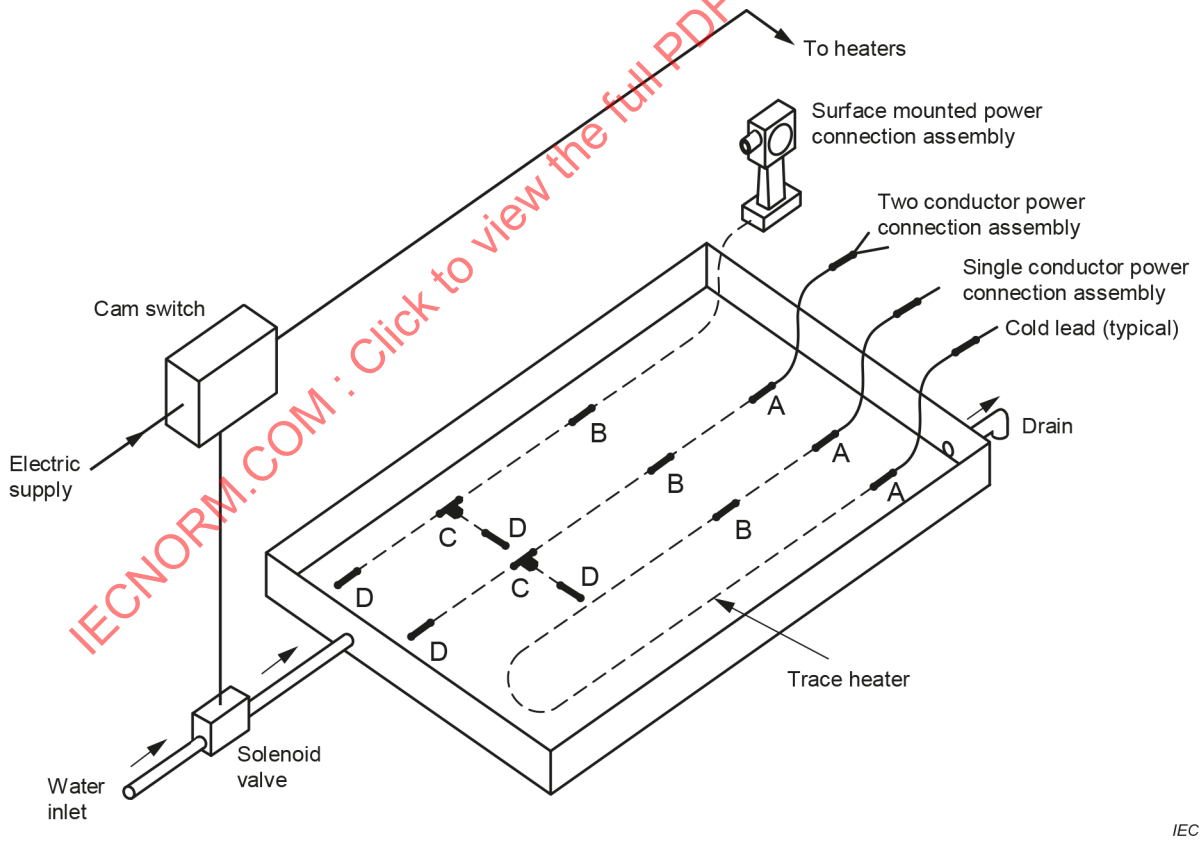
A sample of trace heater at least 3 m in length without integral components, or a sample of surface heater, shall be immersed under at least 50 mm of tap water for a period of 336 h + 48/ - 0 h (14 days). Trace heater ends are not immersed.

After this period, and while still immersed in the water, the sample shall be subjected to the dielectric test outlined in 5.2.1 and the electrical insulation resistance test outlined in 5.2.2.

5.2.9 Integral components resistance to water test

A sample of trace heater with all integral components, or a sample of surface heater with cold leads and integral terminations, shall be placed in a tap water flow and drain apparatus as shown in Figure 5. Water flow shall be initiated and the sample shall be completely immersed. At that point, the water flow is stopped and the trace heater or surface heater is energized. The apparatus is then drained. The total time from the initiation of water flow to the completion of draining shall be no greater than 4,5 min and no less than 2,5 min. The sample shall continue to be energized for at least 30 s after the water has been drained. The sample is then de-energized and water flow is initiated for the next cycle. The test shall be continued for a period of at least 24 h.

After completion, the sample shall be subjected to the dielectric test outlined in 5.2.1 and the insulation resistance test outlined in 5.2.2. All immersed connections and terminations shall be inspected to verify that no water ingress has occurred.



Key

A	integral power connection	C	integral in-line tee
B	integral splice connection	D	integral end termination

Figure 5 – Integral components resistance to water test

5.2.10 Verification of rated output

5.2.10.1 Verification methods

The rated output of the trace heater or surface heater shall be verified by one of the following methods, and the resulting values shall be within the manufacturer's declared tolerance. If a particular application is not covered here, then the procedure shall be agreed between the manufacturer and the testing body.

Table 4 – Applicable test subclauses for the verification of rated output

Verification of rated output test subclause	Applicable examples of installations
5.2.10.2 5.2.10.3	All applications
5.2.10.4.2	Tubing bundles
5.2.10.4.3	Roof deicing[a] Gutter and downspouts deicing[a] Catch basins and drains* Rail heating systems
5.2.10.4.4	Embedded snow melting (without conduit)[a] Embedded frost heave protection Embedded floor warming Embedded energy storage systems Embedded door frames
5.2.10.4.5	Embedded snow melting (with conduit) Embedded frost heave protection Embedded floor warming Embedded energy storage systems Embedded door frames Internal trace heating for freeze protection of potable water lines[a] Enclosed drains and culverts[a]
5.2.10.4.6	Supplementary for: Roof deicing Gutter and downspouts deicing Catch basins and drains Embedded snow melting (without conduit) Internal trace heating for freeze protection of potable water lines Enclosed drains and culverts
[a] Alternatively, the test methods 5.2.10.3 or 5.2.10.4.6 can be conducted. When using one of these alternative test methods, the manufacturer shall have demonstrated the ability to predict the rated output using the test methods in 5.2.10.4.3, 5.2.10.4.4 and 5.2.10.4.5 as applicable.	

5.2.10.2 Method 1 – Resistance approach

The measured DC resistance per unit length at a specified temperature shall be within the manufacturer's declared tolerance.

5.2.10.3 Method 2 – Thermal approach for insulated surfaces

For trace heaters, the power output shall be measured by installation of a 3 m to 6 m sample of trace heater on a metal pipe of 50 mm diameter or greater, as shown in Figure 6. The trace heater shall be installed in accordance with the manufacturer's instructions. The test apparatus shall be completely covered by appropriate insulation of at least 25 mm thickness. (for example with fibreglass or mineral wool).

A suitable heat transfer liquid in the liquid phase shall be circulated through the pipe at a sufficient rate to establish a negligible temperature difference between the fluid and the pipe. The heat transfer fluid shall be maintained at a constant temperature for each test temperature. These parameters are verified by thermocouples placed at the entry and exit ends of the pipe. The pipe temperatures shall not differ by more than 2 K from end to end.

For surface heaters, the test shall be conducted on a flat metal plate fixture with rapid heating and cooling capability, or on a fixture representative of the intended installation. An appropriate thermal insulation (for example with fibreglass or mineral wool) at least 25 mm thick shall be installed over the surface heaters. The surface heaters shall be installed in accordance with the manufacturer's instructions.

A suitable heat transfer fluid in the liquid phase shall be circulated through the metal plate fixture at a sufficient rate to establish a negligible temperature difference between the fluid and the plate temperature. Sufficient means should be utilized to maintain constant temperature of the heat transfer fluid. These parameters shall be verified by thermocouples placed at the entry and exit ends of the pipe or plate. Flow velocity shall be sufficient that the fluid temperature does not differ more than 2 °C from end to end.

The power output of the trace heater or surface heater is measured at three pipe or plate temperatures. For freeze-protection products, the pipe temperatures shall be 10 °C, 25 °C, and 40 °C with a tolerance of +/- 2 K. For process-maintenance products, the pipe temperatures shall be 10 °C and 40 °C, Additionally, a pipe temperature of 70 °C or the maximum maintain temperature minus 20 K whichever is higher shall be used with a tolerance of +/- 2 K. The trace heater or surface heater shall be powered at its rated voltage and allowed to attain equilibrium. The voltage, current, pipe or plate temperatures, and sample length or size are recorded at each test temperature. Three separate determinations are made on separate samples.

5.2.10.4 Method 3 – Thermal approach for other applications

5.2.10.4.1 General

Alternatively to Method 2, for applications other than pipe or vessel heating, the trace heater or surface heater shall be installed in the appropriate test fixture as described in 5.2.13.2.The thermal output of the trace heater or surface heater shall be measured at the rated use temperature for the trace heater or surface heater. The trace heater or surface heater shall be powered at its rated voltage or current and allowed to reach equilibrium. The voltage, current, test temperature and sample dimension(s) shall be recorded. A single sample shall be tested. The resulting power output shall be within the manufacturer's declared tolerance.

5.2.10.4.2 Thermal approach for tubing bundles

For tubing bundles, the test apparatus shall consist of 4,5 m of traced tubing bundle. The quantity of tubes and their diameters in the bundles shall be agreed by the manufacturer and the testing body. Thermocouples shall be used to monitor the temperatures of the tubes near the ends of the test sample. The thermocouples and the connection cables shall be selected and so arranged so they do not significantly affect the thermal behaviour of the temperature measurements, such as 0,2 mm^2 or smaller size Type K or Type J thermocouples.

The tubing within the bundle shall contain flowing water (or a glycol/water solution) at such a flow rate that the variation of temperature from end to end is reduced. The tubing bundle sample shall be tested three times at different target tube temperatures. These shall be 10 °C, 40 °C, and 70 °C with a tolerance of +/- 2 °C. Alternatively, the target tube temperatures can be agreed between the testing body and the manufacturer.

The trace heater sample shall be powered at rated voltage. System temperatures shall be allowed to stabilize. The voltage, current, tube temperatures, and sample length are recorded at each test temperature.

5.2.10.4.3 Outdoor exposed surface heating applications without thermal insulation

For trace heaters or surface heaters intended for outdoor exposed surface heating applications without thermal insulation, the test apparatus described in 5.2.13.2.4 shall be utilized but with the trace heater installation not including any cross-over point. The resulting power output values over the range of ambient temperatures shall be within the manufacturer's declared tolerance.

For roof and gutter heating, the trace heater sample shall be immersed in ice water at 0 °C (recirculated as necessary to maintain the temperature), and the power level shall be verified.

For heating in surface heating applications such as the deicing of rails and metal structures, the test apparatus shall consist of a steel plate or rail having a thickness of at least 6 mm. The trace heater or surface heater shall be installed on the plate or rail, with expansion loops where applicable, along with any accessories, in accordance with the manufacturer's installation instructions. Thermocouples shall be used to monitor the heated plate or rail surface. Thermocouples shall also be located at any anticipated hot spots.

For rated output, the test apparatus shall be placed in an environmental chamber ambient such that the plate or rail temperature is held at 0 °C, and the power level of the trace heater or surface heater shall be verified.

5.2.10.4.4 Embedded heating applications

For trace heaters and surface heaters intended for embedded heating, the test apparatus described in 5.2.13.2.5 shall be utilized, but with the trace heater installation not including any control/expansion joint or cross-over point. The ambient temperature shall be varied to represent the range of ambient temperatures specified by the manufacturer. The resulting values over the range of ambient temperatures shall be within the manufacturer's declared tolerance.

For trace heaters intended for indoor embedded installations in sub-floors, the test apparatus and method described in 5.2.13.2.6 shall be utilized. The resulting values shall be within the manufacturer's declared tolerance.

5.2.10.4.5 Applications of trace heating internal to conduit and piping

NOTE This procedure applies to both pressurized and non-pressurized systems. See 5.2.13.2.7 for the maximum sheath temperature procedure.

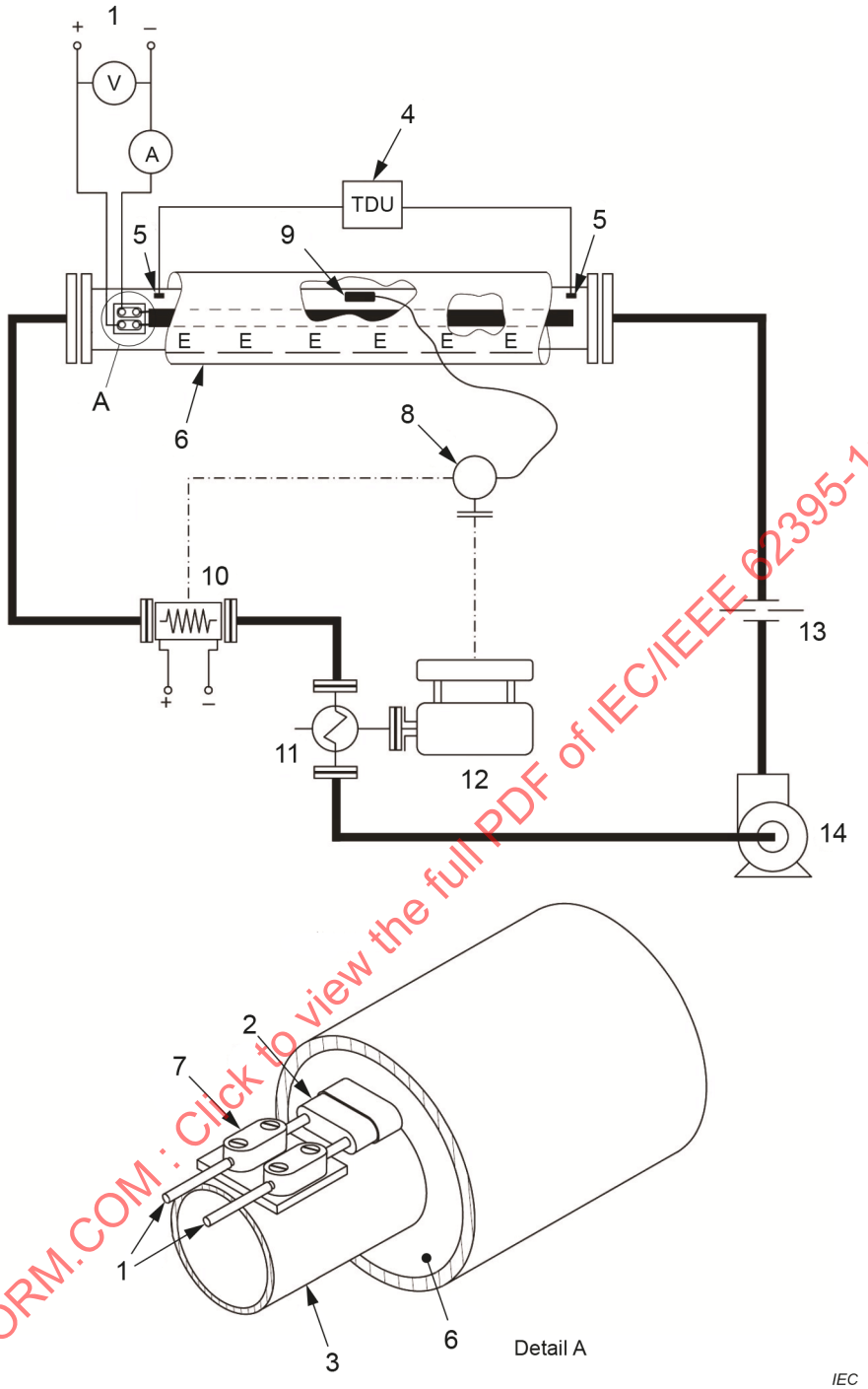
For trace heaters intended for installation internal to conduit and piping, the test apparatus described in 5.2.13.2.7 shall be utilized, but with the trace heater installation not including any cross-over point. In addition, it is not necessary to include the vertical section of pipe or conduit.

The test apparatus shall be placed in an environmental chamber ambient such that the conduit or pipe is held at the rated temperature, and the power output of the trace heater shall be measured. The resulting values shall be within the manufacturer's declared tolerance.

5.2.10.4.6 Supplementary ice bath method

The trace heater shall be tested in an ice bath to determine thermal output in ice conditions. The trace heater or surface heater shall be immersed in ice water at 0 °C (recirculated as necessary to maintain the temperature, or placed in an environmental chamber ambient such that the ice bath is held at 0 °C), and the power output shall be measured. The resulting values shall be within the manufacturer's declared tolerance at 0 °C.

When using this test method, the manufacturer shall have demonstrated the ability to predict the rated output using the test methods in 5.2.10.4.3, 5.2.10.4.4 and 5.2.10.4.5 as applicable.



Key

1	Controlled voltage source	8	Temperature controller
2	Trace heater or surface heater	9	Temperature sensor
3	Test pipe, outside diameter ≥ 50 mm	10	In-line heater
4	Temperature display unit	11	Heat exchanger–
5	Thermocouple	12	Chiller
6	Fibre glass insulation, min 25 mm thickness, approximate density of 3,25 kg/m^3	13	Flow meter
7	Electrical terminals	14	Pump

Figure 6 – Verification of rated output

5.2.11 Thermal stability of electrical insulating material

A sample of trace heater or surface heater shall be placed in a forced air circulation oven. The oven shall be heated to a temperature of 20 K above the maximum withstand temperature declared by the manufacturer and maintained at that temperature for four weeks.

The sample shall be removed from the air oven and cooled to room temperature. Trace heater samples shall be wound six close turns around a mandrel having a radius equal to six times the diameter or six times the thickness of the trace heater. Integral components and non-flexible trace heaters and surface heaters shall not be wound around the mandrel but shall be conditioned as indicated above. Surface heaters shall be wrapped on a mandrel with a radius equivalent to the manufacturer's minimum recommended bending radius. While still on the mandrel the sample, except at terminations or ends where the conductor is exposed, shall be submerged in tap water for at least 5 min. While still in the tap water, the dielectric test 5.2.1 and the insulation resistance test 5.2.2 shall be conducted. Upon completion of these procedures, the sample shall be removed from the water and the outermost sheath shall have no visible cracks when examined with normal vision.

Terminations that insure the vapour tightness of MI trace heaters with electrical insulation that is a hygroscopic material (for example the cold end seals) are subjected to a temperature of (80 ± 2) °C for 4 weeks at not less than 90 % R.H. Compliance of the sample or prototype shall be verified by testing the electrical insulation in accordance with 5.2.1 and 5.2.2.

5.2.12 Thermal performance test

This test demonstrates the thermal safety by verifying the power output stability for all parallel trace heater products with respect to time.

The test apparatus shall consist of a heated metal platen maintained at the specified high test temperature and a cooled metal platen maintained at the specified low test temperature with the test samples being alternated between the platens, or the test shall consist of a metal platen with built in heating and cooling capability to change the temperature within the specified levels. The apparatus is intended to be located in a room temperature environment. The platen(s) shall be sized to expose all parts of the trace heater or surface heater samples, which would be exposed under normal installation conditions, to the temperature levels required by this procedure. The test apparatus shall ensure that the trace heater or surface heater samples are in intimate contact with the platen. The test apparatus can be supplied with a sample mounting fixture. Offsets can be built into the fixture or platen(s) to accommodate end termination/power transition fittings/boots, if provided, where their size profile exceeds the trace heater or surface heater profile. The apparatus shall allow energizing of the trace heater or surface heater samples as required during the test procedure.

The samples shall be thermally insulated on the side not facing the platen so as to enhance effective heat transfer from the platen to the trace heater or surface heater samples.

The temperature of the platen(s) shall be uniformly controlled to a maximum tolerance of ± 5 K for platen temperatures less than 100 °C or ± 10 K for platen temperatures above 100 °C.

The platen described above can be a flat metal plate, a metal pipe, or a metal surface typical of the majority of applications for the trace heater or surface heater being tested.

The trace heater samples shall be within the manufacturer's declared power output tolerance, as validated by 5.2.10. Where the sample is irregular in shape, such as a surface heater, the sample shall consist of at least one heating unit.

If the trace heaters or surface heaters are part of a product range, with common materials (with materials having the same performance ratings) and construction, which have different levels of rated voltages and power outputs, then three samples each shall be selected:

1) the lowest rated voltage level and the maximum rated power output;
2) the highest rated voltage and the minimum rated power output.

If the trace heaters are rated for 300 VAC or higher, an additional three samples of the highest power output and highest voltage shall be selected and tested.

The trace heater or surface heater samples can be conditioned, at the maximum rated voltage for up to 150 h at the manufacturer's declared maximum continuous operating temperature prior to starting the test.

The trace heater samples, having a minimum length of at least 0,3 m, or surface heater samples, shall be installed on the sample mounting fixture or directly applied to the platen. The samples shall be powered at the maximum rated voltage. The temperature of the platen shall be 23 ± 5 °C. The initial power output of the samples shall be determined by measuring voltage and current after the device has reached equilibrium.

Samples of continuous parallel construction, while still installed on the sample mounting fixture or platen and energized at the maximum rated voltage, shall be temperature cycled by alternately exposing the samples to platen(s) temperatures corresponding to 23 ± 5 °C and the maximum continuous operating temperature. The samples are permitted to be de-energized during the cool down period.

Samples of zone type parallel construction shall be temperature cycled in the same manner with the exception that the samples shall be de-energized when not being held at the maximum continuous operating temperature.

If the cycle temperature range exceeds 350 °C, the lower temperature can be set at 350 °C below the maximum continuous operating temperature.

The energized samples shall be exposed to each of these temperature extremes for a minimum of 15 min and a transition time between extremes shall not exceed 15 min with a cycle being one complete exposure at both temperature extremes.

The samples shall be subjected to a pre-conditioning period of 5 continuous temperature cycles. For heater samples of continuous parallel construction, a cycle reference value of the power output of the samples shall be determined by measuring voltage and current during the final 300 seconds of the cold phase of the last pre-conditioning cycle. A minimum of 1 500 cycles shall then be performed. The trace heater samples' power output shall be monitored with measurements recorded during the final 300 seconds of the cold cycle, at intervals not exceeding 50 thermal cycles. In the case of samples having a zone type parallel construction, the power output shall be measured during the final 300 seconds of the hot cycle.

Following the temperature cycling, the temperature of the platen(s) shall be raised to the maximum continuous exposure temperature or the maximum intermittent temperature if higher, declared by the manufacturer, and held for a period of no less than 250 h.

Where the maximum intermittent exposure temperature relates to a temperature while energized, the samples shall be energized at the maximum rated voltage. Where the maximum intermittent exposure temperature relates to a temperature while de-energized, the samples shall not be energized.

After completion of the maximum exposure testing, the samples' power output shall be measured, using the same method and platen temperature as used during the initial power output determination. All samples shall have a final power output within plus 25 % or minus 25 % of the initial power output. All trace heater samples shall also maintain a power measured during the cycles within plus 25 % or minus 25 % of the initial power output, or in the case of trace heater samples of continuous parallel construction, of the cycle reference value.

5.2.13 Maximum sheath temperature

5.2.13.1 General

Maximum sheath temperatures of trace heaters and surface heaters shall be determined to help ensure the safe use of the heater(s). These sheath temperatures shall not exceed the maximum declared withstand temperature of the trace heater or surface heater. The maximum sheath temperature is dependent on the trace heater or surface heater power output, overall heat transfer coefficient, and the maximum possible temperature of the surface to be heated. These factors are used to verify the manufacturer's ability to predict the maximum sheath temperatures.

The maximum allowable power output and sheath temperatures declared by the manufacturer shall be tested by at least one of the following methods.

- A systems approach (see 5.2.13.2), used to validate a manufacturer's design methodology and calculations, in which the trace heater or surface heater is subjected to a test condition where the manufacturer demonstrates ability to design and predict sheath temperatures by conducting specific tests with or without control. Testing for the systems approach can be omitted if test results from the product approach are used exclusively.

  Once a particular application (with and/or without control) has been proven by relating power output and sheath temperature for a particular product, then additional testing for that application or other applications can be limited by analysis and by agreement between the testing body and the manufacturer.
- A product approach (see 5.2.13.3) in which the maximum sheath temperatures are determined in an artificial environment without control.

5.2.13.2 Systems approach, design verification method

5.2.13.2.1 Procedures according to installation type

The following procedures are applied according to the installation type defined in the scope and are intended to validate the manufacturer's design methodology and calculations of maximum sheath temperatures with or without control.

The measured sheath temperatures shall not exceed the manufacturer's calculated values by more than 10 K.

Alternative simulated operating conditions can be agreed between the testing body and the manufacturer.

5.2.13.2.2 Maximum sheath temperature – insulated surfaces with trace heaters

5.2.13.2.2.1 General

These tests shall be conducted three times with varied parameters such as insulation type, thickness, power output or multiple samples.

5.2.13.2.2.2 Test utilizing pipe sculpture fixture

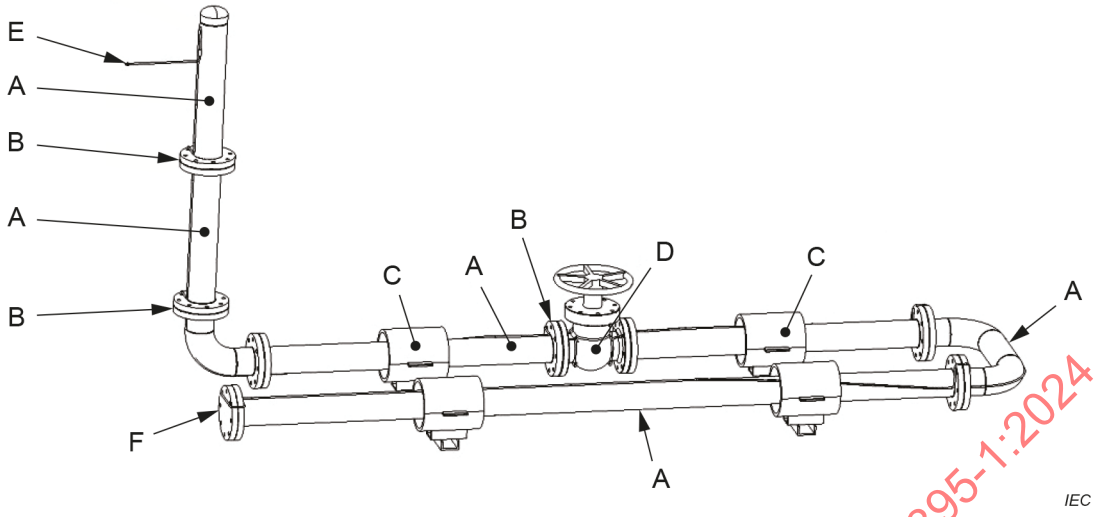
For trace heaters, the test apparatus (see Figure 7) shall consist of a 3 m horizontal run and a minimum 1,5 m vertical run of piping having a pipe size of 100 mm diameter (larger or smaller pipes can be used depending on the application). The pipe shall be empty. A flanged gate valve or equivalent (butterfly valve, globe valve, etc.) shall be located in the centre of the horizontal run. The vertical run shall be so arranged that the flanged pipe ends are in the centre. The trace heater shall be secured in a manner consistent with the manufacturer's installation instructions (including crossing over itself if specified) and typically on the upper portion of the pipe. The sample(s) shall be supplied to cover the complete length of the test apparatus as in Figure 7 and shall be within the upper half of the trace heater or surface heater's power output tolerance or test conditions shall be considered to achieve similar results. Thermocouples shall be used to monitor the outside ambient temperature and the pipe, valve and flange surface temperatures and corresponding heater sheath temperatures at each of these locations (see Figure 7). The thermocouples and the connection cables shall be selected and so arranged so they do not significantly affect the thermal behaviour of the temperature measurements, such as 0,2 mm^2 or smaller size Type J or K thermocouples. Thermocouples for metallic sheaths and heated metallic surfaces shall be suitably attached to reduce measurement error. For metallic braid, polymeric sheaths, or non-metallic heated surfaces the thermocouples should be attached with a suitable adhesive/tape system. Additional thermocouples can be located at anticipated hotspots at the discretion of the testing body. The piping system shall be insulated with a minimum of 25 mm of uniform thickness and type of thermal insulation, for example calcium silicate or expanded perlite, oversized to accommodate the trace heater, and installed in accordance with the manufacturer's installation procedures. Pipe ends shall be plugged and thermally insulated. An additional trace heater length can be added to the test section on either end to reduce end effects.

The trace heater shall be powered at 110 % of its rated voltage. System temperatures shall be allowed to stabilize and thermocouple readings recorded. The manufacturer shall demonstrate the ability to predict the runaway pipe (workpiece) temperature (T_{pr}) and the maximum sheath temperature.

When using the controlled design approach, the control sensor shall be installed according to the manufacturer's instructions at or near the midpoint of the pipe. The predicted maximum sheath temperatures based on the set point of the temperature controller or high temperature limiter shall be compared to the measured maximum trace heater sheath temperatures.

For verifying the control design method with a temperature controller or high temperature limiter sensor shall be installed according to the manufacturer's instructions. The predicted maximum sheath temperature, for a specific set point of the temperature controller or high temperature limiter shall be compared to the measured sheath temperatures.

The measured trace heater sheath temperatures shall not exceed the manufacturer's calculated value by more than 10 K and shall not exceed the manufacturer's declared maximum withstand temperature.



Key

A Pipe and heater sheath thermocouples

B Flange and heater sheath thermocouples

C Isolated support (typical of 2)

D Valve body and heater sheath thermocouples

E Trace heater power connection

F Trace heater end termination

Figure 7 – Verification of sheath temperatures utilizing pipe sculpture fixture

5.2.13.2.2.3 Supplementary test utilizing plate fixture

For the insulated surface trace heating application, the maximum pipe temperature according to the test apparatus and procedures from 5.2.13.2.2.2 shall be used to determine the workpiece temperature that will be used as one of the plate temperatures. When using this test method, the manufacturer shall have demonstrated the ability to predict a runaway pipe (workpiece) temperature (T_{pr}) using the test method in 5.2.13.2.2.2.

When using this test method for all the other application types, the manufacturer shall have demonstrated the applicable test indicated in 5.2.13.2.3, 5.2.13.2.4, 5.2.13.2.5, 5.2.13.2.6, 5.2.13.2.7 and 5.2.13.2.8 as applicable.

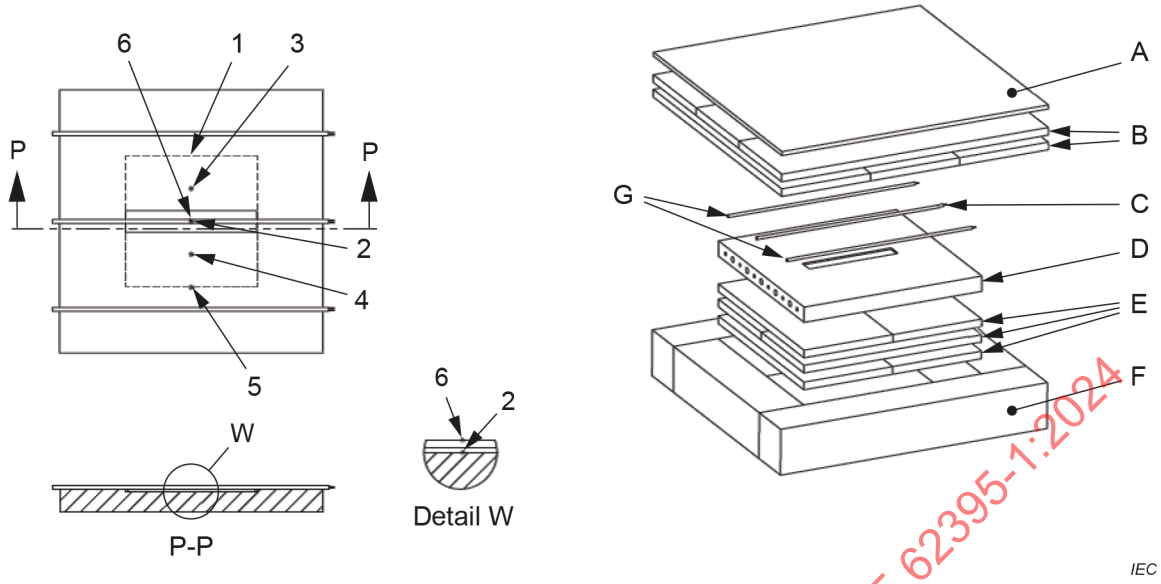
The test apparatus, as shown in Figures 8 through 11, shall consist of an aluminium plate, 600 mm × 600 mm × 50 mm with cartridge heaters, temperature controller and channels for cooling. In the centre of the plate is a trough (approximately 300 mm × 50 mm × 5 mm) over which the trace heater sample is to be placed. The plate is thermally insulated with a minimum of 75 mm of calcium silicate on the bottom and 150 mm wide calcium silicate on the sides of the plate. The top of the apparatus is insulated with two layers, each consisting of three sections of approximately 900 mm × 300 mm × 25 mm calcium silicate sheets, or other suitable insulation as agreed upon with the testing agency. Rigid insulation should be annealed at 300 °C for 4 hours to reduce the possibility of cracking during usage. The rigid insulation shall lie directly on the sample and be supported by two unpowered trace heaters of equal size to the sample as shown in Figure 8. The ends and side gaps shall be filled with mineral wool or rigid insulation. A 900 mm × 900 mm × 13 mm wood board (approximately 10 kg) shall be placed on the top to reduce possible gaps.

The trace heater sample shall be within the upper half of its power output tolerance or, for series trace heaters or for parallel zoned trace heaters, test conditions shall be such as to achieve similar results. The sample shall have a length of at least 600 mm, so the entire heated section of the sample is in contact with the plate as shown in Figure 9. Alternatively, it can be appropriate for the sample to be serpentined on the plate to help ensure the entire heated section of the sample is in contact with the plate as shown in Figure 10. In this case the two unpowered trace heaters supporting the insulation are not necessary. The trace heater sample shall be fixed in place with allowance for trace heater thermal expansion. A thermocouple shall be located within the 300 mm × 300 mm test area which is used to control plate temperature, and three additional thermocouples shall be located on the plate as shown in Figures 8 and 9. A single thermocouple shall be located on the top side of the trace heater sheath in the middle of the trough area, a temperature sensor shall be located within the 300 mm × 300 mm test area to control plate temperature and three additional thermocouples shall be located on the plate as shown in Figure 8 or Figure 9. The thermocouples and the connection cables shall be selected and so arranged so they do not significantly affect the thermal behaviour of the temperature measurements, such as 0,2 mm^2 or smaller size Type K or Type J thermocouples. Thermocouples for metallic sheaths and heated metallic surfaces shall be suitably attached to reduce measurement error. For other electrically conductive coverings, polymeric sheaths, and non-metallic heated surfaces the thermocouples should be attached with suitable adhesive/tape system.

For trace heaters that are allowed to be crossed over, two trace heaters shall be installed perpendicular to each other at a 45° angle to the centre line of the trough as shown in Figure 10. Alternatively, it can be appropriate for a single sample to be crossed over itself at a 45° angle to the centre line of the trough to help ensure the entire heated section is in contact with the plate as shown in Figure 11. In this case, the three thermocouples are installed on the trace heater sheath, at the centre point, and at 75 mm and 150 mm from the centre. The rigid insulation shall lie directly on the top sample and additional supports to keep the insulation parallel to the plate.

The plate temperature shall be set at the designated workpiece temperature. The plate temperature shall be considered stable when the plate temperature controller and the three plate thermocouples are within 2 K of each other. The trace heater shall then be powered at 110 % of rated voltage. After stabilization, when the sheath temperatures rate of change has become less than 2 K in 30 min, the sheath temperatures, the power output(s), and the plate temperatures shall be recorded. The power output(s) recorded shall be adjusted to compensate for any voltage drops associated with the cold lead and/or associated supply power wiring. Verification of sheath temperature measurements shall be made at three plate temperatures and at three power outputs (i.e. 9 sets of measurements), if applicable to the satisfaction of the testing body.

The measured sheath temperature(s) shall not exceed the manufacturer's calculated value by more than 10 K and shall not exceed the manufacturer's declared maximum withstand temperature.

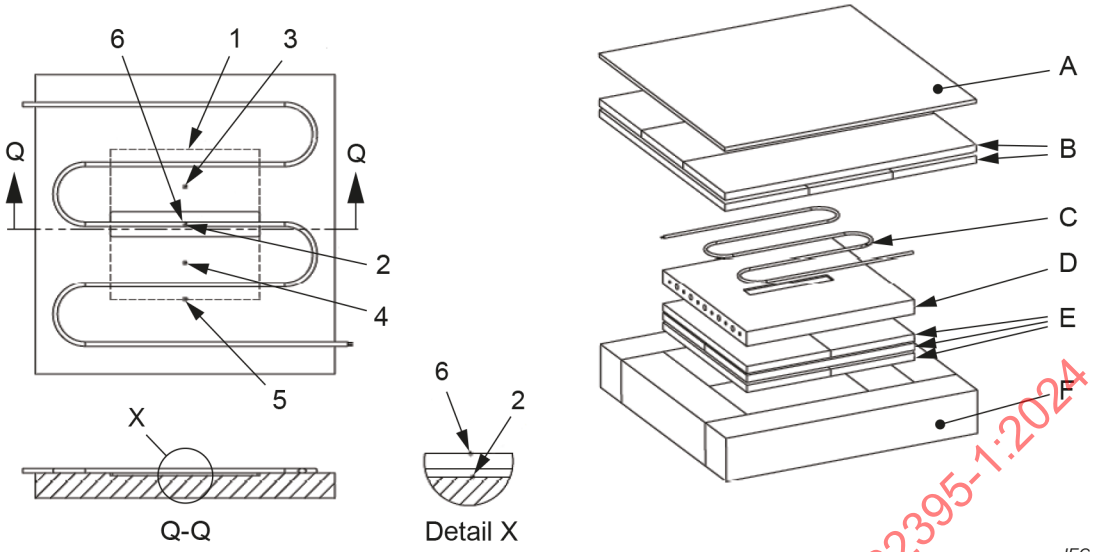


Key

1 300 mm × 300 mm test area
2 Thermocouple on bottom surface of trough
3 Plate temperature control point 75 mm from centreline of trough
4 Thermocouple 75 mm from centre of plate
5 Thermocouple 150 mm from centre of plate
6 Thermocouple on test sample

A Wood board
B Two layers of rigid insulation
C Test sample
D 600 mm × 600 mm plate
E 75 mm insulation below plate
F 150 mm mineral wool sides of plate
G Two unpowered support samples

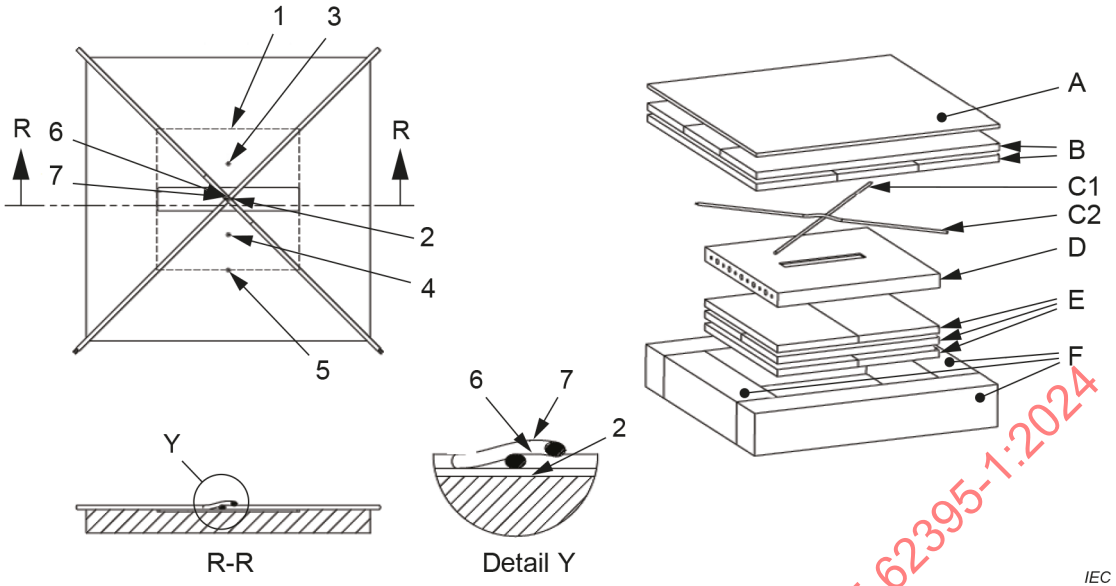
Figure 8 – Verification of sheath temperatures utilizing plate fixture



Key

1	300 mm × 300 mm test area	A	Wood board
2	Thermocouple on bottom surface of trough	B	Two layers of rigid insulation
3	Plate temperature control point 75 mm from centreline of trough	C	Test sample
4	Thermocouple 75 mm from centre of plate	D	600 mm × 600 mm plate
5	Thermocouple 150 mm from centre of plate	E	75 mm insulation below plate
6	Thermocouple on test sample	F	150 mm mineral wool sides of plate

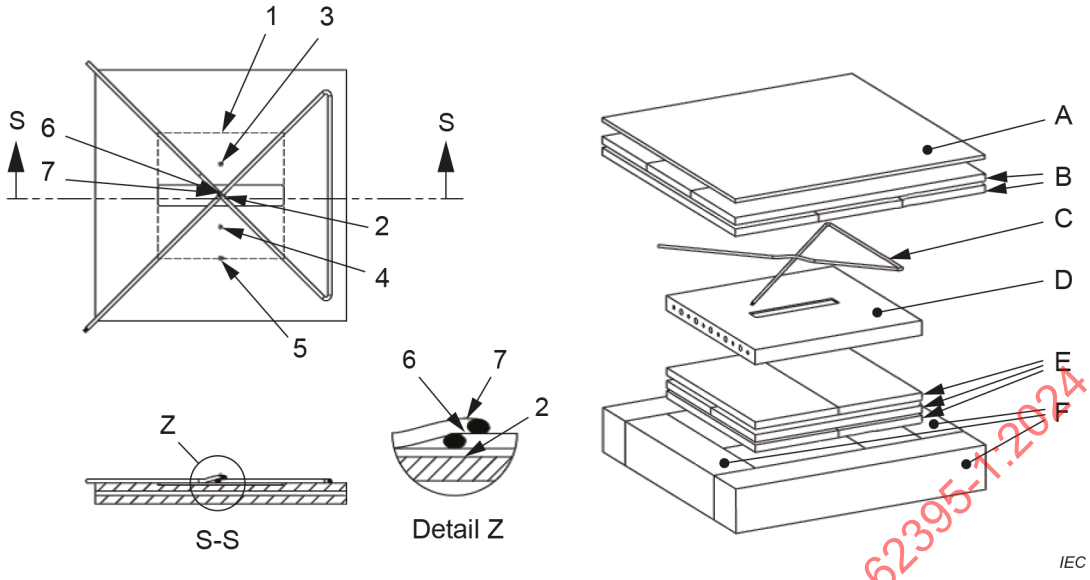
Figure 9 – Verification of sheath temperatures utilizing plate fixture with serpentined sample



Key

1	300 mm × 300 mm test area	A	Wood board
2	Thermocouple on bottom surface of trough	B	Two layers of rigid insulation
3	Plate temperature control point 75 mm from centreline of trough	C1	Test sample – lower sample
4	Thermocouple 75 mm from centre of plate	C2	Test sample – upper sample
5	Thermocouple 150 mm from centre of plate	D	600 mm × 600 mm plate
6	Thermocouple on test sample	E	75 mm insulation below plate
		F	150 mm mineral wool sides of plate

Figure 10 – Plate fixture with two samples crossed over



Key

1	300 mm × 300 mm test area	A	Wood board
2	Thermocouple on bottom surface of trough	B	Two layers of rigid insulation
3	Plate temperature control point 75 mm from centreline of trough	C	Test sample crossed over itself
4	Thermocouple 75 mm from centre of plate	D	600 mm × 600 mm plate
5	Thermocouple 150 mm from centre of plate	E	75 mm insulation below plate
6	Thermocouple on test sample	F	150 mm mineral wool sides of plate

Figure 11 – Plate fixture with a single sample crossed over

5.2.13.2.3 Maximum sheath temperature – insulated surfaces with surface heaters

This test shall be conducted three times with varied parameters such as insulation type, thickness, power output or multiple samples.

For surface heaters, a representative section shall be applied to a 6 mm steel plate in accordance with the manufacturer's instructions. The steel plate shall not extend more than 50 mm from any edge of the surface heater. Thermocouples shall be used to monitor the plate temperatures and the corresponding surface heater sheath temperature at locations in the centremost region or hottest spot of the surface heater. The surface heater sample shall be within the upper half of its power output tolerance or test conditions shall be considered to achieve similar results. The thermocouples and the connection cables shall be selected and arranged so they do not significantly affect the thermal behaviour of the temperature measurements, such as 0,2 mm^2 or smaller size Type K or Type J thermocouples. Thermocouples for metallic sheaths and heated metallic surfaces shall be suitably attached to reduce measurement error. For other electrically conductive coverings, polymeric sheaths, and non-metallic heated surfaces the thermocouples should be attached with suitable adhesive/tape system. Additional thermocouples can be located at other anticipated hot spots at the discretion of the testing body. The heated side of the plate shall be insulated with a uniform thickness of thermal insulation in accordance with the manufacturer's installation procedures. The plate shall be mounted in a vertical position and located in a stable room temperature and no wind environment.

The surface heater shall be powered at 110 % of rated voltage. After stabilization, the thermocouple readings shall be recorded, including the local ambient temperature. The measured heater sheath temperatures shall not exceed the manufacturer's calculated value by more than 10 K and shall not exceed the manufacturer's declared maximum withstand temperature.

When using the controlled design approach, the control sensor shall be installed according to the manufacturer's instructions at a minimum distance of 25 mm from the trace heater pad or panel. The predicted maximum sheath temperatures for a specific set point of the temperature controller or high temperature limiter shall be compared to the measured maximum trace heater or surface heater sheath temperatures.

The measured sheath temperatures shall not exceed manufacturer's calculated value and shall not exceed the manufacturer's declared maximum withstand temperature.

5.2.13.2.4 Maximum sheath temperature - outdoor exposed surface heating

For trace heaters or surface heaters intended for roof and gutter heating, the test apparatus shall consist of a simulated roof consisting of a fir plywood panel 1,2 m × 1,8 m mounted at an angle of 45° to the horizontal. In addition, the fixture shall include a 1,8 m horizontal run of gutter and a 2 m vertical rise of downspout. The trace heater or surface heater and attachment devices shall be installed to the roof, gutter, and downspout according to the manufacturer's instructions. The trace heater or surface heater shall cross over itself on the roof if not prohibited by the manufacturer's instructions. The sheath of the trace heater or surface heater shall have thermocouples installed at the midpoints of both the vertical and horizontal runs, as well as in the midpoint of the roof run (and the crossover if applicable). The trace heater or surface heater shall be energized in no wind conditions at the maximum ambient temperature. The highest sheath temperature shall be recorded after the system reaches normal operating conditions.

For trace heaters or surface heaters intended for applications on outdoor metal structures, such as the deicing of rails, the test apparatus shall consist of a rail, steel plate, or other fixture representative of the intended application. The trace heater or surface heater shall be installed on the mounting surface with expansion loops (if applicable) along with any accessories in accordance with the manufacturer's installation instructions. Thermocouples shall be used to monitor the metal surface, the trace heater or surface heater sheath, and anticipated hot spots to the discretion of the testing body. For maximum temperature testing, the apparatus shall be placed in an environmental chamber at the maximum ambient temperature. The highest sheath temperature shall be recorded after the system reaches normal operating conditions.

The measured sheath temperatures shall not exceed the manufacturer's calculated values and shall not exceed the manufacturer's declared maximum withstand temperature.

5.2.13.2.5 Maximum sheath temperature - embedded heating

For trace heaters or surface heaters intended for embedded applications, such as snow melting of concrete slabs, a test fixture consisting of formed concrete with dimensions of 1 m × 1 m × 90 mm shall be constructed. The fixture shall include one control joint across the width and shall contain no reinforcing steel. If the intended applications do not include concrete, then a similar fixture shall be constructed using representative materials.

The trace heater or surface heater shall be installed according to the product installation instructions, using minimum allowable spacing and maximum power output. The trace heater or surface heater shall be made to cross over itself if not prohibited by the instructions. Thermocouples shall be installed in the embedding media between two successive trace heater or surface heater passes, on the trace heater or surface heater sheath in the centre of the fixture, at the cross-over point if applicable, and on the sheath of the trace heater or surface heater where it exits the substrate. Thermocouples shall also be located at any other anticipated hot spots at the discretion of the testing body. If specified for the application, a covering of specified insulating material shall be placed over the substrate.

The ambient temperature shall be varied to represent the range of ambient temperatures specified by the manufacturer. The resulting values over the range of ambient temperatures shall be within the manufacturer's declared tolerance.

The fixture shall be placed in an environmental chamber on 50 mm of rigid thermal insulation. The environmental chamber ambient shall be varied to represent the range of ambient temperatures specified by the manufacturer, including the maximum specified ambient temperature. The sheath temperatures over the range of ambients including the highest sheath temperature shall be recorded after the system reaches equilibrium.

The measured sheath temperatures shall not exceed manufacturer's calculated values and shall not exceed the manufacturer's declared maximum withstand temperature.

5.2.13.2.6 Maximum sheath temperature - embedded heating installations in indoor sub-floors

This test is intended for trace heater or surface heater applications intended to be embedded in thin-set mortar, or other material specified by the manufacturer, on a wood or concrete sub-floor. The test apparatus shall consist of a minimum 1 m × 1 m × 188 mm floor consisting of 38 mm plywood and nominal 50 mm × 150 mm floor joists, with R20 or similar insulation installed between joists to meet typical building code requirements. Alternately, use insulation with the manufacturer's specified maximum R-value for the trace heater or surface heater installation, provided the specified R-value is included in the product qualification and marking requirements.

The trace heater or surface heater sample shall be embedded in the minimum recommended amount of mortar on the floor. The sample shall be installed in accordance with the manufacturer's installation instructions at the maximum power output and minimum spacing. The apparatus shall have thermocouples installed in the floor between two trace heater or surface heater passes and on the trace heater or surface heater sheath in the centre most area and at other locations in other anticipated hot spots.

For rated output, the test apparatus shall be placed in an environmental chamber and the ambient temperature controlled such that the temperature midway between heating passes is held at the manufacturer's declared temperature differential (between surface of floor and room ambient). The power level and surface temperatures of the sample shall be verified, and the measured output values shall be within the manufacturer's tolerances.

For maximum temperature testing, the test room shall be at an ambient temperature of 28 °C, and the sample operated in a continuous mode at the maximum power output. The maximum temperatures, once stabilized, shall be recorded.

The measured sheath temperatures shall not exceed manufacturer's calculated value and shall not exceed the manufacturer's declared maximum withstand temperature.

5.2.13.2.7 Maximum sheath temperature - trace heating internal to conduit and piping

NOTE This procedure applies to both pressurized and non-pressurized systems. See 5.2.10.4.5 for the verification of rated output procedure.

For trace heaters or surface heaters intended for installation internal to conduit and piping, the test fixture shall consist of a 3 m horizontal run and a 1,5 m vertical run of conduit or pipe of a size representative for the application. The trace heater or surface heater shall be made to cross over itself if not prohibited by the instructions. Thermocouples shall be used to monitor the trace heater or surface heater sheath temperature, the cross-over point if applicable, the temperature of the connections, and the conduit or pipe temperature. Thermocouples shall also be located at any other anticipated hot spots at the discretion of the testing body.

The fixture shall be placed in an environmental chamber, and the chamber ambient shall be raised to the maximum ambient temperature. The highest sheath temperature shall be recorded after the system reaches normal operating conditions.

The measured sheath temperatures shall not exceed manufacturer's calculated values and shall not exceed the manufacturer's declared maximum withstand temperature.

5.2.13.2.8 Maximum sheath temperature – insulated externally heated surfaces – tubing bundles

For tubing bundles, the test apparatus shall consist of 4,5 m of traced tubing bundle. The quantity of tubes and their diameters in the bundles shall be agreed by the manufacturer and the testing body. Thermocouples shall be used to monitor the tubes and corresponding heater sheath temperatures at locations in the midpoint region of the bundle. The thermocouples and the connection cables shall be selected and so arranged so they do not significantly affect the thermal behaviour of the temperature measurements, such as 0,2 mm^2 or smaller size Type K or Type J thermocouples. Thermocouples for metallic sheath and heated metallic surfaces shall be suitably attached to reduce measurement error. Thermocouples shall be attached with suitable adhesive/tape systems when installed on other electrically conductive coverings, polymeric sheaths and non-metallic heated surfaces. Additional thermocouples can be located at other anticipated hot spots at the discretion of the testing body.

The trace heater or surface heater shall be powered at 110 % of rated voltage. System temperatures shall be allowed to stabilize, and thermocouple readings recorded. When using the controlled design method, the temperature sensor shall be installed according to the manufacturer's instructions at or near the midpoint of the bundle. The predicted maximum sheath temperatures based on the set point of the temperature controller or high temperature limiter sensor shall be compared to the measured maximum trace heater sheath temperatures.

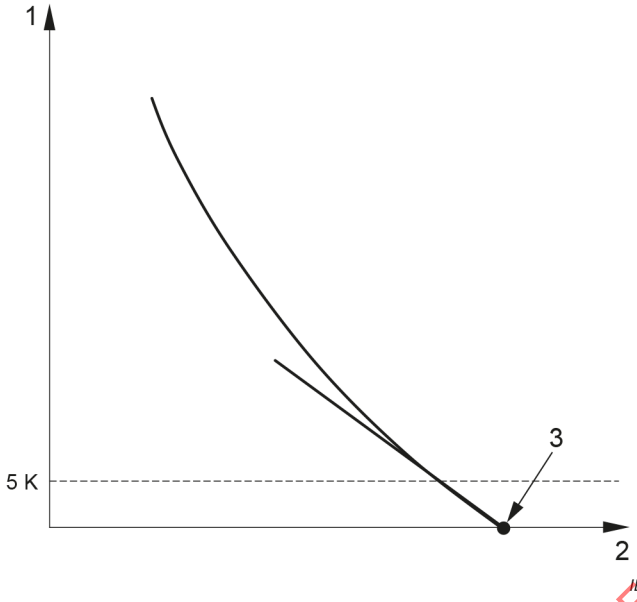
The measured trace heater sheath temperatures shall not exceed the manufacturer's calculated value by more than 10 K and shall not exceed the manufacturer's declared maximum withstand temperature.

The tubing within the bundle shall be empty and the maximum sheath temperature shall be recorded.

5.2.13.3 Maximum sheath temperature – product approach

A sample of trace heater at least 1,5 m in length is placed loosely coiled (i.e. not touching itself and not located on the bottom of the oven) in a forced air circulation oven. For surface heaters, a representative sample is placed horizontally in the oven. The sample shall be within the upper half of the trace heater's or surface heater's power output tolerance, or the data shall be adjusted to reflect the upper limit of the power output tolerance.

Representative thermocouples shall be used to monitor sample sheath temperatures and shall be placed 500 mm from each end. One additional thermocouple shall be used to monitor the oven ambient temperature. The sample shall be energized at 110 % of rated voltage. The oven ambient temperature shall be raised from ambient temperature in increments no greater than 15 K. Sufficient time shall be permitted at each temperature to allow for the oven temperature and the trace heater or surface heater sheath temperature to stabilize and attain thermal equilibrium. Oven and trace heater or surface heater sheath temperatures shall be recorded at each successive level until the difference (ΔT) between the two is 5 K or less. A curve shall be drawn from the test data, and a straight-line drawn tangent to the curve at the 5 K temperature difference point and extended to 0 K. The temperature read at this intercept shall be taken as the maximum sheath temperature, as shown in Figure 12.



Key

1 Sample temperature minus oven air temperature (T_s – T_0), K

2 Oven temperature (T_0), ºC

3 Recorded value of T_s, ºC

Figure 12 – Maximum sheath temperature using the product approach

5.2.14 Verification of start-up current

This test is applicable to trace heaters and surface heaters that have a positive temperature coefficient of resistance greater than that of copper.

The start-up current of the trace heater or surface heater shall be measured as a function of the start-up temperature as designated by the manufacturer. A sample of trace heater, at least 1 m in length, shall be installed in accordance with the manufacturer's instructions on a minimum 50 mm diameter liquid-filled metal pipe or solid steel rod, or for surface heaters a minimum 25 mm thick flat metal heat sink. The testing apparatus can be covered with thermal insulation and shall be conditioned at the designated temperature until equilibrium is achieved. The test shall be initiated only after the pipe, rod, or flat metal heat sink has stabilized to the designated temperature.

NOTE The apparatus described in 5.2.10 can be used for this test.

After the conditioning period, rated voltage shall be applied, and the time and RMS. current characteristic shall be recorded from time 0 to 300 s in intervals of no greater than 1 s. The start-up current recorded shall be correlated to the maximum output tolerance. The data shall be adjusted to reflect the upper limit of the power output tolerance by multiplying the test values by the ratio of the maximum output tolerance level for the sample divided by the actual power output for the sample. This time-current characteristic shall not be more than the value declared by the manufacturer.

5.2.15 Verification of the electrical resistance of the electrically conductive covering

The electrical resistance of the metallic braid, sheath or other electrically conductive covering shall be measured at 10 °C to 40 °C, of at least a 3 m length of trace heater or a representative sample of a surface heater. The resistance shall be equal to, or less than, the manufacturer's declared value. Additional consideration shall be applied by the testing body for evaluation of equivalent materials other than metallic braid or sheath.

5.2.16 Test for heating device / heating device set glands - General

5.2.16.1 General

The requirements of this clause apply to cable entries for trace heating and/or surface heating systems designed to insert the exposed power supply cables, cold ends and/or trace heaters directly to exposed enclosures, by a clamping and/or sealing system containing elastomeric material.

NOTE These requirements would not apply to the following:

- glands for power cables and cold leads that are part of the power supply branch circuits within the temperature and electric rating.
- metallic gland fittings without elastomeric seal for metallic sheathed cables such as MI heating devices.

5.2.16.2 Strain relief

One sample of each connection that provides strain relief shall be subjected to the test. The specimens will consist of at least 300 mm of trace heater attached to the subject fitting according to the manufacturer's instructions. A steady load as shown in Table 5 shall be gradually applied between the trace heater or surface heater and the fitting. The load shall be maintained for a period of 1 min. As a result of this test, the power leads of the trace heater or surface heater shall not loosen or separate by more than 2 mm from the fitting when measured after removal of the load, and there shall be no visual damage to the conductors, insulation, or fitting.

Table 5 – Pulling forces for strain relief test

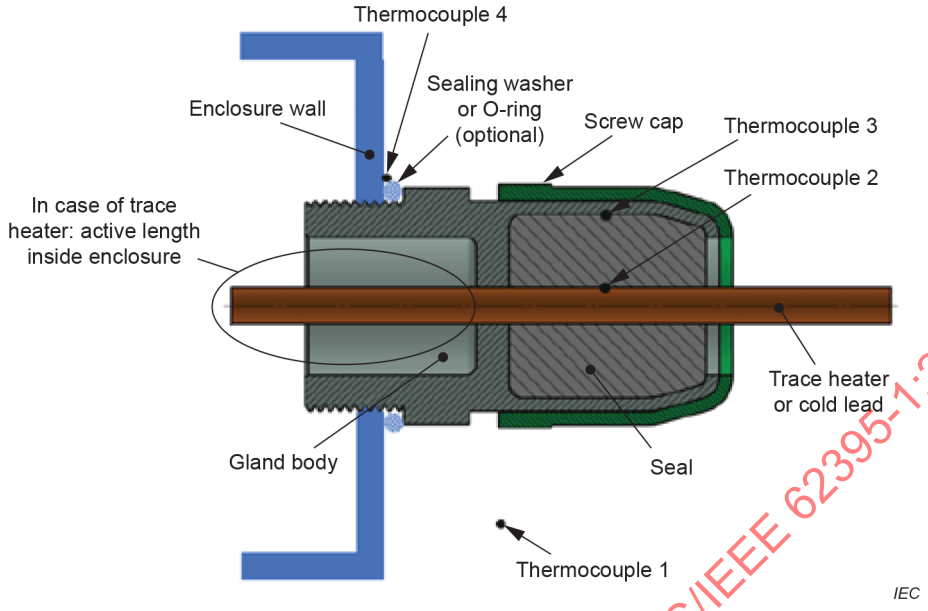
Installation type	Pulling force F_p depending on shape of trace heater, cold lead or mandrel N, Newton	
	Circular	Non-circular
Non-fixed installations	F_p = 158 N	F_p = 158 N
Fixed installation	F_p [N] = 0,25 × 20 × OD [mm]	F_p [N] = 0,25 × 6 × OP [mm]
For connections to fixed installed cold leads or trace heaters, the cold lead or trace heater should be arranged to permit installation into and removal for maintenance from the termination enclosure without affecting the fixed part of the installation. This means that the cold lead or trace heater cannot be affixed for a reasonable length. That non affixed length cannot exceed the fixing distance of the applicable national installation standards (typically 300 mm). OD Outer Diameter in mm OP Outer Perimeter in mm		

5.2.16.3 Temperature

The temperature rating of the materials used to construct the trace heating connection system, shall be selected such that they can withstand the temperatures that are occurring in the vicinity of the trace heater.

The thermocouples and their connection cables shall be selected and so arranged so they do not significantly affect the thermal behaviour of the temperature measurements, such as 0,2 mm^2 or smaller size Type K or Type J thermocouples. The thermocouples shall be placed as shown in Figure 13 and logged. After stabilization, when the rate of change of the temperatures has become less than 2 K in 30 min, the temperatures shall be recorded. The measured temperatures shall not exceed the maximum continuous operation temperature of the gland body, grommet or any other component of the assembly such as sealing washers, O-ring, or gaskets each. The temperatures shall be logged in at least 5-minute intervals in order to be able to determine stabilisation of the temperatures and provide evidence.

Thermocouples shall be placed at the following locations:



Key locations of thermocouples

1 ambient

2 between trace heater grommet and trace heater

3 between trace heater grommet and gland body

4 at sealing to enclosure

5 hottest anticipated surface temperature inside the enclosure with which filed wired power cables and/or conductors may get contact (to be listed in the instructions)

Figure 13 – Gland temperature measurement – location of thermocouples

5.2.16.4 Degree of ingress protection (IP)

The degree of protection for the connections to the trace heating system shall be verified in accordance with IEC 60529. The following IP ratings are required.

- dry applications:IP5X;
- wet applications: Minimum IP54.

5.2.17 Connection Integrity (integral components)

5.2.17.1 General

Insulated integral connections, other than those brazed or welded or those at an attachment plug, shall be capable of withstanding all applicable tests without the breakage of the conductors, the shearing of parts, or other damage to the connections.

Three samples of the insulated connection, assembled in accordance with 5.2.17.2, shall have the maximum current rating declared by the manufacturer for the trace heater when operated at room temperature passed through all connections. Uninsulated connections and conductor can be used for the connection integrity tests. The average stabilized temperature rise above ambient for each connection, as measured by a thermocouple (or equivalent) directly attached to each connection, shall be recorded in a draft-free, temperature-controlled room or enclosure for each connection. This average stabilized temperature rise value shall be referred to as the heating reference temperature rise above ambient for each such connection.

NOTE

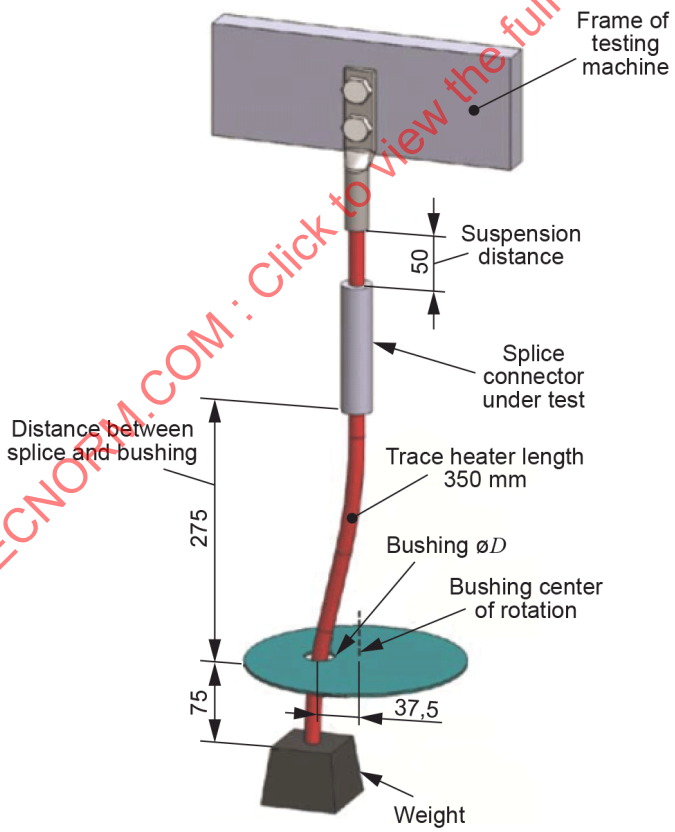
1) Integral connections are considered a complete connection assembly: complete heating to non-heating assembly or complete end splice or seal assembly when covered by a common insulating cover. A splice assembly can consist of two or more current-carrying leads, bonding conductor or braid, and splice connectors. An end seal can consist of two or more current-carrying leads connected together with the splice connector.

2) Temperatures are considered stable when three temperature readings taken at not less than 10 min intervals show no more than a 2 °C variation between the three consecutive readings. The ambient temperature during this time period is used for determining the temperature rise.

5.2.17.2 Firm Attachment

The samples from 5.2.17.1 shall be suspended in a vertical position from the frame of the testing machine as noted in Figure 14. Each sample shall be fastened to a length of trace heater not less than 350 mm long and to a length of non-heating lead not less than 50 mm long. The free end shall be passed through a bushing having a diameter to the nearest 1.6 mm equal to the diameter of the finished connection plus 3.2 mm. The bushing shall be attached to an arm driven by a motor at a rate of approximately 9 revolutions per min and in such a manner that the centre of the bushing is made to describe a circle in a horizontal plane. The circle shall have a diameter of 75 mm, and its centre shall be vertically below the point of mounting of the connector. The distance, within 13 mm, between the upper side of the bushing and the centre of the connector shall be 275 mm, and the distance between the point of suspension and the centre of the connector shall be 50 mm. A weight with a mass of 0,9 kg for conductors less than or equal to 1,5 mm^{2}shall be suspended from the free end of the trace heater. A weight with a mass of 2,3 kg for conductors greater than 1,5 mm^2 shall be suspended from the free end of the trace heater. The duration of the test shall be at least 30 min.

NOTE Connectors of an end termination that employ a single crimp connector crimping two or more conductors are exempt from being subjected to this 5.2.17.2.



with mass of 0,9 kg for conductor size less than or equal to 1,5 mm^2
and a mass of 2,3 kg for conductor size greater than 1,5mm^2

IEC

Figure 14 – Typical splice firm attachment apparatus

5.2.17.3 Current cycling

After the firm attachment testing, the maximum declared current rating of the trace heater shall be passed through each connection for a minimum of 42 cycles. Each cycle shall consist of a current ON period of 3.5 h followed by a current OFF period of 0.5 h. The temperatures at each connection shall be recorded throughout the cycle. The average temperature rise above ambient shall be calculated during the last 2 h of each ON cycle. The average temperature rise above ambient shall not increase by more than 10 K when compared from the first to any of the subsequent cycles.

5.2.17.4 Heating

After the current cycling, each connection shall be capable of carrying continuously the maximum declared current rating of the trace heater, and the average stabilized temperature rise above ambient at any connection shall not increase by more than 20 K over the initial heating reference temperature rise above ambient determined in 5.2.17.1 for that connection.

5.2.17.5 Pullout

After the heating test, the connections shall not become separated from the conductors when tested as follows:

a) Each connection shall be subjected for 1 min to a direct pull of a weight of 7.0 kg for solid conductors or a weight of 3.5 kg for conductors other than solid conductors. The pull shall be exerted by means of a tension-testing machine or the equivalent, so that there will be no sudden application or jerking during the test.

b) The test shall be made with the insulation removed from the connection. In the case of a spirally wound conductor, the pull shall be applied to the assembly of the core and the spirally wound heating conductor.

c) When the connection assembly is such that no single conductor or lead is able or likely to be pulled individually, the complete connection assembly with the common insulation removed shall be subjected to the pull force.

NOTE Connectors of an end termination that employ a single crimp connector crimping two or more conductors are exempt from being subjected to this 5.2.17.5.

5.3 Type tests – Additional tests for outdoor exposed surface heating installations without thermal insulation

5.3.1 Verification of rated output

The rated output of the trace heater or surface heater shall be verified by 5.2.10.4.3 or 5.2.10.2 as applicable. Subsequent verification can be done by one of the procedures described in 5.2.10.2, 5.2.10.3, and 5.2.10.4.6.

5.3.2 Determination of maximum sheath temperature

The maximum sheath temperatures of the trace heater or surface heater shall be verified by the procedures described in 5.2.13.2.4 or 5.2.13.3 as applicable. Subsequent verification can be done by one of the procedures described in 5.2.13.2.2.3 and 5.2.13.3.

5.3.3 Increased moisture resistance test

A minimum 3 m sample of trace heater or a representative surface heater, complete with any integral connections and end terminations, shall be immersed in water at 10 C to 25 C for a period of 2 000 h (12 weeks).

After conditioning as above, the sample shall be tested to the dielectric test in 5.2.1, and the electrical insulation resistance test in 5.2.2.

5.3.4 UV and condensation test

Trace heaters, surface heaters and integral components having a continuous metal sheath with no outer jacket shall be exempt from this test. Integral components shall be subjected to the same evaluation as trace heaters and surface heaters, except as noted in the referenced procedures. System components other than those identified as integral shall be evaluated in accordance with national and international standards relevant to their construction and use.

Three samples of the trace heater or surface heater approximately 450 mm in length or a representative sample of a surface heater, including integral components shall be placed in a xenon-arc light-exposure apparatus as described in ASTM G155 or ISO 4892-2.

The procedure shall be as described in ASTM G155 cycle 1 or ISO 4892-2 cycle 1 or cycle 4. The narrowband irradiance can be:

a) of 0,35 W/(m^2 nm) at 340 nm for a total period of 1 000 h, or

b) of 0,51 W/(m^2 nm) at 340 nm for a total period of 690 h

At the end of this time, the samples shall be removed from the chamber and independently (one test per sample) subjected to the mechanical tests in 5.2.4, 5.2.5, and 5.2.7 (room temperature impact, cold impact, and cold bend). After the mechanical tests the outermost sheath shall be subjected to a dielectric voltage of 500 VAC, applied between the conductive layer and tap water (resistivity typically 500 Ω·m) for 1 min without dielectric breakdown. The sample shall be exposed to the water for a minimum of 5 minutes prior to the application of the dielectric test.

Alternatively, materials that have been independently qualified for outdoor exposure according to this test procedure are acceptable.

5.3.5 Resistance to cutting test

A sample of trace heater or surface heater, at least 200 mm in length, shall be tested. The sample shall be placed on top of a rigid flat steel support. A trace heater sample having a non-circular cross-section shall be positioned such that the proof load is applied along the minor axis (i.e. positioned flat on the steel plate). A metal cutting edge with a 0,25 mm radius shall be mounted above the sample such that the cutting edge is at a right angle to the sample. An ohmmeter shall be attached to the trace heater or surface heater conductors shorted together and to the metal cutting edge. Alternatively, a signalling device circuit can be utilized in series with the blade, specimen conductor, and a 120 V ac supply such that the signal will operate when the cutting blade contacts the specimen conductor (note that the fixture components are energized if utilizing this method).

A proof load of 445 N shall be gradually applied to the cutting edge as it impinges on the sample. The ohmmeter or signalling device circuit shall be used to verify that the cutting edge has not cut through the insulation and make contact with the conductors of the trace heater or surface heater.

5.3.6 Abrasion test

Six samples of trace heater, approximately 1 m in length, shall be tested. The electrical resistance of the metallic sheath, braid, screen or equivalent electrically conductive covering of each of the samples shall be measured with an ohmmeter having an accuracy of ± 1 %. The average initial resistance shall be calculated.

The samples shall be placed in the abrasion test apparatus shown in Figure 15. One end of each of the samples shall be attached to a horizontal reciprocating table and the other end of each sample shall be attached to a mass of 340 g. Each sample shall be laid over a 90 mm radius cylinder positioned at the end of the table and covered with an unused layer of grade 1/2 (medium) emery cloth, or 120 grit silicon carbide/resin bond abrasive paper. The longitudinal axis of the cylinder shall be horizontal and perpendicular to each of the samples.

The table shall commence reciprocating at a rate of approximately 30 cycles per minute. Each cycle shall consist of one complete back-and-forth motion with a stroke of approximately 160 mm. The table shall be stopped every 50 cycles and the abrasive material shall be repositioned or replaced so that all the samples shall be subject to abrasion by a fresh surface of the abrasive material in subsequent cycles. After 2 500 cycles, the test shall be stopped and the resistance of the conductive braid or sheath of each of the samples shall be measured again. The average resistance shall be calculated and compared to the initial average value. The final average resistance value shall not exceed 125 % of the initial average value. Also, if the samples are overjacketed, the underlying conductive braid or sheath shall not have become exposed.

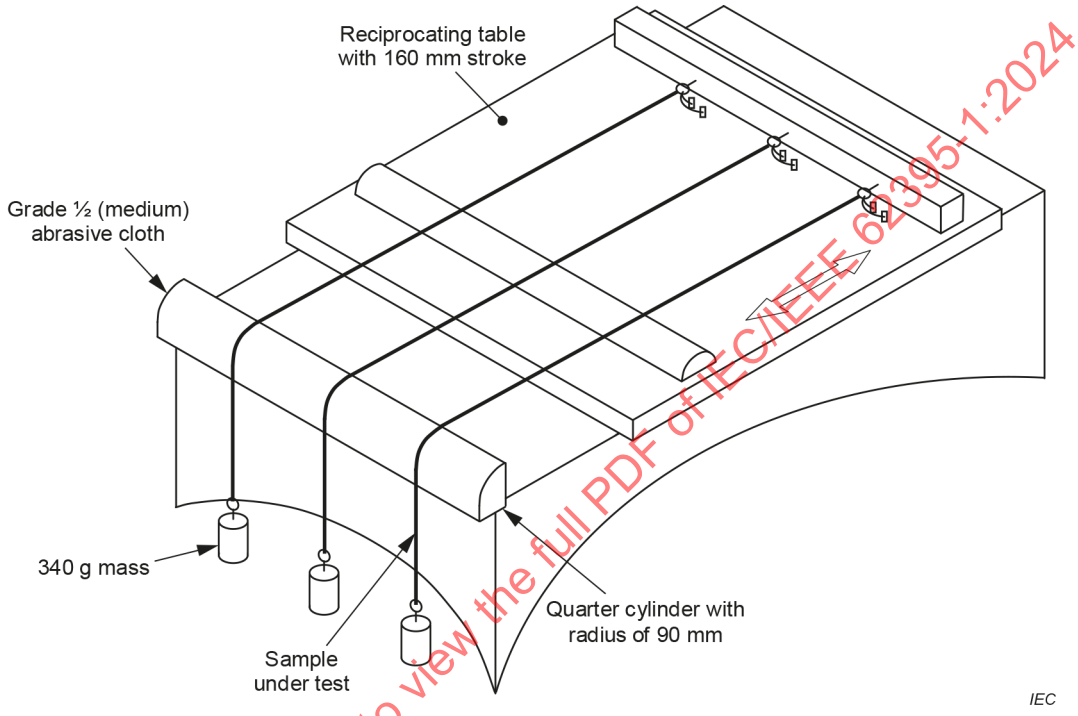


Figure 15 – Abrasion test

5.3.7 Tension test

A 30 kg mass, or a mass sufficient to impose the manufacturer's stated maximum tensile value, whichever is greater, shall be suspended from the free end of the heating section of a 1 m long sample for 1 h, with the other end of the sample secured tightly. There shall be no breakage of the conductors or braid and there shall be no visual damage to the insulation (except in the areas where the sample was secured).

5.3.8 Rail system voltage spike test

Rail heating systems are routinely subjected to voltage spikes stemming from the voltage supply. For trace heaters or surface heaters intended for applications on outdoor metal structures, such as the deicing of rails, a sample of trace heater at least 2 m in length, or a representative surface heater, shall be subjected to 1 000 cycles of 5 000 V impulses. Each impulse should have a 1,2 ∝s rise time and a 50 ∝s fall time. The sample shall then pass the requirements of 5.2.1 and 5.2.2.