IEC/IEEE 60079-30-1

Edition 1.0 2015-09

INTERNATIONAL STANDARD

Explosive atmospheres –
Part 30-1: Electrical resistance trace heating – General and testing requirements

IEC/IEEE 60079-30-1:2015-09(en)

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colour inside

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EXPLOSIVE ATMOSPHERES –

Part 30-1: Electrical resistance trace heating – General and testing requirements

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation.

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2) The formal decisions of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees. The formal decisions of IEEE on technical matters, once consensus within IEEE Societies and Standards Coordinating Committees has been reached, is determined by a balanced ballot of materially interested parties who indicate interest in reviewing the proposed standard. Final approval of the IEEE standards document is given by the IEEE Standards Association (IEEE-SA) Standards Board.

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International Standard IEC/IEEE 60079-30-1 has been prepared by IEC technical committee 31: Equipment for explosive atmospheres, in cooperation with the Petroleum & Chemical Industry Committee of the IEEE Industrial Applications Society under the IEC/IEEE Dual Logo Agreement.

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

NOTE A list of IEEE participants can be found at the following URL: http://standards.ieee.org/downloads/60079/60079-30-1-2015/60079-30-1-2015_wg-participants.pdf .

This first edition of IEC/IEEE 60079-30-1 cancels and replaces the first edition of IEC 60079-30-1 published in 2007 and constitutes a technical revision.

This edition includes the following significant changes, apart from the general revision and updating of the first edition of IEC 60079-30-1 and harmonization with IEEE Std 515, with respect to the previous edition:

- the inclusion of a minimum temperature impact test;
- the addition of a mechanical procedure in the thermal stability test;
- the inclusion of a thermal performance test to replace the thermal safety requirements;
- the inclusion of a second procedure utilizing a plate fixture for sheath temperature determination;
- the inclusion of an ultraviolet and condensation test;
- the revision and significant expansion of documentation requirements;
- the addition of Annexes covering requirements for Divisions 1 and 2;
- the addition of a table covering the applicability of requirements from IEC 60079-0;
- the addition of an Annex covering trace heater product design verification methodology (formerly located in IEC 60079-30-2);
- the further harmonization of this edition with several national standards.

The significance of changes between IEC 60079-30-1, Edition 1.0 (2007) and IEC/IEEE 60079-30-1, Edition 1.0 (2015) is as listed below:

		Type		
Changes	**Clause**	**Minor and editorial changes**	**Extension**	**Major technical changes**
Addition of clarification for the exclusion of EPLs Ga and Da	1	X		
Addition of requirements for the Division method of area classification that may be applied by some users	1		X	
Addition of table specifying the application or exclusion of specific clauses of IEC 60079-0 Edition 6	1	X		
For stabilized designs, a clarification for the need for verification by testing and the addition of a table for the specific requirements	4.5.2	X		
For controlled designs, a clarification for the need for verification by testing and the addition of a table for the specific requirements	4.5.3	X		
For controlled designs, clarifications and additions on the separate requirements for Gb/Db and Gc/Dc	4.5.3		X	
The requirements for calibration of the flammability test fixture are replaced with equivalent requirements for the energy levels of the test gases	5.1.4	X		
Addition of a minimum temperature impact test	5.1.5			C1

		Type		
Changes	**Clause**	**Minor and editorial changes**	**Extension**	**Major technical changes**
For thermal stability, the addition of a bending requirement on a mandrel	5.1.11			C1
The replacement of the thermal safety procedure with a thermal performance procedure	5.1.12			C2
The addition of a second procedure utilizing a plate fixture for the systems method for maximum sheath temperature determination	5.1.13.2			C3
Addition of outdoor exposure test	5.1.16			C4
Requirement changed for the marking of the minimum installation temperature	6.1			C5
Addition of new markings requirements for field assembled components	6.2			C5
Additions and changes to the documentation requirements	7			C5
Addition of Annex	Annex A	X		
Addition of Annex	Annex B	X		
Addition of Annex specifying trace heating design verification methodology, moved from IEC 60079-30-2	Annex C			C6
Addition of Annex for the Division method of area classification that may be applied by some users	Annex D		X	
Addition of Annex for the Division method of area classification that may be applied by some users	Annex E		X	

NOTE The technical changes referred to include the significance of technical changes in the revised IEC Standard, but they do not form an exhaustive list of all modifications from the previous version.

Explanations:

A) Definitions

Minor and editorial changes

clarification
decrease of technical requirements
minor technical change
editorial corrections

These are changes which modify requirements in an editorial or a minor technical way. They include changes of the wording to clarify technical requirements without any technical change, or a reduction in level of existing requirement.

Extension addition of technical options

These are changes which add new or modify existing technical requirements, in a way that new options are given, but without increasing requirements for equipment that was fully compliant with the previous standard. Therefore, these will not have to be considered for products in conformity with the preceding edition.

Major technical changes

addition of technical requirements
increase of technical requirements

These are changes to technical requirements (addition, increase of the level or removal) made in a way that a product in conformity with the preceding edition will not always be able to fulfil the requirements given in the later edition. These changes have to be considered for products in conformity with the preceding edition. For these changes additional information is provided in clause B) below.

NOTE These changes represent current technological knowledge. However, these changes should not normally have an influence on equipment already placed on the market.

B) Information about the background of 'Major Technical Changes'

C1 – The requirements for additional mechanical testing have been included for harmonization and for added safety.

C2 – The requirements for thermal performance have been included to recognize the necessity for thermal stability of products in explosive atmospheres.

C3 – A second procedure utilizing a plate fixture has been included for sheath temperature determination, which may be used in lieu of the sheath temperature verification part of 5.1.13.4.2.

C4 – An outdoor exposure test has been added to cover products that may be exposed to sunlight and moisture in the intended application.

C5 – Additional marking and documentation requirements have been added to provide additional information to the end user.

C6 – The trace heating design verification methodology has been added to align with the evaluation requirements for the stabilized design and the controlled design methods of maximum sheath temperature determination.

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

FDIS	Report on voting
31/1191/FDIS	31/1201/RVD

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

International standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

This standard is intended to be used in conjunction with IEC/IEEE 60079-30-2:2015, *Explosive atmospheres – Part 30-2: Electrical resistance trace heating – Application guide for design, installation and maintenance.*

A list of all parts of IEC 60079 series, under the general title *Explosive atmospheres,* can be found on the IEC website.

The IEC Technical Committee and IEEE Technical Committee have decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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

A bilingual version of this publication may be issued at a later date.

IMPORTANT – The 'colour inside' logo on the cover page of this publication 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.

INTRODUCTION

IEC/IEEE 60079-30-1 is intended to provide a comprehensive overview of the essential requirements and testing appropriate to electric surface heating equipment used in explosive atmospheres. The requirements of this part of IEC 60079 are considered to be the minimum requirements for equipment protection levels Gb, Gc, Db, and Dc in explosive atmospheres for gases, dusts, and fibres/flyings. While some of this work already exists in national standards or international standards, this standard has collated much of this existing work and considerably added to it. This standard also contains the minimum requirements for users applying the Division method of area classification.

EXPLOSIVE ATMOSPHERES –

Part 30-1: Electrical resistance trace heating – General and testing requirements

1 Scope

This part of IEC 60079 specifies general and testing requirements for electrical resistance trace heaters for application in explosive atmospheres with the exclusion of those for EPL Ga and Da. This standard covers trace heaters that comprise either factory or field (work-site) assembled units, and which may be series trace heaters, parallel trace heaters, trace heater pads, or trace heater panels that have been assembled and/or terminated in accordance with the manufacturer's instructions.

This standard also includes requirements for termination assemblies and control methods used with trace heating systems. The explosive atmospheres referred to in this standard are those defined in IEC 60079-10-1 and IEC 60079-10-2.

Annexes D and E outline the application of this standard for those users applying the Division method of area classification.

This standard supplements and modifies the general requirements of IEC 60079-0, except as indicated in Table 1. Where a requirement of this standard conflicts with a requirement of IEC 60079-0, the requirement of this standard takes precedence.

Table 1 – Application or exclusion of specific clauses of IEC 60079-0

IEC 60079-0		Electrical resistance trace heaters and integral components		Terminations as separate components
Ed. 6.0 (2011) (informative)	Clause / Subclause title (normative)	Group I and Group II	Group III	
1	Scope	Applies	Applies	Applies
2	Normative references	Applies	Applies	Applies
3	Terms and definitions	Applies, except ambient temperature, see 3.1	Applies, except ambient temperature, see 3.1	Applies, except ambient temperature, see 3.1
4	Equipment grouping	Applies	Applies	Applies
4.1	Group I	Applies	Excluded	Applies
4.2	Group II	Applies, always IIC	Excluded	Applies
4.3	Group III	Excluded	Applies, outside of thermal insulation only, always IIIC	Applies, outside of thermal insulation only
4.4	Equipment for a particular explosive atmosphere	Excluded	Excluded	Applies
5.1	Environmental influences	Applies	Applies	Applies
5.1.1	Ambient temperature	Replaced by 6.1e)	Replaced by 6.1e)	Applies, see 3.1
5.1.2	External source of heating or cooling	Applies	Applies	Applies
5.2	Service temperature	Modified	Modified	Applies

IEC 60079-0		Electrical resistance trace heaters and integral components		Terminations as separate components
Ed. 6.0 (2011) (informative)	**Clause / Subclause title (normative)**	**Group I and Group II**	**Group III**	
5.3.1	Determination of maximum surface temperature	Replaced by 4.5 in conjunction with 5.1.13	Replaced by 4.5 in conjunction with 5.1.13 only when tested in accordance with 5.1.13.3.	Applies
5.3.2.1	Group I electrical equipment	Applies	Excluded	Applies
5.3.2.2	Group II electrical equipment	Applies	Excluded	Applies
5.3.2.3.1	Group III electrical equipment, Maximum surface temperature determined without a dust layer	Excluded	Applies, where the maximum sheath temperatures determined by IEC/IEEE 60079-30-1 are used in place of the method for temperature determination from IEC 60079-0.	Applies
5.3.2.3.2	Group III electrical equipment Maximum surface temperature with respect to dust layers	Excluded	Applies, where the maximum sheath temperature is determined only for those surfaces that are specified to be exposed to layers of combustible dust. Does not apply for trace heaters specified to be covered by thermal insulation.	Applies
5.3.3	Small component temperature for Group I and Group II electrical equipment	Excluded	Excluded	Applies
6.1	Requirements for all electrical equipment – General	Applies	Applies	Applies
6.2	Mechanical strength	Replaced by 4.2	Replaced by 4.2	When in direct contact with the trace heater, may be substituted by 4.2
6.3	Opening times	Excluded	Excluded	Applies
6.4	Circulating currents in enclosures (e.g. of large electrical machines)	Excluded	Excluded	Excluded
6.5	Gasket retention	Excluded	Excluded	Applies
6.6	Electromagnetic and ultrasonic radiating equipment	Excluded	Excluded	Applies
7.1.1	Non-metallic enclosures and non-metallic parts of enclosures – Applicability	Replaced by the last paragraph of 4.1	Replaced by the last paragraph of 4.1	Applies
7.1.2.1	Specification of materials, General	Replaced by the last paragraph of 4.1	Replaced by the last paragraph of 4.1	Applies
7.1.2.2	Specification of materials, plastic materials	Replaced by the last paragraph of 4.1	Replaced by the last paragraph of 4.1	Applies
7.1.2.3	Elastomers	Replaced by the last paragraph of 4.1	Replaced by the last paragraph of 4.1	Applies
7.2	Thermal endurance	Replaced by requirements and tests	Replaced by requirements and	Applies

IEC 60079-0		Electrical resistance trace heaters and integral components		Terminations as separate components
Ed. 6.0 (2011) (informative)	**Clause / Subclause title (normative)**	**Group I and Group II**	**Group III**	
		of this standard	tests of this standard	
7.3	Resistance to light	Replaced by 5.1.16 for trace heaters and integral components specified for outdoor exposure	Replaced by 5.1.16 for trace heaters and integral components specified for outdoor exposure	Applies
7.4.1	Electrostatic charges on external non-metallic materials, Applicability	Excluded	Excluded	Applies
7.4.2	Avoidance of a build-up of electrostatic charge on Group I or Group II electrical equipment	Excluded	Excluded	Applies
7.4.3	Avoidance of a build-up of electrostatic charge on equipment for Group III	Excluded	Excluded	Applies
7.5	Accessible metal parts	Excluded	Excluded	Applies
8.1	Material composition	Excluded	Excluded	Applies
8.2	Group I	Excluded	Excluded	Applies
8.3	Group II	Excluded	Excluded	Applies
8.4	Group III	Excluded	Excluded	Applies
9	Fasteners	Excluded	Excluded	Applies
10	Interlocking devices	Excluded	Excluded	Applies
11	Bushings	Excluded	Excluded	Applies
12	Materials used for cementing	Replaced by the last paragraph of 4.1	Replaced by the last paragraph of 4.1	Applies
13	Ex Components	Applies	Applies	Applies
14	Connection facilities and termination compartments	Covered by the requirements of this standard	Covered by the requirements of this standard	Applies
15	Connection facilities for earthing and bonding conductors	Replaced by 5.1.15	Replaced by 5.1.15	Applies
16	Entries into enclosures	Excluded	Excluded	Applies
17	Supplementary requirements for rotating electrical machines	Excluded	Excluded	Excluded
18	Supplementary requirements for switchgear	Excluded	Excluded	Excluded
19	Supplementary requirements for fuses	Excluded	Excluded	Applies
20	Supplementary requirements for plugs and sockets	Excluded	Excluded	Applies
21	Supplementary requirements for luminaires	Excluded	Excluded	Excluded
22	Supplementary requirements for caplights and handlights	Excluded	Excluded	Excluded
23	Equipment incorporating cells and batteries	Excluded	Excluded	Applies
24	Documentation	Applies	Applies	Applies
25	Compliance of prototype or	Applies	Applies	Applies

IEC 60079-0		Electrical resistance trace heaters and integral components		Terminations as separate components
Ed. 6.0 (2011) (informative)	**Clause / Subclause title (normative)**	**Group I and Group II**	**Group III**	
	sample with documents			
26.1	General	Applies	Applies	Applies
26.2	Test configuration	Applies	Applies.	Applies
26.3	Tests in explosive test mixtures	Excluded	Excluded	Applies
26.4	Tests of enclosures	Excluded	Excluded	Applies
26.4.1	Order of tests	Excluded	Excluded	Applies
26.4.1.1	Metallic enclosures, metallic parts of enclosures and glass parts of enclosures	Excluded	Excluded	Applies
26.4.1.2	Non-metallic enclosures or non-metallic parts of enclosures	Excluded	Excluded	Applies
26.4.2	Resistance to impact	Replaced by 5.1.5	Replaced by 5.1.5	Applies
26.4.3	Drop test	Excluded	Excluded	Excluded
26.4.4	Acceptance criteria	Replaced by 5.1.5	Replaced by 5.1.5	Applies
26.4.5	Degree of protection by enclosure	Replaced by 5.1.8 and/or 5.1.9	Replaced by 5.1.8 and/or 5.1.9.	Applies
26.5	Thermal tests	Modified.	Modified	Applies
26.5.1	Temperature measurement	Replaced by 5.1.13	Replaced by 5.1.13	Applies
26.5.2	Thermal shock test	Excluded	Excluded	Applies
26.5.3	Small component ignition test	Excluded	Excluded	Applies
26.6	Torque test for bushings	Excluded	Excluded	Applies
26.7	Non-metallic enclosures or non-metallic parts of enclosures	Excluded	Excluded	Applies
26.8	Thermal endurance to heat	Replaced by 5.1.11	Replaced by 5.1.11	Applies
26.9	Thermal endurance to cold	Replaced by 5.1.7	Replaced by 5.1.7	Applies
26.10	Resistance to light	Replaced by 5.1.16for trace heaters and integral components specified for outdoor exposure	Replaced by 5.1.16 for trace heaters and integral components specified for outdoor exposure	Applies
26.11	Resistance to chemical agents for Group I electrical equipment	Applies for Group I	Excluded	Applies
26.12	Earth continuity	Excluded	Excluded	Applies
26.13	Surface resistance test of parts of enclosures of non-metallic materials	Excluded	Excluded	Applies
26.14	Measurement of capacitance	Excluded	Excluded	Applies
26.15	Verification of ratings of ventilating fans	Excluded	Excluded	Excluded
26.16	Alternative qualification of elastomeric sealing O-rings	Excluded	Excluded	Applies
27	Routine tests	Applies	Applies	Applies
28	Manufacturers responsibility	Applies	Applies	Applies
29	Marking	Modified	Modified	Applies

IEC 60079-0		Electrical resistance trace heaters and integral components		Terminations as separate components
Ed. 6.0 (2011) (informative)	Clause / Subclause title (normative)	Group I and Group II	Group III	
30	Instructions	Modified	Modified	Applies
Annex A	Supplementary requirements for Ex cable glands	Excluded	Excluded	Applies
Annex B	Requirements for Ex components	Excluded	Excluded	Applies
Annex C	Example of rig for resistance to impact test	Replaced by 5.1.5	Replaced by 5.1.5	Applies
Annex D	Motors supplied by converters	Excluded	Excluded	Excluded
Annex E	Temperature rise testing of electric machines	Excluded	Excluded	Excluded
Annex F	Guideline flowchart for tests of non-metallic enclosures or non-metallic parts of enclosures (26.4)	Excluded	Excluded	Applies
NOTE 1 Clause numbers in the three right-hand columns of this table refer to IEC/IEEE 60079-30-1 NOTE 2 The clause number in the above table is shown for information only. The applicable requirements of IEC 60079-0 are identified by the clause title which is normative.				
Applies: this requirement of IEC 60079-0 is applied without change. Excluded: this requirement of IEC 60079-0 does not apply. Modified: this requirement of IEC 60079-0 is modified as detailed in this standard.				

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-151:2001, *International Electrotechnical Vocabulary – Part 151: Electrical and magnetic devices*

IEC 60050-426:2008, *International Electrotechnical Vocabulary – Part 426: Equipment for explosive atmospheres*

IEC 60079-0:2011, *Explosive atmospheres – Part 0: Equipment – General requirements*

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

ISO 4582, *Plastics – Determination of changes in colour and variations in properties after exposure to daylight under glass, natural weathering or laboratory light sources*

ISO 4892-1, *Plastics – Methods of exposure to laboratory light sources – Part 1: General guidance*

ISO 4892-2, *Plastics – Methods of exposure to laboratory light sources – Part 2: Xenon-arc lamps*

ASTM D5025, *Standard specification for laboratory burner used for small-scale burning tests on plastic materials*

ASTM G155, *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 terms and definitions given in IEC 60079-0, IEC 60079-7, IEC 60050-151 and IEC 60050-426 (except as modified by this clause) as well as the following apply.

NOTE Definition 3.40 is identical to definition 3.16 of IEC 60079-7: 2006.

3.1
ambient temperature
<trace heating>
temperature surrounding the workpiece including the trace heater and any thermal insulation or weather barrier that may be applied

3.1.1
maximum ambient temperature
highest specified ambient temperature

3.1.2
minimum ambient temperature
<trace heating>
lowest ambient temperature specified at which trace heating is operable and performs according to specified requirements (and on which heat-loss calculations are based)

[SOURCE: IEC 60050-426:2008, 426-20-20]

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

[SOURCE: IEC 60050-426:2008, 426-20-02]

3.3
connections (terminations)

3.3.1
cold lead
electrically insulated conductor or conductors used to connect a trace heater to a branch circuit and designed so that it does not produce significant heat

[SOURCE: IEC 60050-426:2008, 426-20-03]

3.3.2
end termination
termination, which may be heat producing, applied to a trace heater at the end opposite to that where the power is supplied

[SOURCE: IEC 60050-426:2008, 426-20-04]

3.3.3
power termination
termination applied to the end of a trace heater at which the power is supplied

[SOURCE: IEC 60050-426:2008, 426-20-05]

3.3.4
tee
electrical connection of trace heaters, in series or in parallel, to accommodate a branch or a branch circuit

[SOURCE: IEC 60050-426:2008, 426-20-06, modified ("tee or branch" replaced by "branch or a branch circuit")]

3.4
controlled design
design where the set point of the applicable temperature controller or high-limit device is used in establishing the maximum sheath temperature

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

[SOURCE: IEC 60050-426:2008, 426-20-07]

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 60050-426:2008, 426-20-08]

3.7
electrically conductive covering
metallic sheath, metallic braid or other conductive material

3.8
factory fabricated
<trace heating>
assembled into units or sets, including the necessary terminations and connections

[SOURCE: IEC 60050-426:2008, 426-20-09]

3.9
field assembled
<trace heating>
supplied in bulk with terminating components to be assembled at the work site

[SOURCE: IEC 60050-426:2008, 426-20-10]

3.10
heat loss
energy flow from a pipe, vessel or equipment to its surroundings

[SOURCE: IEC 60050-426:2008, 426-20-11]

3.11
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.

[SOURCE: IEC 60050-426:2008, 426-20-12]

3.12
heat transfer aids
thermally conductive materials, such as metallic foils or heat transfer compounds used to increase the heat transfer efficiency from trace heaters to the workpiece

[SOURCE: IEC 60050-426:2008, 426-20-13]

3.13
high limit temperature
maximum allowable temperature of the system, including piping, fluid and trace heating system

[SOURCE: IEC 60050-426:2008, 426-20-16, modified (addition of "trace")]

3.14
integral components
components such as heat shrink terminations, cold lead connections, moulded end seals, or splices, which may conform to the general shape of the trace heater and are exposed to the same environments (such as under the thermal insulation) as the trace heater, that are not intended to be re-used in the event of a repair or modification, which may be factory fabricated or field assembled

3.15
maximum continuous exposure temperature (trace heater de-energized)
highest allowable continuous temperature to which the trace heating system may be exposed as declared by the manufacturer

3.16
maximum maintain temperature / maximum continuous operating temperature (trace heater energized)
specified maximum workpiece temperature the trace heater operates at continuously as declared by the manufacturer

3.17
maximum intermittent exposure temperature (trace heater energized or de-energized)
highest allowable intermittent temperature to which a trace heater may be exposed, as declared by the manufacturer

3.18
maintain temperature
specified temperature of a workpiece or process that the trace heaters shall be able to maintain

3.19
maximum sheath temperature
maximum temperature of the outermost covering of a trace heater

3.20
maximum withstand temperature
maximum operating or exposure temperature that will not adversely affect the thermal stability of the trace heater and its component parts

[SOURCE: IEC 60050-426:2008, 426-20-18]

3.21
minimum installation temperature
minimum temperature at which the trace heating system may be handled and installed

3.22
MI trace heater
mineral insulated metal sheathed trace heater typically containing one or more heating conductors

3.23
operating voltage
actual voltage applied to the trace heater when in service

[SOURCE: IEC 60050-426:2008, 426-20-21]

3.24
outdoor exposure
exposure to outdoor conditions of ultraviolet light and moisture

3.25
overjacket
continuous layer of material applied outside the electrically conductive covering to protect against corrosion

3.26
parallel trace heater(s)
heating elements that are electrically connected in parallel, either continuously or in zones, so that the watt density per lineal length is maintained, irrespective of any change in length for the continuous type or for any number of discrete zones

3.27
power density
power output for a trace heater expressed in watts per linear length or in watts per unit surface area

3.28
rated output
total power or power per unit length or unit surface area of a trace heater, at rated voltage, temperature and length or area

[SOURCE: IEC 60050-426:2008, 426-20-24, modified (removal of "which is normally expressed in watts, watts per metre or watts per square metre")]

3.29
rated voltage
<trace heating>
voltage assigned by the manufacturer to which operating and performance characteristics of trace heaters are referred

[SOURCE: IEC 60050-426:2008, 426-20-25, modified (addition of "assigned by the manufacturer")]

3.30
series trace heater(s)
heating elements electrically connected in series with a single current path and with a specific resistance at a given temperature for a given length

[SOURCE: IEC 60050-426:2008, 426-20-26]

3.31
sheath
<trace heating>
uniform and continuous metallic or non-metallic outer covering enclosing the trace heater used to provide protection against influence from the surroundings (corrosion, moisture etc.)

Note 1 to entry: See overjacket, 3.25.

[SOURCE: IEC 60050-426:2008, 426-20-26, modified (addition of Note 1 to entry)]

3.32
sheath temperature
<trace heating>
temperature of the outermost continuous covering that may be exposed to the surrounding atmosphere

[SOURCE: IEC 60050-426:2008, 426-20-28]

3.33
stabilized design
design where the temperature of the trace heater, by design and use, stabilizes below the high limit temperature, under the most unfavourable conditions, without the need for a protective system to limit the temperature

[SOURCE: IEC 60050-426:2008, 426-20-29]

3.34
start-up current
current response of a trace heater following energization

[SOURCE: IEC 60050-426:2008, 426-20-30, modified ("immediately upon energizing" replaced by "following energization")]

3.35
system documentation
<trace heating>
information prepared by the manufacturer to allow satisfactory understanding, installation and safe use of the trace heating system

[SOURCE: IEC 60050-426:2008, 426-20-31]

3.36
temperature control device
device that serves to maintain the temperature within a specified temperature range

[SOURCE: IEC 60050-426:2008, 426-20-33]

3.37
temperature controller
device or combination of devices incorporating a means of sensing temperature and of controlling the power to the trace heater

[SOURCE: IEC 60050-426:2008, 426-20-34]

3.38
temperature limiting device
safety device that serves to switch off power to the trace heater before the maximum specified surface temperature is exceeded

3.39
temperature sensor
(temperature sensing element)
device designed to respond to temperature providing an electrical signal or mechanical operation

3.40
thermal insulation
material having air- or gas-filled pockets, voids, or heat reflecting surfaces that, when properly applied, retards the transfer of heat

[SOURCE: IEC 60050-426:2008, 426-20-36]

3.41
trace heater
device designed for the purpose of producing heat on the principle of electrical resistance and typically composed of one or more metallic conductors and/or an electrically conductive material, suitably electrically insulated and protected

[SOURCE: IEC 60050-426:2008, 426-20-37]

3.42
trace heater pad
trace heater comprising series or parallel connected elements having sufficient flexibility to conform to the shape of the surface to be heated

3.43
trace heater panel
non-flexible trace heater comprising series or parallel connected elements fabricated to conform to the general shape of the surface to be heated

3.44
trace heater unit
(trace heater set)
series trace heater, parallel trace heater, trace heater pad or trace heater panel suitably terminated in conformity with the manufacturer’s instructions

3.45
trace heating
utilization of electric trace heaters, trace heater pads, trace heater panels and support components, used to maintain or to raise the temperature of contents in piping, tanks and associated equipment

[SOURCE: IEC 60050-426:2008, 426-20-39, modified (removal of "externally applied")]

3.46
trace heating system
utilization of trace heating including all necessary design and installation documentation

3.47
trace ratio
ratio of trace heater length to pipe length

3.48
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

[SOURCE: IEC 60050-426:2008, 426-20-40, modified (replacement of "sleet" by "ice pellets")]

3.49
workpiece
<trace heating>
object to which a trace heater is applied

Note 1 to entry: Examples include process equipment such as piping, vessels, tanks, valves, instruments and similar equipment.

[SOURCE: IEC 60050-426:2008, 426-20-41, modified (addition of Note 1 to entry)]

4 General requirements

4.1 General

The requirements of this standard confirm that electrical resistance trace heating within the scope of this standard has been designed and constructed so as to validate electrical, thermal and mechanical durability and reliable performance.

Electrical resistance trace heaters and integral components shall comply with or be excluded from the requirements of IEC 60079-0, as listed in Table 1.

Trace heaters shall be provided with an evenly-distributed electrically conductive covering that shall cover at least 70 % of the surface. Trace heater pads and panels shall be constructed such that the electrically conductive covering shall be opposite the surface to be heated. The electrically conductive covering shall either be suitable for use in the particular atmosphere(s) or have a suitable non-metallic overjacket over the covering. The manufacturer shall declare the maximum withstand temperature in degrees Celsius. The materials used in the trace heater and integral components shall withstand a temperature of no less than the manufacturer's declared maximum withstand temperature +20 K, when tested in accordance with 5.1.11. The 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 Mechanical strength

The mechanical strength of trace heaters shall be determined by the tests in 5.1.5, 5.1.6, 5.1.7 and 5.1.11.

Trace heaters which are identified for use only in areas with a low risk of mechanical damage are subjected to a reduced energy in the impact tests in 5.1.5 and a reduced force in the deformation test in 5.1.6, and shall be clearly marked as specified in 7.4 e).

Trace heaters may be supplied with additional mechanical protection to meet the requirements of this standard if they are supplied as an integral assembly (prefabricated), and contain the following statement in the instructions: "This mechanical covering shall not be removed and the trace heaters shall not be operated without the mechanical covering being in place". In this case the tests in 5.1.5 and 5.1.6 shall be performed with the additional mechanical protection installed on the trace heater.

4.3 Terminations and connections

Terminations and connections may be identified as an integral part of a trace heater, or may be identified separately, as Ex equipment or as Ex components in accordance with IEC 60079-0. Integral terminations and connections are tested as part of a representative trace heater unit; see 5.1.1.

Electrical connectors supplied with integral components shall be certified for the current-carrying capacity of the trace heating conductors declared by the manufacturer and shall meet the other prescribed testing in this standard.

Electrical resistance trace heater terminations identified as separate components shall comply with the requirements of one or more of the types of protection listed in IEC 60079-0 suitable for the application, which may be supplemented and modified by the requirements of this standard. See also Table 1.

4.4 Circuit protection requirements for branch circuits

The minimum requirements for trace heating systems for use in explosive atmospheres are as follows:

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

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

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

   1) For TT and TN systems, each trace heater or trace heater branch circuit, the electrical protection shall be capable of interrupting high impedance earth faults as well as short-circuit faults. This shall be accomplished by an earth-fault protective device, or a controller with earth-fault interruption capability for use in conjunction with suitable circuit protection. 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 supplier.

   2) For IT systems, an electrical insulation monitoring device shall be installed to disconnect the supply whenever the electrical resistance is not greater than 50 Ω/V of rated voltage.

   Exception: Where conditions of maintenance and supervision ensure that only qualified persons 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 to assure an acknowledged response.

The requirements of a), b), and c) may be performed by one device.

NOTE 1 The application of the above exception is intended to be at the discretion of the end user.

NOTE 2 This information is specified to be provided with the product documentation as indicated in Clause 7.

4.5 Temperature requirements

4.5.1 General

A trace heating system shall be designed so that the sheath temperature of the trace heaters is limited to the temperature class or ignition temperature, minus 5 K for temperatures less than or equal to 200 °C or minus 10 K for temperatures greater than 200 °C. The maximum sheath temperature of the trace heater shall also be less than the maximum withstand temperature.

Maximum sheath temperatures of trace heaters shall be determined for the proper application of the heater. The sheath temperature is dependent on the heater power output density, overall heat transfer coefficient, and the temperature of the surface being heated.

This shall be achieved either by:

1) determining the trace heater's maximum sheath temperature according to the product classification method in accordance with 5.1.13.3;
2) a stabilized design in accordance with 4.5.2; or
3) a controlled design in accordance with 4.5.3.

For 2) and 3) above, when multiple trace heaters (especially on pipes with different flow conditions) are grouped together under a single temperature control device, each design condition shall be analyzed.

Requirements for equipment for use in facilities using the Division method of area classification are given in Annex D.

4.5.2 Stabilized design

The maximum sheath temperature obtained by stabilized design is based on the energy balance of heat loss and heat production of a system. The energy balance is determined by calculations based on system parameters.

The design calculations, system parameters and methods for stabilized design shall be demonstrated to the certification body by the manufacturer by comparison to the test results from 5.1.13.2. Table 2 gives the design conditions for various equipment protection levels for the stabilized design approach.

Design conditions of no-wind, the maximum ambient temperature and the system heat transfer coefficient shall be used to calculate the maximum workpiece temperature and maximum sheath temperature. Guidance for the design calculations is provided in Annex C.

Table 2 – Sheath temperature design conditions based on equipment protection levels – Stabilized design approach

Item	EPL Gb/Db	EPL Gc/Dc
Percent of operating voltage	110	110
Maximum workpiece temperature for calculation	---[a]	---[a]
Maximum wind speed for calculation	0	0
[a] The workpiece temperature (T_{pr} or T_{pm}, whichever is greater) is used to calculate the maximum sheath temperature- see Annex C.		

4.5.3 Controlled design

4.5.3.1 General

The maximum sheath temperature obtained through controlled design is based on energy limitation by temperature controllers or limiting devices. These protective temperature limiting devices are to be set to a temperature no greater than the maximum allowable sheath temperature corresponding to the temperature class reduced by;

(1) the predicted temperature difference between the temperature limiter's set point and the maximum sheath temperature of the trace heater, and by

(2) the amount specified in 4.5.1.

There are three controlled design methods for limiting the maximum sheath temperature. These are only suitable for situations where the workpiece is not subjected to additional sources of heat.:

a) By limiting the maximum workpiece temperature. The temperature control sensor and/or the temperature limiter sensor is installed directly on the workpiece.
b) By using a high temperature limiter with the sensor attached to the trace heater which is installed on the workpiece. Each application requires correlation for the specific trace heater, power output level, and the limiter/sensor characteristics.
c) By creating an artificial hot spot where a high temperature limiter sensor is attached to the trace heater which is located on a thermal insulation spacer on the workpiece. Each application requires correlation for the specific trace heater, power output level, limiter/sensor characteristics, and insulation spacer.

The manufacturer predicts the offset (ΔT_{offset}) between the trace heating sheath temperature and the temperature control device's set point. For design conditions see Table 3. The manufacturer shall support the calculation method for sheath temperature by comparing the predicted results to test results from 5.1.13.2.

NOTE For calculation of ΔT_{offset} (= $T_{sh} - T_L$) refer to Annex C. ΔT_{offset} is the empirically determined temperature difference between the sensor and the actual maximum tracer sheath temperature. ΔT_{offset} is a function of variables such as geometry and mass of trace heater and sensor, power output of the trace heater, heat transfer coefficient, and control system hysteresis.

Table 3 – Sheath temperature design conditions based on equipment protection levels EPLs – Controlled design approach

Item	EPL Gb/Db	EPL Gc/Dc
Percent of operating voltage	110	110
Maximum workpiece temperature for calculation	---[a]	---[a or b]
Maximum wind speed for calculation	0	0

[a] Use the set point of the temperature limiter according to 4.5.3.2.
[b] Use the set point of the temperature controller according to 4.5.3.3.

4.5.3.2 Requirements for temperature control devices for EPLs Gb and Db

A temperature limiter or similar control device shall de-energize the system to prevent exceeding the maximum permissible sheath temperature. Any device used for temperature control shall satisfy requirements for EPLs Gb and/or Db.

Additionally a high temperature limit function shall:

1) operate independently from the temperature controller;
2) de-energize the trace heater when the set point of the high temperature limiter is reached;
3) annunciate when the high temperature limit function is activated;
4) have a high limit function that requires acknowledgement to be reset;
5) mechanically or electronically lock the high limit set point of the device to prevent unauthorized access;
6) have a safety function that de-energizes the circuit if the temperature sensor malfunctions;
7) be possible to re-set only after the normal operating conditions have been returned, or if the switching state is monitored continuously;

8) be evaluated to a minimum of 100,000 cycles of endurance when multiple devices are used for controlling and limiting.

4.5.3.3 Requirements for temperature control devices for EPLs Gc and Dc

A single temperature controller may be specified provided that it incorporates annunciation of failure conditions and has been evaluated for a minimum of 250 000 cycles of operation. Alternatively, temperature control devices according to 4.5.3.2 may be specified.

If a single temperature controller with failure annunciation is specified, provision of adequate monitoring of such an annunciation, such as 24 h surveillance, shall be made.

5 Testing

5.1 Type tests

5.1.1 General

The provisions of IEC 60079-0 as specified in Table 1 apply with the following additions. Samples of trace heaters at least 3 m in length, unless otherwise specified, shall be selected for testing. Tests shall be conducted at a temperature between 10 °C and 40 °C unless otherwise stated. Integral components shall be subjected to the same tests as the trace heater, except where otherwise noted. The test samples needed for the type tests are summarized in Annex A.

NOTE As specified in IEC 60079-0, due to the safety factors incorporated in the types of protection, the uncertainty of measurement inherent in good quality, regularly calibrated measurement equipment is considered to have no significant detrimental effect and need not be taken into account when making the measurements necessary to verify compliance to this standard.

5.1.2 Dielectric test

The dielectric test shall be performed on trace heaters in accordance with Table 4 on test sample(s) prepared as described in 5.1.1.

Table 4 – Test voltages for the dielectric test

Rated voltage	Test voltage V a.c. (r.m.s.)
< 30 V a.c. (r.m.s.)	500
< 60 V d.c.	500
≥ 30 V a.c. (r.m.s.)	$2\ U + 1\ 000$
≥ 60 V d.c.	$\sqrt{2}\ U + 1\ 000$

The test voltage, where U is the rated voltage, shall be applied between the conductors and the electrically conductive covering at a rate of rise of neither less than 100 V/s nor more than 200 V/s and maintained for $(60\ ^{-0}_{+5})$ s without dielectric breakdown. The test voltage waveform shall be essentially sinusoidal, with a frequency of 45 Hz to 65 Hz. Alternatively the dielectric test may be conducted by submerging the trace heater in tap water at room temperature (resistivity typically 500 Ω·m). The ground braid or sheath shall be bonded to the water and the voltage shall be applied between the conductors and the water.

When determining U, the correct use of Phase to Phase or Phase to Neutral voltage levels shall be considered.

For type tests 5.1.5, 5.1.6, 5.1.7, 5.1.8, 5.1.9, 5.1.11, and the routine test in 5.2.1, for MI trace heaters the required test voltage is reduced to $2U + 500$ V a.c. for trace heaters rated over

30 V a.c., or to $\sqrt{2}\,U + 500$ V d.c. for trace heaters rated over 60 V d.c. due to the dielectric characteristics of the MI trace heater construction and electrical insulation materials.

5.1.3 Electrical insulation resistance test

The electrical insulation resistance test shall be conducted after the dielectric test specified in 5.1.2 on the same test sample(s). The resistance of the electrical insulation shall be measured between conductors and the electrically conductive covering, by means of a d.c. source voltage (nominal) of 500 V. The measured value shall be not less than 50 MΩ.

Alternatively the insulation resistance test may be conducted by submerging the trace heater in tap water at room temperature (resistivity typically 500 Ω·m). The ground braid or sheath shall be bonded to the water and the voltage shall be applied between the conductors and the water.

5.1.4 Flammability test

A flammability test shall be performed on trace heaters and on trace heaters with integral components. The full range of sizes shall be capable of complying with the test. The test shall be carried out in a room free from draughts and in a flame chamber or fume hood with a minimum volume of 0,5 cubic metres. For trace heaters, the sample shall be at least 450 mm in length, and shall be supported in a vertical position. For trace heater pads and panels (as applicable) the sample width shall be 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 250 mm.

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

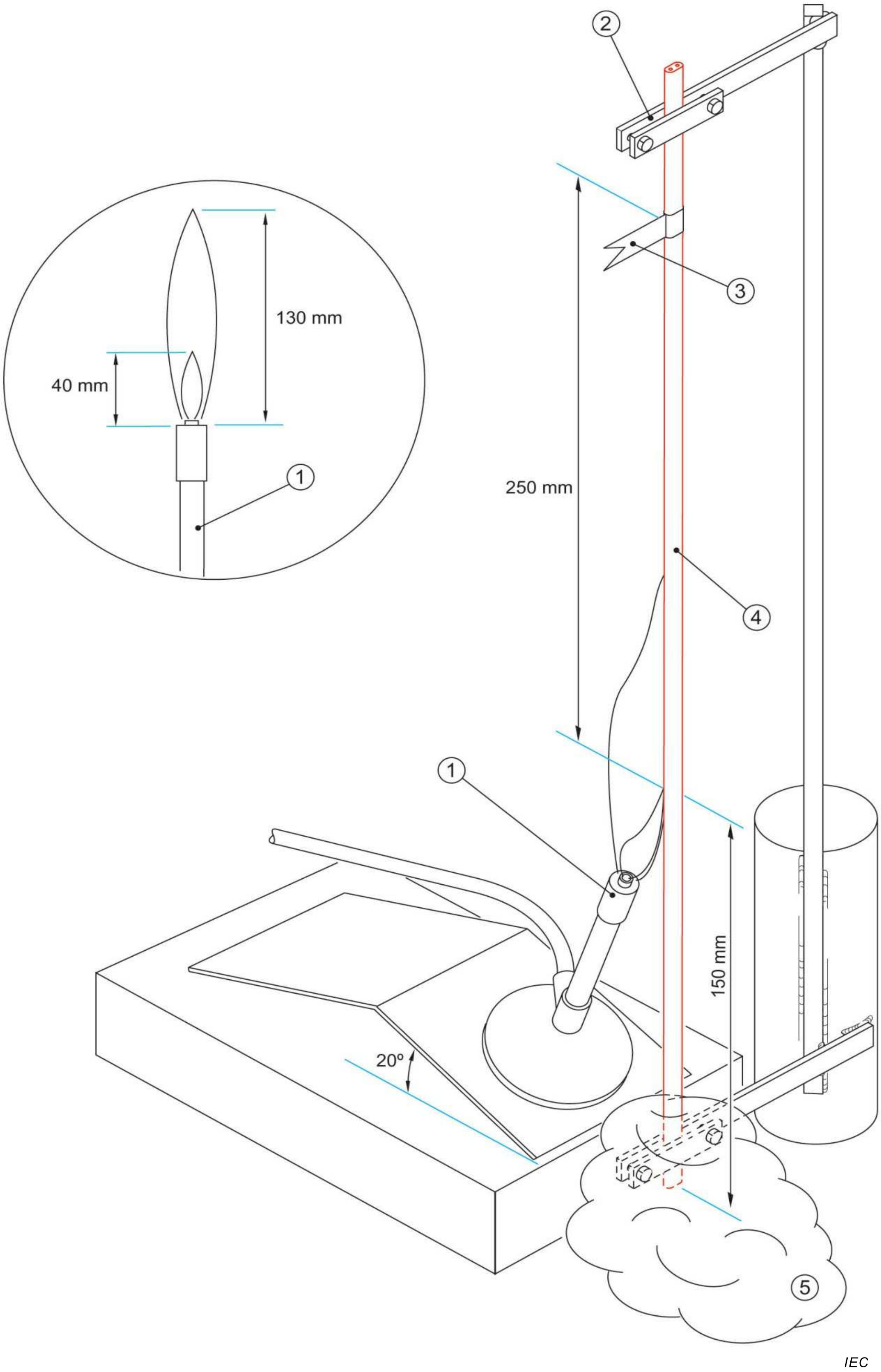
a) Methane or natural gas – For methane: technical grade, 98 % minimum purity; For methane or natural gas: heating value of (37 ± 1) MJ/m^3 at 25 °C
b) Propane – Technical grade, 98 % minimum purity, heating value of (94 ± 2) MJ/m^3 at 25 °C
c) Butane – CP grade, 99 % minimum purity, heating value of (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 trace heater 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 termination assemblies, the flame shall be set such that it contacts the material at the most vulnerable point. Clamps used to support the sample shall be above the paper indicator and at least 80 mm below the point of flame application. For trace heater pads and panels, 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, then removed for 15 s, until five such applications have been made.

The test results shall be considered satisfactory if the trace heater 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 D5207 standards.



Key

1 burner

2 support

3 unbleached paper flag

4 test sample

5 dry pure surgical cotton

Figure 1 – Flammability test

5.1.5 Impact tests

NOTE Electric trace heaters are, in the majority of applications, covered by thermal insulation and therefore afforded some mechanical protection. In some applications, however, trace heaters can be installed under conditions where they are not always 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.

5.1.5.1 Room temperature impact test

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 trace heater pads and panels (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 trace heater 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 intended for use in applications with a low risk of mechanical damage in accordance with 4.1, the height may be reduced to $0{,}4\ ^{+0{,}01}_{-0}$ m. Trace heaters submitted to such a test shall be clearly marked as specified in 7.4 e) to caution the user as to its reduced mechanical capability.

Immediately after impact, conformity is verified by testing the electrical insulation in accordance with 5.1.2 and 5.1.3 while the steel cylinder and hammer are still in place on the sample.

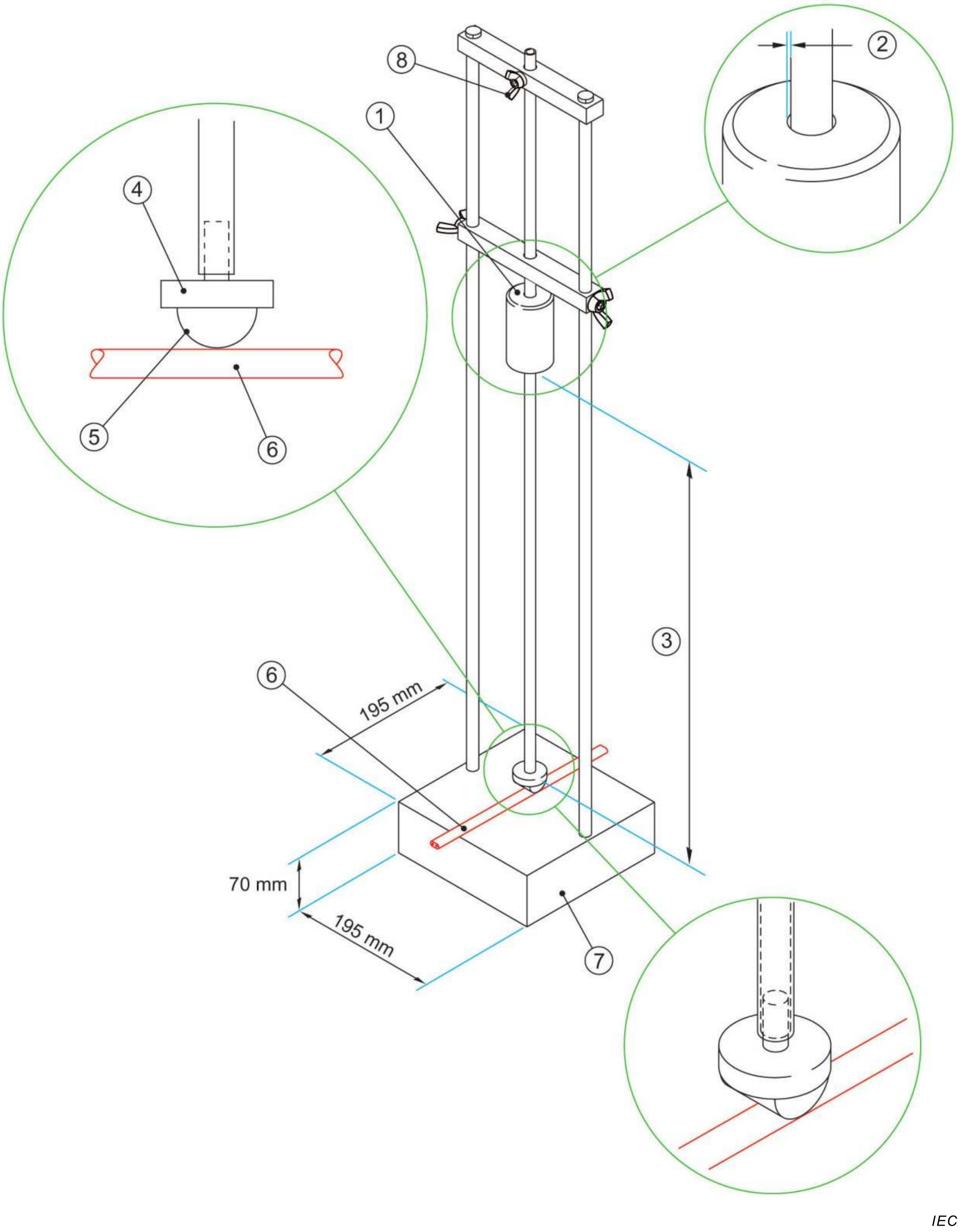
5.1.5.2 Minimum temperature impact test

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 specified minimum installation temperature. The apparatus used for this test is shown in Figure 3.

After conditioning, and other than in tests on electrical trace heaters intended for use in applications with low risk of mechanical damage, a sample, while 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 may be reduced to $0{,}42\ ^{+0{,}01}_{-0}$ m. Trace heaters submitted to such a test shall be clearly marked as specified in 7.4 e) to caution the user as to its reduced mechanical capability.

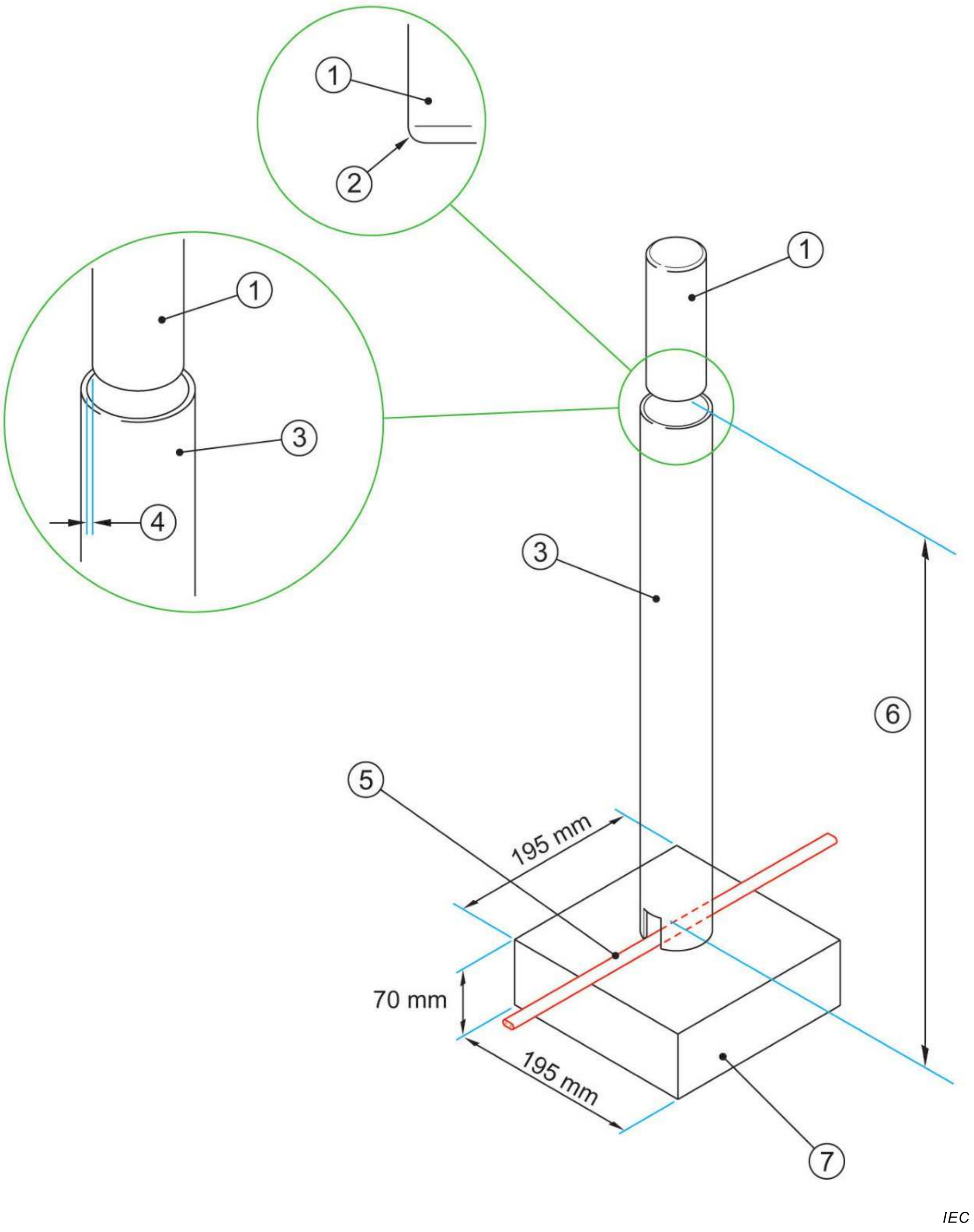
The impacted portion of the sample shall then be immersed in tap water at room temperature for at least 5 minutes, and the dielectric test 5.1.2 and insulation resistance test 5.1.3 shall be conducted. For trace heater pads and panels, both the heating region and cold leads shall be impacted.



Key

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

Figure 2 – Example of room temperature impact test



Key

1 50,8 mm diameter hammer with mass of 1,8 kg

2 smoothly rounded edges (~5 mm rounding)

3 guide tube

4 sufficient clearance to allow for free-fall

5 trace heater sample

6 height of fall of hammer: 0,76 m or 0,42 m

7 base with minimum 20 kg mass

Figure 3 – Example of minimum temperature impact test

5.1.6 Deformation test

A sample approximately 450 mm in length is placed on a rigid flat steel plate. A crushing force of 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 at a right angle. In the case of a pad, the cylinder shall rest across the active element.

For electrical trace heaters intended for use in applications with low risk of mechanical damage, the crushing force may be reduced to 800 N. Trace heaters submitted to such a test shall be clearly marked as specified in 7.4 e) to caution the user concerning its reduced mechanical capability.

After the deformation load is applied for at least 30 s, conformity is verified by testing the electrical insulation in accordance with 5.1.2 and 5.1.3 while the horizontal steel rod is still in place on the sample and the load applied.

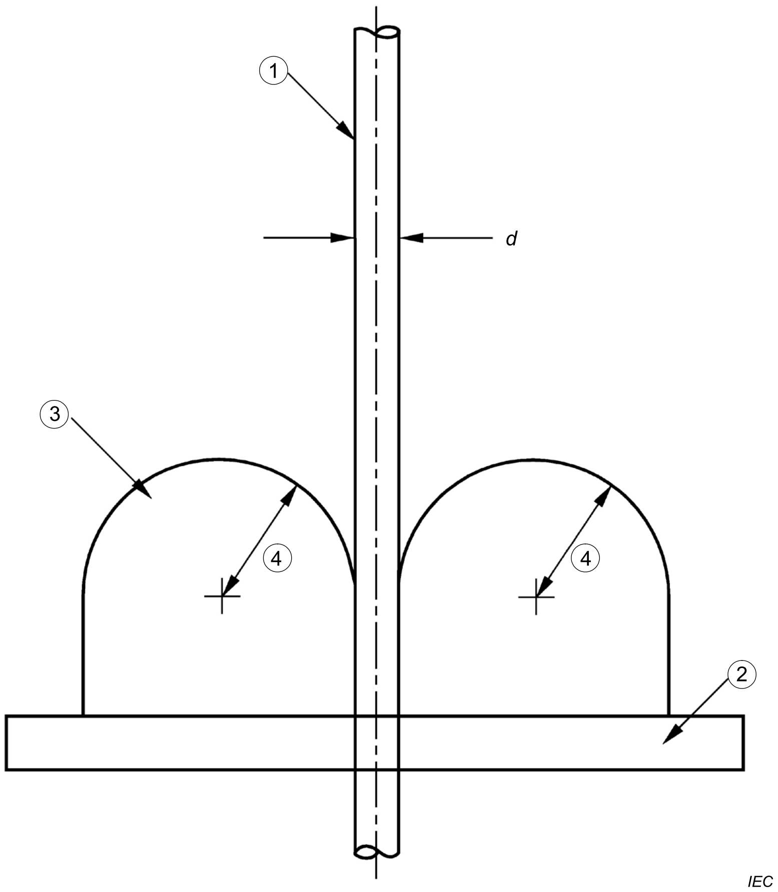
5.1.7 Cold bend test

This test applies only to trace heaters that have a stated minimum bend radius of 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, without integral terminations or connections, 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 of not less than 4 h. At the end of this period and while still at the manufacturer’s specified minimum installation temperature, the sample shall be bent through at least 90º around one of the mandrels, then bent through at least 180º 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.

Conformity is verified by testing the electrical insulation in accordance with 5.1.2 and 5.1.3.



Key

1 trace heater sample

2 steel base

3 metal mandrel

4 manufacturer's stated minimum bend radius

d = trace heater diameter or primary bending plane

Figure 4 – Cold bend test

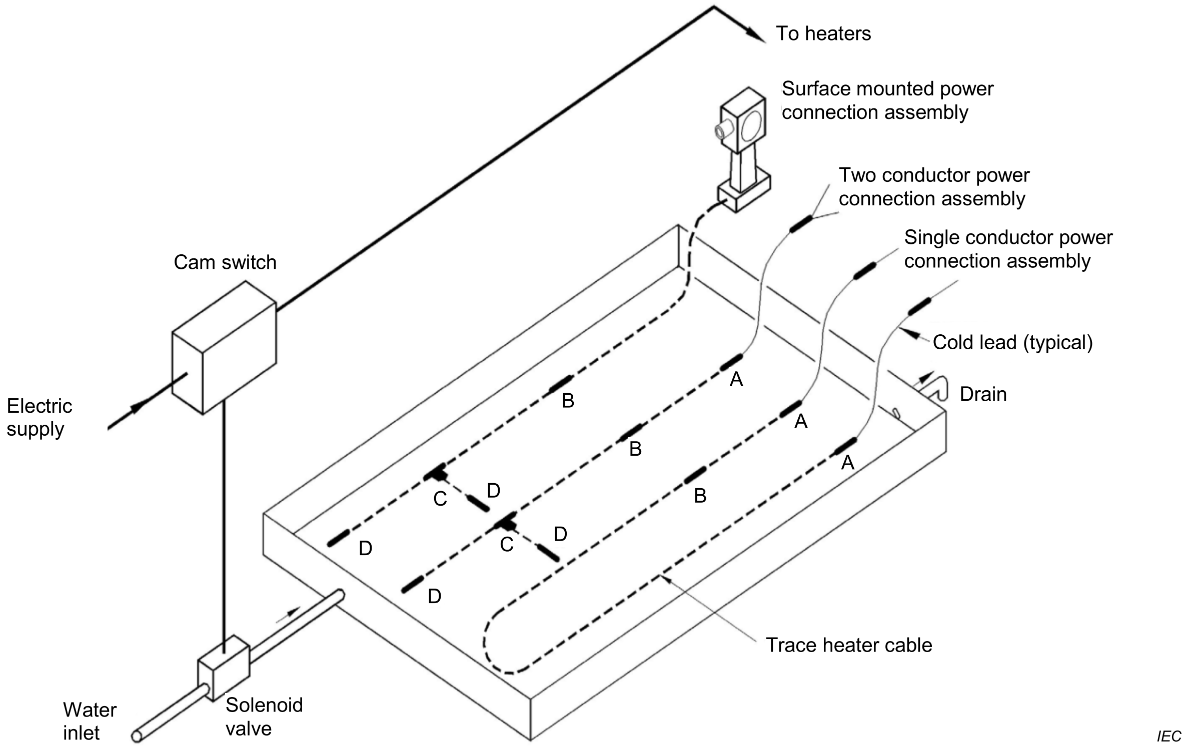
5.1.8 Water resistance test

A sample as described in 5.1.1, excluding integral components shall be immersed in tap water for a period of 14 days. Trace heater ends are not immersed.

Within 1 h after conditioning as above, and while still immersed in the water, the sample shall be subjected to the dielectric test outlined in 5.1.2 and the insulation resistance test outlined in 5.1.3.

5.1.9 Integral components resistance to water test

A sample of the trace heater with all integral components shall be placed in a tap water flow and drain apparatus as shown in Figure 5. For trace heater pads or panels, a unit with cold leads shall be used. Water flow shall be initiated and the sample shall be completely immersed. At that point, the water flow is stopped and the trace 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 trace heater shall continue to be energized for at least 30 s after the water has been drained. The trace heater is then de-energized and water flow is initiated for the next cycle. The test shall be continued for a period of 24 h. After completion, the sample shall be subjected to the dielectric test outlined in 5.1.2 and the insulation resistance test outlined in 5.1.3. The immersed connections of the trace heater shall be inspected to verify no evidence of water ingress.



Key

A integral power connection

B integral splice connection

C integral in-line tee

D integral end termination

Figure 5 – Integral components resistance to water test

5.1.10 Verification of rated output

The rated output of the trace heater or heating panel or pad shall be verified by one of the following two methods:

a) resistance: the measured d.c. resistance per unit length at a specified temperature shall be within the manufacturer's declared tolerance;

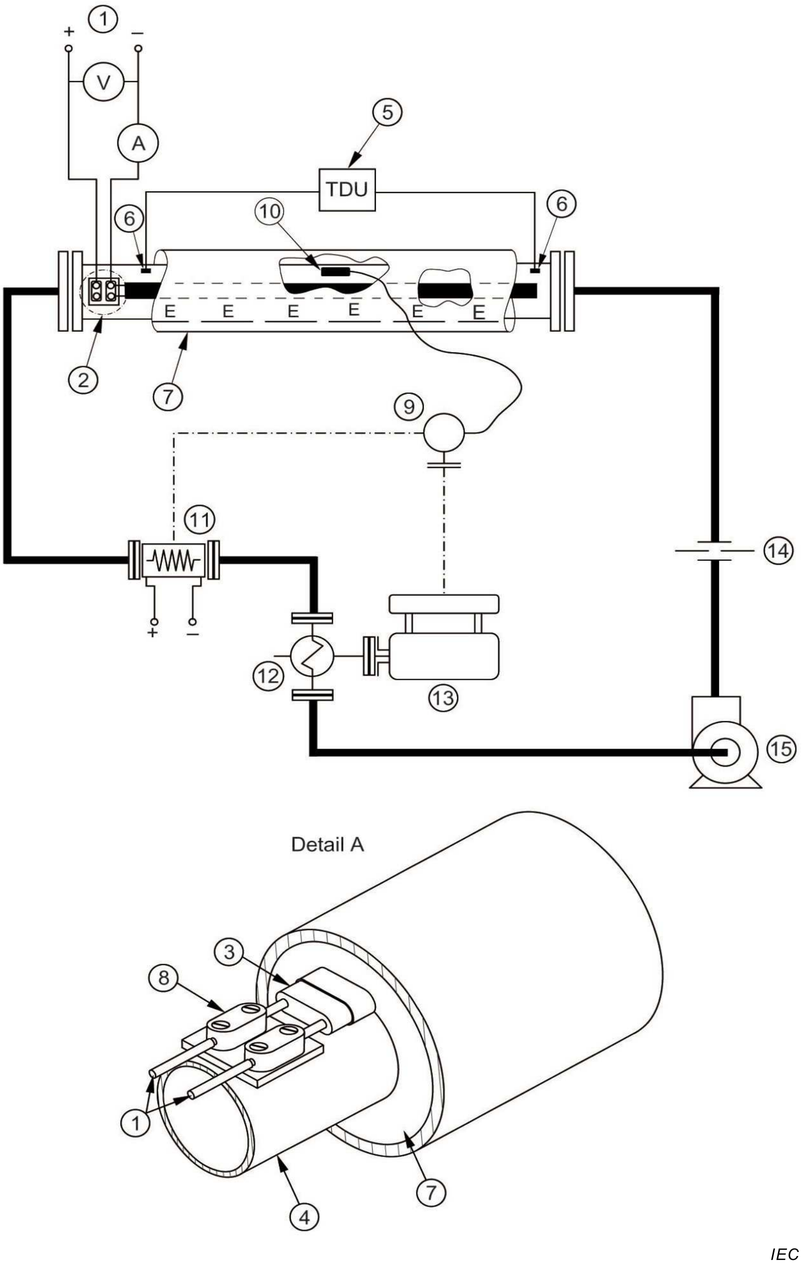
   NOTE This method is appropriate for products with metallic heating elements.

b) thermal: the thermal output of trace heaters is measured by installation of a single sample, 3 m to 6 m in length, on a carbon steel pipe of 50 mm diameter or greater, as shown in Figure 6. The sample is installed in accordance with the manufacturer's instructions. The test apparatus is completely covered with thermal insulation of at least 25 mm thickness.

   For trace heater pads and panels, the test is conducted on a liquid-cooled flat metal plate with at least 25 mm of thermal insulation installed over the surface of the trace heater pad or panel.

   A suitable heat transfer liquid is circulated through the pipe at a sufficient rate to establish turbulent flow such that there is a negligible temperature difference between the fluid and the pipe. The heat transfer fluid is maintained at a constant temperature. These parameters are verified by thermocouples placed at the entry and exit ends of the pipe. Flow velocity shall be such that the fluid temperature does not differ by more than 2 K from end to end.

The thermal output of the trace heater is measured at three workpiece temperatures representative of the full operating range. The trace heater is powered at its rated voltage and allowed to attain equilibrium. The voltage, current and liquid temperatures, and sample length are recorded at each test temperature. Three separate determinations are made on separate samples. The resulting values shall be within the manufacturer's declared tolerance.



Key

1 controlled voltage source
2 see detail A
3 trace heater sample
4 50 mm outside diameter or greater test pipe (workpiece)
5 TDU – temperature display unit
6 thermocouples
7 fibreglass insulation, 25 mm minimum thickness and a density of approximately 3,25 kg per cubic metre
8 electrical terminals
9 temperature controller
10 temperature sensor
11 in-line heater
12 heat exchanger
13 chilling unit
14 flow meter
15 pump

Figure 6 – Verification of rated output

5.1.11 Thermal stability of electrical insulating material

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

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 trace heater panels shall not be wound around the mandrel. Trace heater pads 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 5.1.2 and the insulation resistance test 5.1.3 shall be conducted. Upon completion of these procedures, the sample shall be removed from the water and 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 5.1.2 and 5.1.3.

5.1.12 Thermal performance test

In explosive atmospheres, it is critical that the maximum sheath temperature of a trace heater is lower than the ignition temperature of the explosive atmosphere. 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 samples, which would be exposed under normal installation conditions, to the temperature levels required by this procedure. The test apparatus shall insure that the trace heater samples are in intimate contact with the platen. The test apparatus may be supplied with a sample mounting fixture. Offsets may 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 profile. The apparatus shall allow energizing of the trace heater samples as required during the test procedure.

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

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

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

The trace heater samples shall be within the upper half of the manufacturer's declared thermal output tolerance, as validated by clause 5.1.10 (method B). For trace heaters that are irregular in shape, and for trace heater pads and panels, the sample shall consist of at least one heating unit.

If the trace heaters are part of a trace heater 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 of each of the following shall be selected (for a total of six samples):

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

Trace heater samples may 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, 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 fixture has reached equilibrium.

The trace heater 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 may be de-energized during the cool down period.

The trace heater 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 may 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 minutes and a transition time between extremes shall not exceed 15 minutes with a cycle being one complete exposure at both temperature extremes.

The trace heater samples shall be subjected to a pre-conditioning period of 5 continuous temperature cycles. A minimum of 1 500 cycles shall then be performed. The trace heater samples' power output shall be continuously 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 is declared as "energized", the samples shall be energized at the maximum rated voltage.

After completion of the maximum exposure testing, the trace heater samples' power output shall be measured, using the same method and platen temperature as used during the initial measurements. The trace heater samples shall maintain a power level within plus 25 % or minus 25 % of the initial measured output. This applies at the end point as well as the intermediate measurements.

5.1.13 Determination of maximum sheath temperature

5.1.13.1 General

In explosive atmospheres, it is critical that the maximum sheath temperature for trace heaters is less than the ignition temperature of the explosive atmosphere. The maximum sheath temperature is dependent on the trace heater power density, overall heat transfer coefficient, and the maximum possible temperature of the surface to be heated. These factors are used to verify the temperature classification of particular trace heaters and to verify the manufacturer's ability to predict the maximum sheath temperatures of trace heaters.

At least one of the following two methods shall be used for verifying a trace heater's sheath temperature or temperature class as declared by the manufacturer:

a) Product classification approach in which the maximum sheath temperature is determined in an artificial environment simulating adverse conditions.
b) Systems method in which the manufacturer demonstrates the ability to design and predict sheath temperatures of trace heaters by conducting tests on representative installations representing adverse design and operating conditions when installed according to the manufacturers installation instructions.

5.1.13.2 Product classification approach

A sample of the trace heater at least 1 500 mm in length is placed loosely coiled in a forced air circulation oven. For a trace heater pad or panel, a representative sample is placed horizontally in the oven. The sample shall be within the upper half of the trace heater's thermal output tolerance. Representative thermocouples are used to monitor sample sheath temperatures and are placed approximately 500 mm from each end. One additional thermocouple is used to monitor oven ambient temperature. The trace heater shall be powered at 110% of rated voltage as specified in Table 2, Table 3, Table D.2, and Table D.3. The oven ambient temperature is incrementally raised from room ambient in approximately 15 K increments. Sufficient time is permitted at each temperature for the oven ambient and heater sheath temperatures to stabilize and attain thermal equilibrium. Oven ambient and heater sheath temperatures are recorded at each successive level until the difference (ΔT) between the two approaches 5 K or less. A curve is drawn from the test data, and a straight line is drawn tangent to the curve at 5 K temperature difference point and extended to the X axis (oven temperature). The temperature read at this intercept is taken as the maximum sheath temperature, as shown in Figure 7.

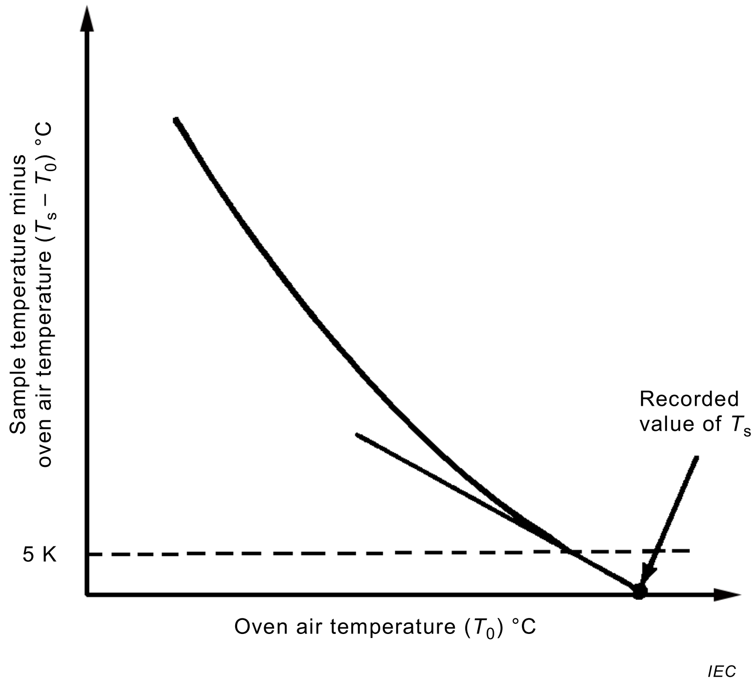


Figure 7 – Maximum sheath temperature using product classification approach

5.1.13.3 Systems approach – stabilized and controlled design verification

In the systems approach, the trace heater is subjected to test conditions where the manufacturer shall demonstrate the ability to predict maximum sheath temperatures by conducting tests on application representative test apparatus as described in 5.1.13.4.2 to 5.1.13.4.5 and compare the sheath temperature results to predicted values.

This approach is used for both stabilized design as well as controlled design temperature verifications. Sheath temperatures are validated by sampling varied parameters, such as power densities and pipe temperatures, as agreed between the certification body and manufacturer. For controlled design temperature verification, these procedures are used to validate a manufacturer's predicted maximum trace heater sheath temperatures when controlled by a suitable combination temperature-limiting and regulating control device or by a suitable high temperature limiter device (see 4.5.3.2, C.7.2, and C.7.4). The maximum sheath temperature of the trace heater shall not exceed the predicted values by more than 10 K, and the temperature shall not be greater than the manufacturer's maximum declared withstand temperature.

The trace heater shall be powered at 110% of rated voltage as specified in Table 2, Table 3, Table D.2, and Table D.3. The trace heater sample selected for maximum sheath temperature testing shall be in the upper half of the manufacturer's declared power output tolerance window of the trace heater or, for series trace heaters or for parallel zoned trace heaters, test conditions shall be such as to achieve similar results. All maximum sheath temperature testing shall be done at the maximum ambient temperature (or extended from ambient test temperature data to maximum ambient temperature levels) and in no wind conditions. All temperature testing shall be done under continuously energized trace heater operation (controls bypassed) for stabilized system design verifications. For controlled designs, temperature testing shall be done with the control or limiter system is in place. Controlled designs include systems where a combination temperature-limiting and regulating device or a suitable high-temperature-limiter (having either manual reset control action or alarm annunciation and trace heater shutdown capability), is included in each trace heater circuit. In these cases, the maximum sheath temperature shall be measured when the heated surface is at the controller turnoff point plus accuracy tolerance of the controller and adjusted for system thermal inertia.

If the trace heaters are rated for multiple power outputs, testing shall be performed at three power outputs, or at three other varied parameters, such as insulation type or thickness, if applicable, to the satisfaction of the certification body.

5.1.13.4 Test apparatus and procedure

5.1.13.4.1 General

One of the following test apparatus shall be used for establishing power output and verifying sheath temperatures for trace heaters.

5.1.13.4.2 Insulated externally heated surfaces – pipe sculpture

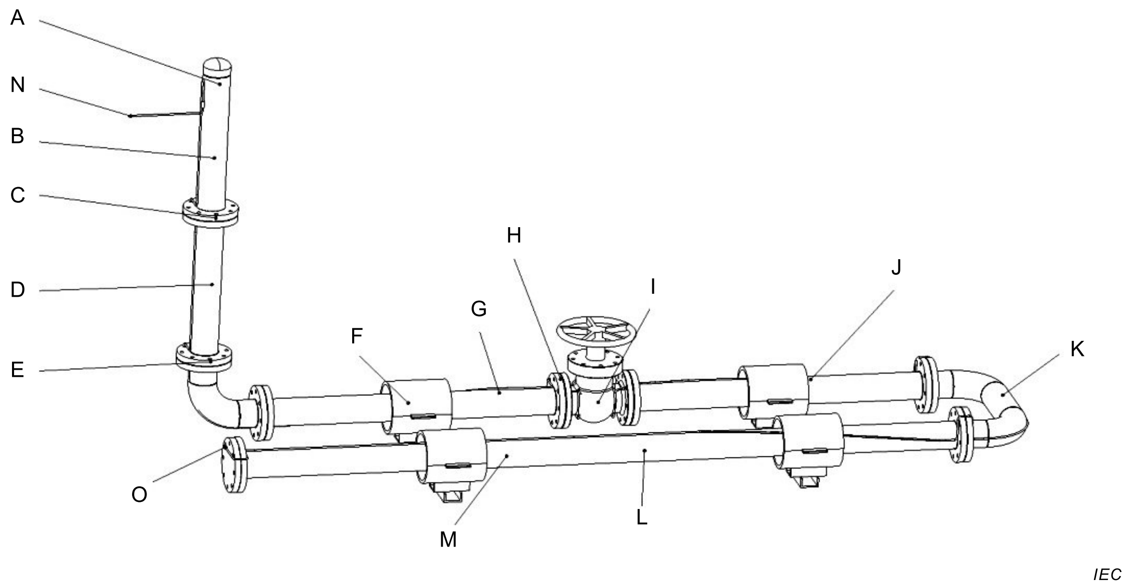
For insulated trace heaters on piping, the test apparatus as shown in Figure 8 shall consist of two 3 m (minimum length) horizontal runs of piping in a U arrangement and a 1,5 m (minimum length) vertical run of piping having a pipe size of 100 mm (larger or smaller pipes may be used depending on the application). The pipe shall be empty. A flanged gate valve shall be located in the center portion of one of the horizontal runs. The trace heater shall be installed in a manner consistent with the manufacturer's installation instructions (including crossing over itself if specified) and be between the 9 o'clock and 3 o'clock postions of the pipe circumference (upper portion of the pipe). The sample(s) shall be supplied to cover the complete length of the test apparatus as in Figure 8 and shall be within the upper half of the trace heater's thermal output tolerance or, for series trace heaters or for parallel zoned trace heaters, test conditions shall be considered to achieve similar results. Thermocouples shall be used to monitor the pipe, valve, and flange surface temperatures and corresponding heater sheath temperatures at each of these locations.(see Figure 8) The thermocouples and the connection cables shall be selected and arranged such that they do not significantly affect the thermal behavior 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 minimize measurement error. For other electrically conductive coverings, polymeric sheaths, and non-metallic heated surfaces, thermocouples shall be attached with a suitable adhesive/tape system. Additional thermocouples may be located at other anticipated hot spots at the discretion of the certification 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. Pipe ends shall be plugged and thermally insulated. An additional trace heater length may be added to the test section on either end to minimize end effects.

The trace heater device shall be powered at 110% of rated voltage according to Table 2, Table 3, Table D.2, and Table D.3. After stabilization, the thermocouple readings shall be recorded, including the local ambient temperature. The manufacturer shall demonstrate the ability to predict the runaway pipe (workpiece) temperature (Tpr) 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 control device or limiter shall be compared to the measured maximum trace heater sheath temperatures.

For verifying the control design method with a combination temperature-limiting and regulating device or a suitable high-temperature-limiter, the high temperature control device or limiter sensor shall be installed according to the manufacturer's instructions. The predicted maximum sheath temperature, for a specific set point of the temperature control device or 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	H	Flange and heater sheath thermocouples
B	Pipe and heater sheath thermocouples	I	Valve body and heater sheath thermocouples
C	Flange and heater sheath thermocouples	J	Isolated support (typical of 2)
D	Pipe and heater sheath thermocouples	K	Pipe and heater sheath thermocouples
E	Flange and heater sheath thermocouples	L	Pipe and heater sheath thermocouples
F	Isolated support (typical of 2)	M	Pipe and heater sheath thermocouples
G	Pipe and heater sheath thermocouples	N	Trace heater power connection
		O	Trace heater end termination

Figure 8 – Verification of sheath temperatures using pipe sculpture

5.1.13.4.3 Insulated externally heated surfaces – vessels

For trace heater pads and panels, a representative sample shall be applied to an approximately 6 mm thick steel plate in accordance with the manufacturer's installation instructions. The steel plate shall not extend more than 50 mm from any edge of the trace heater pad or panel. Thermocouples shall be used to monitor the plate temperatures and the corresponding trace heater pad or panel sheath temperature at locations in the centermost region or hottest spot of the trace heater pad or panel. The trace heater pad or panel sample shall be within the upper half of its thermal 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 behavior of the temperature measurements, such as 0,2 mm2 or smaller size Type K or Type J thermocouples. Thermocouples for metallic sheaths and heated metallic surfaces shall be suitably attached to minimize 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 may be located at other anticipated hot spots at the discretion of the certification 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 mounted in a vertical position is then located in a stable room temperature and no wind environment. The trace heater pad or panel shall be powered at 110 % of rated voltage according to Table 2, Table 3, Table D.2, and Table D.3. 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 suitable combination temperature-limiting and regulating control device or suitable high temperature limiter shall be compared to the measured maximum heating device sheath temperatures. The measured 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.

5.1.13.4.4 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 certification 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 behavior 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 minimize 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 may be located at other anticipated hot spots at the discretion of the certification body.

The heating device shall be powered 110 % of rated voltage according to Table 2, Table 3, Table D.2, and Table D.3. 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 combination temperature-limiting and regulating device or a suitable high-temperature-limiter 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.

For maximum temperature testing, the tubing within the bundle shall be empty and the maximum sheath temperature shall be recorded. For power output testing, the tubing within the bundle shall contain flowing water or water glycol at the rated temperature value when the power level is verified.

5.1.13.4.5 Sheath temperature verification – utilizing plate test procedure

This procedure may be used in lieu of the sheath temperature verification part of 5.1.13.4.2.

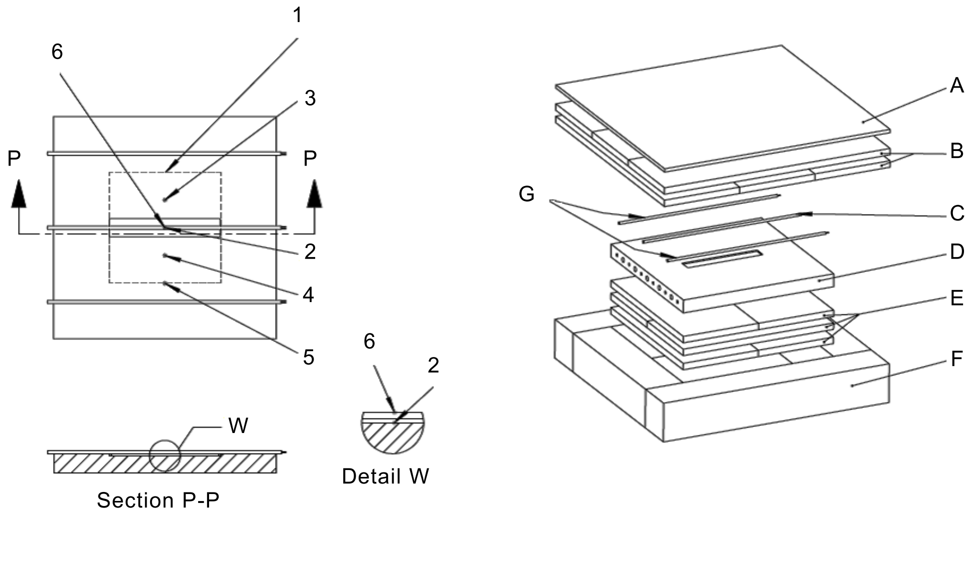
The test apparatus and procedures from section 5.1.13.4.2 and the design conditions from Table 2, Table 3, Table D.2, and Table D.3 shall be used to determine the maximum workpiece temperature that is to be used as one of the plate temperatures. When using this test method, the manufacturer shall have demonstrated the ability to predict a runaway pipe (workpiece) temperature (Tpr) using the test method in Clause 5.1.13.4.2.

The test apparatus, as shown in Figure 9, shall consist of an aluminum plate, 600 mm × 600 mm × 50 mm with cartridge heaters, temperature controller, and channels for cooling. In the center of the plate is a trough (approximately 300 mm × 50 mm × 5 mm) over which the trace heater is to be placed. The plate shall be thermally insulated with approximately 75 mm of calcium silicate on the bottom and approximately 150 mm wide mineral wool 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 or other suitable insulation as agreed upon with the certification body. Rigid insulation shall 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 9. 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 thermal 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. Alternately it may be appropriate for the sample to be serpentined on the plate to 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 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 9 or Figure 10. 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 minimize 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 center line of the trough as shown in Figure 11. Alternately, it may be appropriate for a single sample to be crossed over iteslf at a 45° angle to the centerline of the trough to ensure the entire heated section is in contact with the plate as shown in Figure 12. In this case, the three thermocouples are installed on the trace heater sheath, at the center point, and at 75 mm and 150 mm from the center. 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°C of each other. The trace heater shall then be powered at 110% of rated voltage as specified in Table 2, Table 3, Table D.2, and Table D.3. 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 certification body.

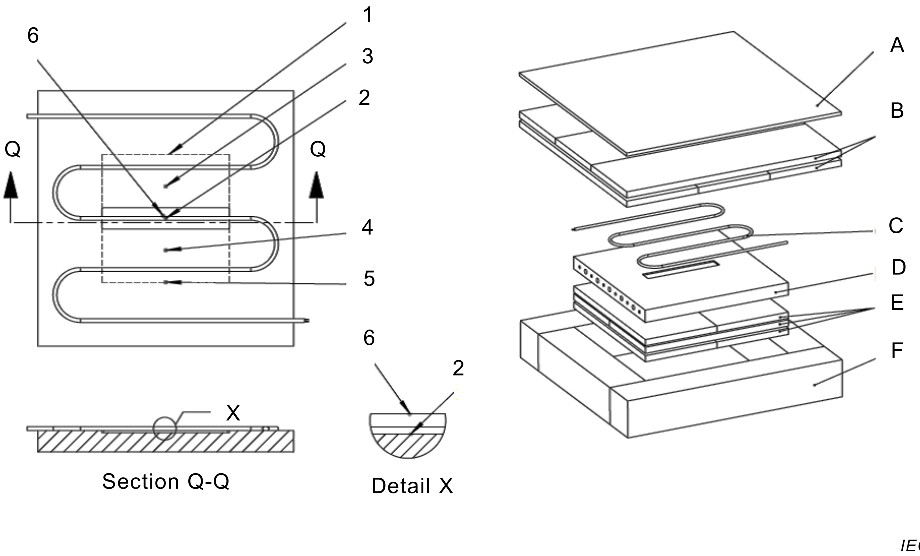
The measured sheath temperature(s) shall not exceed the manufacturer’s calculated value by more than 10 K and shall not exceed the manufacturer’s declared maximum withstand temperature.



Key

1	300 mm × 300 mm test area	**A**	Wood board
2	Thermocouple on bottom surface of trough	**B**	Two layers of rigid insulation
3	Plate tempreature control point 75 mm from centerline 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
		G	Two unpowered support samples

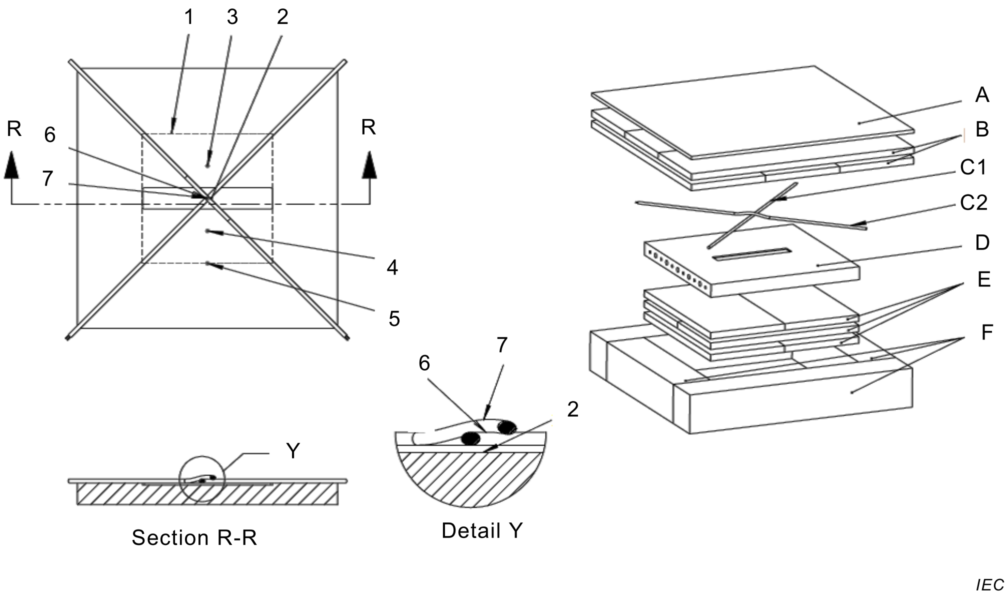
Figure 9 – Verification of sheath temperature, plate test



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 tempreature control point 75 mm from centerline 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

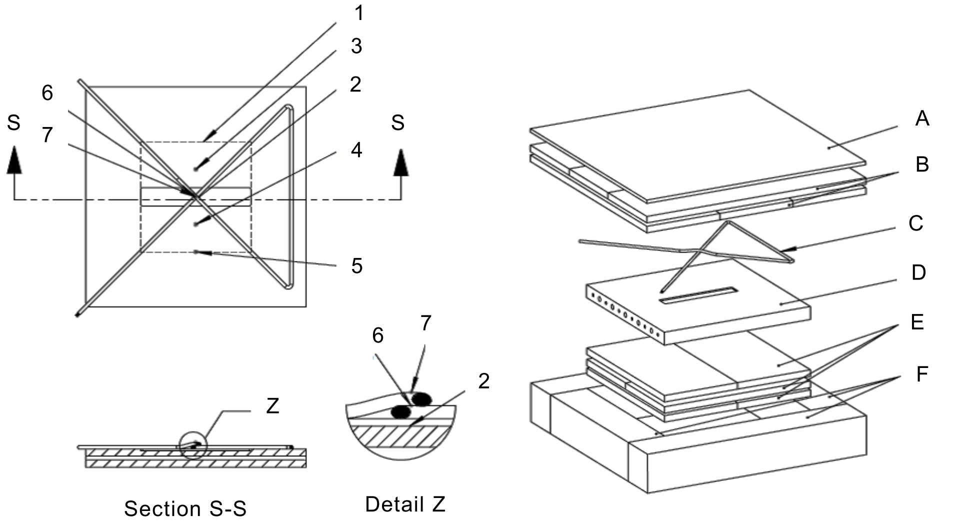
Figure 10 – Verification of sheath temperature – plate test with serpentined sample



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 tempreature control point 75 mm from centerline 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 11 – Plate test 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 tempreature control point 75 mm from centerline 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 12 – Plate test with a single sample crossed over

5.1.14 Verification of start-up current

The start-up current of the trace 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 steel pipe or solid rod, or for heating panels or pads a flat metal heat sink. The testing apparatus shall be completely covered with thermal insulation and conditioned at the designated temperature for at least 4 h.

NOTE The apparatus described in 5.1.10 can be used for this test.

After the conditioning period, rated voltage shall be applied and the time/r.m.s. current characteristic shall be recorded from time zero to 300 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.

5.1.15 Verification of the electrical resistance of electrically conductive covering

The resistance of the electrically conductive covering at least 3 m length of the trace heater, excluding integral components, shall be measured at room temperature.

For trace heater pads and panels, a representative sample shall be selected.

The resistance shall be equal to or less than the manufacturer's declared value.

5.1.16 Outdoor exposure test

Only trace heaters and integral components specified for outdoor exposure are subject to this test. In addition, trace heaters and integral components having a continuous metal sheath with no outer jacket shall be exempt from this test.

A sample of the trace heater, approximately 450 mm in length, 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/ISO 4582/ISO 4892-1 for a total period of 1 000 h. The cycle rate shall be set for 102 min of light and 18 min of combined light and water spray. At the end of this time, the sample shall be removed from the chamber and subjected to the impact tests in 5.1.5 and the cold bend test in 5.1.7. In addition, the outermost sheath shall be subjected to a dielectric voltage of 500 Vac, applied between the conductive layer and water for 1 min without dielectric breakdown.

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

5.2 Routine tests

5.2.1 Dielectric test

The primary electrical insulation jacket of the trace heater shall withstand a dry-spark test at a minimum of 6 000 Vac. As an alternative to the dry-spark test, the dielectric test method in 5.1.2 shall be conducted on production lengths or units.

After the application of an electrically conductive covering, the trace heater shall have the dielectric test method described in 5.1.2 conducted on production lengths or units.

Non-metallic overjackets shall withstand an additional dry-spark test with a minimum test voltage of 3 000 Vac. As an alternative to the dry-spark test, the dielectric test method in 5.1.2 shall be conducted on production lengths or units.

5.2.2 Verification of rated output

The output rating for each manufactured length of parallel trace heater shall be verified for linearity of power output through continuous or statistical test methods. The power output rating for each length of series resistance trace heater or fixed resistive trace heater shall be verified by measurement of the d.c. resistance, or conductance or current at rated voltage and given temperature. The test measurement criteria shall be established or correlated to the output verification test specified in 5.1.10. The power output shall be within the manufacturer’s declared tolerances.

6 Marking

6.1 Product markings for trace heaters

Trace heaters shall be clearly and permanently surface marked in accordance with IEC 60079-0 with the following modifications. For trace heaters with factory fabricated terminations, or surfaces where legible printing cannot be applied, the marking shall be on a durable tag/label permanently affixed within 75 mm of the power connection fitting or gland.

a) The required serial number or batch number may be substituted with the month and year of manufacture, date coding, or equivalent.

b) The rated or operating voltage shall be marked for a parallel trace heater, or the maximum operating voltage for a series trace heater.

c) The rated power output per unit length at the rated voltage (and at a stated reference temperature for trace heaters that change output with temperature), or the resistance in ohms for unit length for series trace heater, or the operating current or total wattage as applicable shall be marked.

d) The symbol provided for the "type of protection used" for trace heating shall be "60079-30-1", for example, typical Ex marking strings would be "Ex 60079-30-1 IIC T4 Gb" and "Ex 60079-30-1 IIIC T135°C Db", which does not preclude the use of additional types of protection appropriate for the components intended to be supplied or recommended for use with the trace heaters;

e) The marking requirements of IEC 60079-0 for ambient temperature ranges do not apply, but trace heaters or trace heater systems shall be marked with the minimum installation temperature along with the required temperature class;

f) For marking trace heaters for use with the Division method of area classification, see D.6.

6.2 Markings for field assembled components

Field assembled components that are accessible after installation shall be marked in accordance with IEC 60079-0 and shall additionally include the following information:

a) the name of the manufacturer, trademark, or other recognized symbol of identification;

b) the catalog number, reference number, or model;

c) the month and year of manufacture, date coding, applicable serial number, or equivalent;

d) applicable environmental requirements, such as IP (ingress protection) ratings, and area use requirements.

In the case of components with small surface areas or surfaces where legible printing cannot be applied, the markings may be placed on the smallest unit container in lieu of the component itself.

7 Documentation requirements

7.1 General

The manufacturer's documents shall provide product specific instructions and requirements for documentation retention. Instructions for various components and trace heaters may be combined where termination/installation instructions are identical. The instructions shall be clearly identified as to the products and locations that apply.

Any Specific Conditions of Use, including the provision in 7.4 e), shall be outlined in the installation instructions and in the certificate, and the certificate number shall include the suffix "X".

The documents shall include:

a) the information on circuit protection specified in 4.4, as applicable;

b) requirements for circuit designs, see 7.2;

c) requirements for trace heating system documentation, see 7.3;

d) instructions for installation of trace heating system, see 7.4;

e) instructions for commissioning, see 7.5;

f) instructions for maintenance / repair or modification, see 7.6.

7.2 Circuit design documentation

The information given in the documentation for designing circuits shall include the following statement or its equivalent "The design of electrical resistance trace heating systems shall be overseen by persons knowledgeable of trace heating following the design methodology for explosive atmospheres as specified by the manufacturer".

7.3 Trace heating system documentation

7.3.1 General

The requirements shall include the following statement or its equivalent "The trace heating system documentation shall be retained for each trace heating circuit for as long as the system is in use". As a minimum, the trace heating system documentation shall include the information specified in 7.3.2, 7.3.3 or 7.3.4 as applicable.

7.3.2 For trace heating systems according to the product classification method

The trace heating system documentation shall include the following information:

a) trace heating circuit identification;

b) trace heating system design parameters:

   1) temperature class or maximum sheath/surface temperature as applicable;

   2) trace heater type;

   3) operating voltage.

This information may be supplemented by the information listed in IEC/IEEE 60079-30-2.

7.3.3 For trace heating systems according to stabilized design method

The trace heating documentation shall include the following information:

a) trace heating circuit identification;

b) trace heating system design parameters:

   1) pipe size or workpiece dimensions;

   2) temperature to be maintained or the maximum process / exposure temperature;

   3) maximum ambient temperature;

   4) trace heater type;

   5) operating voltage;

   6) trace ratio;

   7) length or dimensions of trace heater;

   8) maximum workpiece temperature;

   9) temperature class or maximum sheath/surface temperature as applicable;

   10) thermal insulation type, size, and thickness;

   11) thermal insulation cladding specification, if applicable.

7.3.4 For trace heating systems according to controlled design method

The trace heating system documentation shall include the following information:

a) trace heating circuit identification;

b) trace heating system design parameters:

   1) location of the sensor of the temperature controller / limiter on the pipe / workpiece;

   2) details of the mounting of the sensor in accordance with 4.5.3, a), b) or c);

   3) temperature to be maintained or the maximum process / exposure temperature;

   4) maximum ambient temperature;

5) temperature controller / limiter set point;
6) trace heater type;
7) operating voltage;
8) trace ratio;
9) length or dimensions of trace heater;
10) temperature class or maximum sheath/surface temperature as applicable.
11) Details for any failure annunciation and monitoring in accordance with 4.5.3.3.

This information may be supplemented by the information listed in IEC/IEEE 60079-30-2.

7.4 Instructions for installation of trace heating system

The instructions shall include:

a) the following statement or its equivalent "Suitable for use with" and a listing of applicable trace heaters, or a listing of applicable connection fittings, as applicable;
b) the statement "Earth fault equipment protection is required for each circuit";
c) the statement "De-energise circuits before installation or servicing";
d) the following statement or its equivalent "Keep ends of trace heaters and kit components dry before and during installation";
e) for trace heaters certified for reduced levels of impact and/or deformation, the statement "Caution: Only use in areas with low risk of mechanical damage". And if applicable (see 4.1), the statement "Caution: This mechanical covering shall not be removed and the trace heaters shall not be operated without the mechanical covering being in place";
f) for trace heaters, the following statement or its equivalent "The electrically conductive covering of this trace heater shall be connected to a suitable earthing terminal";
g) the following statement or its equivalent "The presence of the trace heaters shall be made evident by the posting of caution signs or markings at appropriate locations and/or at frequent intervals along the circuit";
h) test requirements to be performed in the field and documented on a trace heater installation record; an example is provided in Annex B;
i) the following statement or its equivalent "The insulation resistance of the trace heater shall be measured and recorded after installation and shall not be less than 20 MΩ (or a higher value if specified by the manufacturer)";
j) the following statements or their equivalent "Persons involved in the installation and testing of electric trace heating systems shall be suitably trained in all special techniques required. Installation shall be carried out under the supervision of a qualified person";
k) any restrictions that the heating portion of the trace heater set shall not touch, cross over, or overlap itself;
l) the minimum bending radius;
m) the minimum installation temperature.

7.5 Instructions for commissioning

The instructions shall include a statement that the trace heating system parameters (as indicated in 7.3.2, 7.3.3, and 7.3.4) shall be verified during commissioning.

7.6 Instructions for maintenance / repair or modification

The instructions shall include:

a) the statement "Caution: consult the trace heating system documentation prior to maintenance/repair/modification";

b) the statement "After maintenance/repair/modification, test the operation of the earth-fault device of each affected circuit" or equivalent;

c) the statement "In the event of an earth fault or over current interruption, the device shall not be reset until the cause of the trip has been investigated by qualified personnel" or equivalent;

d) the statement "Upon completion of maintenance/repair/modification, the insulation resistance of the trace heater shall be measured and recorded after installation and shall not be less than 20 MΩ, except that MI trace heaters shall not be less than 5 MΩ (or higher values if specified by the manufacturer)" or equivalent.

Annex A
(informative)

Type test matrix for EPLs Gb/Gc/Db/Dc (Refer to IEC 60079-14 for the relationship of EPLs to Zones)

Table A.1 demonstrates determination of test samples.

Table A.1 – Determination of test samples

Clause	Type test	Quantity/Length of Samples		Temperature controller / limiter	Terminations	
		Trace Heater	Trace Heater Pad / Panel		Integral	Separate
5.1.2	Dielectric test	3 m	[f]		X	
5.1.3	Electrical insulation resistance test	3 m	[f]		X	
5.1.4	Flammability test	0,45 m	[f]		X	X
5.1.5 5.1.5.1 5.1.5.2	Impact test Room temperature impact test Minimum temperature impact test	 0,45 m 0,45 m	 [f] [f]		 X X	
5.1.6	Deformation test	0,45 m	[f]		X	
5.1.7	Cold bend test	0,45 m	[f]			
5.1.8	Water resistance test	3 m	[f]			
5.1.9	Integral components resistance to water test	3 m	[f]		X	X
5.1.10 5.1.10 a) 5.1.10 b)	Verification of rated output Resistance Thermal	 3 m 3 × 3 m [b]	 [f] [f]			
5.1.11	Thermal stability of electrical insulating material	3 m	[f]		X	
5.1.12	Thermal performance test	3 × 0,3 m[c]	[f]			
5.1.13 5.1.13.4.2 5.1.13.4.3 5.1.13.4.4 5.1.13.4.5	Product classification approach[d] Systems approach – pipe Sculpture[a,d] Systems approach – vessels[a,d] Systems approach – tubing Bundles[a,d] Systems approach – plate test[a,d]	1,5 m 10 m[e] -4,5 m[e] 3 × 0,7 m or 1 × 3,5 m or 2 × 0,9 m or 1 × 2,5 m	[f] [f]	 X [g] X [g] X [g] X X X X		
5.1.14	Verification of start-up current	1 m	[f]			
5.1.15	Verification of the electrical resistance of electrically conductive covering	3 m	[f]			
5.1.16	Outdoor exposure test	0,45 m	[f]		X	

[a] Use parameters of Table 2, Table 3 D.2 orD.3 as appropriate.

[b] From three separate samples.

[c] The lowest rated voltage level and the maximum rated power output; The highest rated voltage and the minimum rated power output.

[d] All samples in the upper half of power output tolerance.

[e] Length of sample determined by the installation instructions and test apparatus, amount of samples may vary.

[f] At least one representative sample is required. The exact size is to be agreed between the testing station and manufacturer.

[g] If applicable as required by the test.

Annex B
(informative)

Checklist for installation

Table B.1 gives an example of a trace heater installation record.

Table B.1 – Trace heater installation record – Example

Location	System	Project number	Reference drawing(s)
Line number	Trace heater number	Area classification	Temperature class or maximum sheath/surface temperature
Panel number	Location	Circuit number	Circuit amp/voltage
Trace heater manufacturer	Trace heater model	Trace heater wattage unit length/voltage rating	
Verify certification marking:			
Megohm meter manufacturer/model		Voltage setting	Accuracy/full scale
Megohm meter date of last calibration			
Multimeter manufacturer/model	Ohm setting	Accuracy/full scale	
TRACE HEATER TESTING	Test value/remarks	Date	Initials
NOTES Minimum acceptable insulation resistance shall be 20 MΩ except that for #4 below for MI trace heaters the minimum is 5 MΩ when measured at the trace heater junction box. Minimum acceptable test voltage is 500 V d.c. However, 1 000 V d.c. recommended for MI, 2 500 V d.c. for polymeric trace heaters.			
1 Receipt of material on reel			
Continuity test on reel			
Insulation resistance test on reel			
2 Piping completed (approval to start trace heater installation)			
3 Trace heater installed (approval to start thermal insulation installation)			
Trace heater correctly installed on pipe, vessel or equipment			
Trace heater correctly installed at valves, pipe supports, other heat sinks			
Components correctly installed and terminated (power, tee-end seal)			
Installation agrees with manufacturer's instructions and circuit design			
4 Thermal insulation installation complete			
Continuity test			
Insulation resistance test (5 MΩ for MI trace heaters)			
SYSTEM INSPECTED			
5 Marking, tagging and identification complete (see IEC/IEEE 60079-30-1:2014, Clause 6)			
6 Trace heater effectively earthed			
7 Temperature controls properly installed and set points verified			
8 Junction boxes all certified and closed			
9 Thermal insulation weather tight (all penetrations sealed)			
10 End seals, covered splices marked on insulation outer cladding			
11 Drawings, documentation marked as-built			
Performed by:		Company	Date
Witnessed by:		Company	Date
Accepted by:		Company	Date
Approved by:		Company	Date

Annex C
(normative)

Trace heater product design verification methodology

C.1 General

The determination of system temperatures, particularly product sheath temperatures in specified adverse conditions, is critical for controlled designs and stabilized designs of circuits. The manufacturer shall maintain the capability to correctly calculate system temperatures over the range of parameters covered by the certification, and to demonstrate this capability by test and by comparison of the results to the system design calculations.

Calculation methodology is typically based on the use of widely known and accepted heat transfer formulae, which are adjusted as necessary to reflect the empirical data and which typically incorporate safety factors as needed.

This Annex indicates the formulae and considerations that manufacturers typically rely on to create their system design capability.

C.2 Design methodology and selection of trace heaters

It is important that the design methodology includes trace heater selection criteria to optimize the determination of the maximum possible system temperature under specified adverse conditions as specified in this standard. The temperature may be reduced, for example, through adjustments to the system parameters, by the use of multiple tracers to reduce the power produced per unit length, or by the selection of the temperature control system.

The maximum withstand temperature of the trace heaters shall be greater than the maximum possible workpiece temperature (which may be greater than the normal operating temperature).

As indicated in 4.5.1, the maximum sheath temperatures of trace heaters are determined by the product classification method, by stabilized design, or by controlled design. For the product classification method, further temperature limiting control measures are not necessary, provided that the temperature class of the trace heater is lower in temperature than that specified for the application. Nevertheless the control limiting and stabilized design measures can be applied to operate the system in a narrower band of process temperatures. The considerations for stabilized design and for controlled design are similar, with a need in both cases to accurately determine the system heat loss and the maximum system and sheath temperatures. In the case of stabilized design, the evaluation of energy balance of the system is additionally necessary.

C.3 Stabilized design calculations

Stabilized design is based on the principle of determining the maximum workpiece and trace heater sheath temperatures under specified adverse conditions. This is a calculation of the equilibrium conditions that occur when the heat input equals the system heat loss. The specified adverse conditions include:

a) maximum ambient temperature, typically assumed to be 40 °C unless otherwise specified;

c) no wind (still air);

d) use of a conservative or minimum value for the thermal conductivity of the thermal insulation;

e) no temperature control by design or to simulate a failed temperature controller;

f) the trace heater is operated at its stated operating voltage plus 10 %;

g) the trace heater is assumed to be operating at the upper limit of the manufacturing tolerance, or at the minimum specific resistance for series trace heaters.

h) the maximum runaway workpiece temperature, or the maximum equilibrium process temperature if greater.

Testing for stabilized design is given in 5.1.13. Typically the maximum sheath temperature of the trace heater is calculated from formulae derived from the evaluation of empirical data, or by the theoretical approach described below. Alternatively, design programs that calculate the maximum sheath temperature on the basis of these specified adverse parameters may be used.

C.4 Trace heater performance and equilibrium conditions

Depending on the application and the type of heat tracing, it may be necessary to evaluate the system at equilibrium conditions. Trace heating systems with no controls and trace heating systems with ambient sensing controls are typical examples. Figure C.1 shows examples of power output curves for constant wattage trace heaters and for PTC (positive temperature coefficient) trace heaters with different slope characteristics. The heat loss line represents the conditions that occur at the lowest ambient temperature. This illustrates that the constant wattage trace heater maintains the workpiece at the highest temperature (80 °C), but since it also has the highest output (32 W/m) it also has the highest operating temperature. The PTC trace heater with the steepest slope maintains the workpiece at the lowest temperature (50 °C), but also has the lowest output (23 W/m) and therefore the lowest operating temperature.

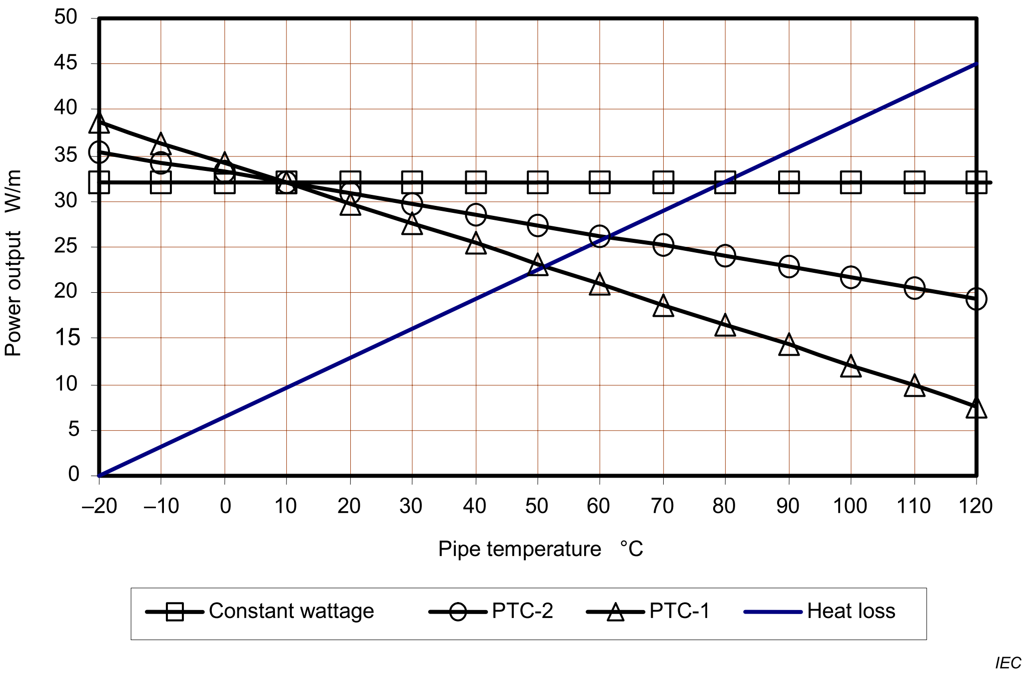


Figure C.1 – Equilibrium conditions for workpiece maintenance

Figure C.2 shows the same example, but from the perspective of evaluating the upper limits. In this case the heat loss line is shifted to the highest possible ambient, and the crossing points illustrate the maintain temperature and relative power outputs at these conditions. The PTC-1 trace heater now has a higher maintain temperature than before (91 °C), but the output level has decreased (16 W/m) due to the decreasing slope of the output curve. This same approach may be used when evaluating the upper limit operating conditions for the stabilized design approach.

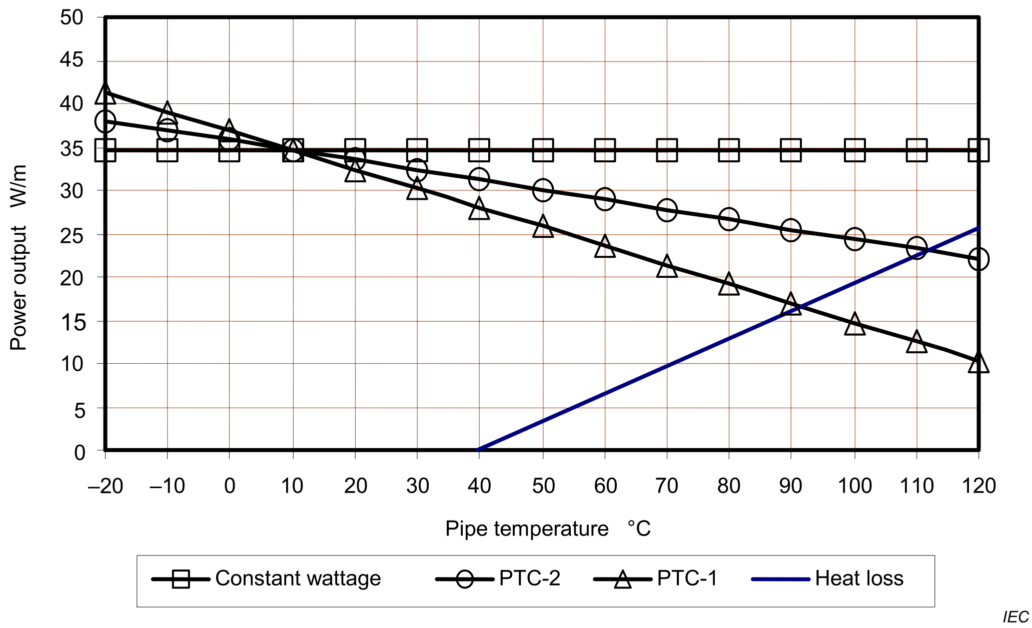


Figure C.2 – Equilibrium conditions for upper limit evaluation

The power output levels of different trace heaters are typically provided by the manufacturer in the product literature and/or in a design program. In most cases, the output curves for the PTC trace heater types are defined based on empirical data from test fixtures correlated to the test of 5.1.10.

The output of series type trace heaters is typically defined from its electrical parameters by using the following formula:

$$Q = \frac{V^2}{r_s l^2} \tag{C.1}$$

where

Q is the power output of the trace heater (W/m);

V is the system voltage (V);

r_s is the specific resistance of each conductor (ohm/m);

l is the length of each conductor (m).

The specific resistance of the conductor is a function of the conductor temperature, as given by the formula:

$$r_s = r(1 + \alpha \Delta T) \tag{C.2}$$

where

r is the resistance of the conductor at 20 °C (ohm/m);

α is the alpha coefficient for the type of material of the conductor (1/K);

ΔT is the difference between the temperature of the conductor in the operating state and 20 °C (K).

It is important to recognize that the following characteristics of a trace heating system should exist for the installation to be successful:

a) The output of the trace heater(s) should be greater than the system heat loss including a suitable safety factor. This can be achieved by installing a single trace heater with suitable output, by using multiple passes, or by spiraling if needed to keep the output level as low as possible.
b) Potential voltage deviations or other changes in system parameters over time should be determined and compensated for by the safety factor.
c) The upper limit of the system shall be evaluated for applications where process temperature accuracy is critical, or that have a wide range of ambient temperatures, or for systems that have no control or that have ambient sensing control.

C.5 Heat loss calculations

To determine actual heat losses for a given set of conditions, a complete insulation specification, including the thermal conductivity of the insulation at several mean temperatures, the type of weather barrier specified, insulation size and thickness, desired pipe maintenance temperature, and the ambient temperature and wind conditions, is required.

Given these parameters, the heat loss for pipes and tubes may be evaluated by Equation (C.3):

$$q = \frac{(T_p - T_a)}{\frac{1}{\pi D_1 h_i} + \frac{\ln(D_2/D_1)}{2\pi k_1} + \frac{\ln(D_3/D_2)}{2\pi k_2} + \frac{1}{\pi D_3 h_{co}} + \frac{1}{\pi D_3 h_o}} \tag{C.3}$$

where

q is the heat loss per unit length of pipe (W/m);

T_p is the desired maintenance temperature (°C);

T_a is the specified design ambient temperature (°C);

D_1 is the inside diameter of the inner insulation layer (m);

D_2 is the outside diameter of the inner insulation layer (m), (inside diameter of the outer insulation layer when present);

D_3 is the outside diameter of the outer insulation layer (m), (when present);

k_1 is the thermal conductivity of the inner layer of insulation evaluated at its mean temperature (W/m·K);

k_2 is the thermal conductivity of the outer layer of insulation, when present, evaluated at its mean temperature (W/m·K);

h_i is the inside air contact coefficient from the workpiece to the inner insulation surface when present (W/m^2·K);

h_{co} is the inside air contact coefficient from the outer insulation surface to the weather barrier when present (W/m^2·K);

h_o is the outside air film coefficient from the weather barrier to ambient (W/m^2·K) (typical values for this term range from 5 W/m^2·K to 50 W/m^2·K for low-temperature applications below 50 °C).

The heat loss for pipes and tubes is described in more detail, with an example, in IEC/IEEE 60079-30-2.

Following the same process, the heat loss for vessels may be evaluated by Equation (C.4):

$$q = \frac{(T_p - T_a)}{\frac{1}{h_i} + \frac{b_1}{k_1} + \frac{b_2}{k_2} + \frac{1}{h_{co}} + \frac{1}{h_o}} \quad \text{(C.4)}$$

where

q is the heat loss per unit area of vessel (W/m^2);

b_1 is the thickness of the inner insulation layer (m);

b_2 is the thickness of the outer insulation layer (m), (when present).

Other terms are defined with formula (3).

The heat loss for vessels is described in more detail in IEC/IEEE 60079-30-2.

For ease of product selection, trace heating suppliers often furnish simple charts and graphs of heat losses for various maintain temperatures and insulations, which usually include a safety factor.

C.6 Heat loss design safety factor

Since heat loss calculations based on theoretical values do not account for imperfections associated with actual work site installations, a safety factor should be applied to the calculated values. The safety factor should be based upon the user's requirements that typically range from 10 % to 25 %. The addition of a safety factor is used to compensate for tolerances in the trace heating system. Safety factors should be considered for:

a) thermal insulation degradation;
b) supply voltage variations;
c) branch wiring voltage drop;
d) trace heater voltage drop;
e) increased radiation and convection on higher temperature applications;
f) quality of installation of thermal insulation.

C.7 Maximum temperature determination

C.7.1 Theoretical pipe and sheath temperature calculations – Metallic applications

The maximum possible pipe temperature is calculated at maximum ambient temperature with the trace heater continuously energized. The formula for calculating the maximum potential pipe temperature is a rearrangement of the terms of the heat loss formula:

$$T_{pr} = \frac{Q_{sf}}{\pi}\left[\frac{1}{D_1 h_i} + \frac{\ln(D_2/D_1)}{2k_1} + \frac{\ln(D_3/D_2)}{2k_2} + \frac{1}{D_2 h_{co}} + \frac{1}{D_2 h_o}\right] + T_a \quad \text{(C.5)}$$

where

T_{pr} is the maximum calculated runaway pipe temperature (°C);

Q_{sf} is the trace heater output. For determining temperature classes for stabilized design, Q_{sf} is the highest declared power output at the maximum manufacturer's output tolerance (W/m), adjusted for 110 % of rated voltage;

T_a is the maximum specified design ambient temperature (°C).

Other terms are defined with formula (3). Iterative techniques may need to be applied to the calculation of formula (5) in order to arrive at T_{pr}, since the thermal conductivity of the insulation and the trace heater output may be a function of pipe temperature.

The sheath temperature of the trace heater shall be calculated as follows, using the equation for T_{pm} if T_{pm} is greater than T_{pr}:

$$T_{sh} = \frac{Q_{sf}}{UC} + T_{pr} \quad \text{or} \quad T_{sh} = \frac{Q_{sf}}{UC} + T_{pm} \qquad \text{(C.6) and (C.7)}$$

where

T_{sh} is the trace heater sheath temperature (°C);

U is the overall heat transfer coefficient (W/m^2·K) which is an empirically determined value;

C is the trace heater circumference (m);

T_{pr} is the maximum calculated runaway pipe temperature (°C);

T_{pm} is the maximum declared process temperature (°C).

The overall heat transfer coefficient is different for each trace heater type, installation method and system configuration. It is a combination of conductive, convective and radiation heat transfer modes. The value of U can vary from 12 for a cylindrical trace heater in air (primarily convective), to 170 or more for a trace heater applied using heat transfer aids (primarily conductive). Upon request, the trace heating supplier should provide the U-factor for given applications, or furnish calculated or experimentally determined sheath temperatures.

The power output Q_{sf} of the trace heater selected shall provide the stabilized design and T_{sh} shall not exceed the temperature class.

C.7.2 Theoretical vessel and sheath temperature calculations – Metallic applications

Similarly, for vessels, the maximum possible vessel temperature is calculated at maximum ambient temperature with the trace heater continuously energized. The formula for calculating the maximum potential vessel temperature is a rearrangement of the terms of the heat loss formula:

$$T_{wr} = Q_{sf}\left[\frac{1}{h_i} + \frac{b_1}{k_1} + \frac{b_2}{k_2} + \frac{1}{h_{co}} + \frac{1}{h_o}\right] + T_a \qquad \text{(C.8)}$$

where

T_{wr} is the maximum calculated runaway vessel temperature (°C);

Q_{sf} is the trace heater output. For determining temperature classes for stabilized design, Q_{sf} is the highest declared power output at the maximum manufacturer's output tolerance (W/m^2), adjusted for 110 % of rated voltage;

T_a is the maximum specified design ambient temperature (°C).

Other terms are defined above. Iterative techniques may need to be applied to the calculation of formula (8) in order to arrive at T_{wr}, since the thermal conductivity of the insulation and the trace heater output may be a function of the temperature of the vessel.

The sheath temperature of the trace heater pad or panel shall be calculated as follows, using the equation for T_{wm} if T_{wm} is greater than T_{wr}:

$$T_{sh} = \frac{Q_{sf}}{U} + T_{wr} \quad \text{or} \quad T_{sh} = \frac{Q_{sf}}{U} + T_{wm} \qquad \text{(C.9) and (C.10)}$$

where

T_{sh} is the trace heater sheath temperature (°C);

U is the overall heat transfer coefficient (W/m^2·K) which is an empirically determined value;

T_{wr} is the maximum calculated runaway vessel temperature (°C);

T_{wm} is the maximum declared process temperature (°C).

The overall heat transfer coefficient is different for each trace heater type, installation method and system configuration. It is a combination of conductive, convective and radiation heat transfer modes. The value of U can vary from 12 for a trace heater in air (primarily convective), to 170 or more for a trace heater applied using heat transfer aids (primarily conductive). Upon request, the trace heating supplier should provide the U-factor for given applications, or furnish calculated or experimentally determined sheath temperatures.

The power output Q_{sf} of the trace heater selected over the combination of heat loss q and heat transfer from the tracer, shall provide the stabilized design and ensure that T_{sh} shall not exceed the temperature class or any other maximum temperature limitations listed above.

C.7.3 Sheath temperature – metallic applications utilizing a temperature limiter control sensing the trace heater sheath or an artificial hot spot

When the limiter control sensor is located directly on the trace heater the following shall be included in the evaluation of sheath temperatures:

$$T_{sh} = T_L + \Delta T_{offset} \qquad \text{(C.11)}$$

where

T_L is the set point of the temperature limiter

ΔT_{offset} is the empirically determined temperature difference between the sensor and the actual maximum tracer sheath temperature. ΔT_{offset} is a function of variables such as geometry and mass of the trace heater and sensor, power output of the trace heater, heat transfer coefficient, and control system hysteresis.

C.7.4 Theoretical sheath temperature calculations – Non-metallic applications

For non-metallic applications, the workpiece wall thermal resistance should be considered, as the non-metallic material is a poor heat transfer medium. These materials may have a thermal conductivity (k-factor) 1/200 of that of steel, and a substantial temperature difference may develop across the pipe or tank wall depending on the trace heater power density. This higher than normal temperature (when compared to tracing metallic pipes and vessels) may have two adverse effects:

a) the non-metallic workpiece maximum allowable temperature may be exceeded;
b) the trace heater maximum allowable temperature may be exceeded.

The sheath temperature of the trace heater under normal operating conditions is in principle obtained from formulae (6), (7), (9) or (10). However, in obtaining *U,* the effect of the thermal resistance of the workpiece wall should be included. The overall heat transfer coefficient for a plastic surface is:

$$\frac{1}{U_p} = \frac{1}{U_m} + \frac{L}{k_p} \tag{C.12}$$

where

U_p is the overall heat transfer coefficient for a non-metallic pipe (W/m^2·K);

U_m is the overall heat transfer coefficient for a metallic workpiece (W/m^2);

L is the workpiece wall thickness, in metres (m);

k_p is the thermal conductivity of workpiece wall material (W/m·K).

Because of the additional thermal resistance of the non-metallic material, a temperature difference exists across the workpiece wall; that is, the outside workpiece wall and fluid temperature are not the same as in the case of a metallic workpiece. Therefore, fluid temperature should be considered.

For non-metallic pipe, then:

$$T_{sh} = \frac{Q_{sf}}{U_p C} + T_f \tag{C.13}$$

where

Q_{sf} is the trace heater output. For determining temperature classes for stabilized design, Q_{sf} is the highest declared power output at the maximum manufacturer's output tolerance (W/m), adjusted for 110 % of rated voltage;

T_f is the fluid temperature (°C).

Similarly, for non-metallic vessels, the equation is:

$$T_{sh} = \frac{Q_{sf}}{U_p} + T_f \tag{C.14}$$

where

Q_{sf} is the trace heater output. For determining temperature classes for stabilized design, Q_{sf} is the highest declared power output at the maximum manufacturer's output tolerance (W/m^2), adjusted for 110 % of rated voltage;

T_f is the fluid temperature (°C).

Formulae (13) and (14) represent a conservative simplification of a complex problem that involves criteria beyond the scope of this standard. The trace heating manufacturer shall provide sheath temperature data for specific applications.

The power output of the trace heater selected shall provide the stabilized design and T_{sh} shall not exceed the temperature class or any other maximum temperature limitations.

C.7.5 Sheath temperature – non-metallic applications utilizing a temperature limiter control sensing the trace heater sheath or an artificial hot spot

When the limiter control sensor is located directly on the trace heater the following shall be included in the evaluation of sheath temperatures:

$$T_{sh} = T_L + \Delta T_{offset} \quad \text{(C.9, repeated)}$$

where

T_L is the set point of the temperature limiter

ΔT_{offset} is the empirically determined temperature difference between the sensor and the actual maximum tracer sheath temperature. ΔT_{offset} is a function of variables such as geometry and mass of the trace heater and sensor, power output of the trace heater, heat transfer coefficient, and control system hysteresis.

Annex D
(normative)

Requirements for Division 1 and Division 2 trace heating systems

D.1 Application

The Division method of area classification, including the indication of Classes I, II, or III for explosive atmospheres for gases, dusts, or fibres/flyings respectively, may be applied by some users of this standard.

Trace heating systems identified for Division 1 are not intended for installation in applications where ignitable concentrations of flammable gases or vapors, or combustible dusts, or ignitable fibers or flyings are present continuously or for long periods of time.

NOTE Information on the Division method is given in NFPA 70 and CSA C22.1.

D.2 General

Trace heating systems identified for Divisions shall comply with the requirements for the EPL shown in Table D.1, supplemented or modified by the requirements shown in D.3 through D.7.

Table D.1 – Division trace heating systems

Division	Equipment protection level (EPL)
Class I, Division 1	‘Gb’
Class II, III Division 1	‘Db’
Class I, Division 2	‘Gc’
Class II, III Division 2	‘Dc’

D.3 Terminations and connections

Where possible, trace heater terminations and connections are intended to be located outside explosive atmospheres classified as Division 1. In case this is not possible, the terminations and connections in addition to the trace heater shall be identified for installation in Division 1 areas.

D.4 Control and temperature requirements

D.4.1 General

The Class, Division, Group, and minimum gas, dust or fiber/flying autoignition temperature for the location shall be specified. As an alternative to autoignition temperature, the temperature class indicated in NFPA 70 and CSA C22.1 may be specified.

D.4.2 Stabilized design

Table D.2 defines the design conditions for the Division method of area classification for the stabilized design approach.

Table D.2 – Sheath temperature design conditions – Stabilized design approach

Item	Class I, II or III	
	Division 1	Division 2
Percent of rated voltage	110	110
Maximum workpiece temperature for calculation	---[a]	---[a]
Maximum wind speed for calculation	0	0
Sheath temperatures for Division 1 shall be calculated using minimum heat transfer coefficient, *U*, without heat transfer aids.		
[a] The workpiece temperature (T_{pr} or T_{pm}, whichever is greater) used to calculate the maximum sheath temperature – see Annex C.		

D.4.3 Controlled design

The application of temperature control to limit sheath temperatures varies by area classification as indicated below and in Table D.3.

a) Class I, II or III Division 1 – temperature controller and high temperature limiter.

b) Class I, II or III Division 2 – temperature controller.

Table D.3 – Sheath temperature design conditions – With temperature control device

Item	Class I, II or III	
	Division 1	Division 2
Percent of rated voltage	110	110
Maximum workpiece temperature for calculation	---[a]	---[a or b]
Maximum wind speed for calculation	0	0
Sheath temperatures for Division 1 shall be calculated using minimum heat transfer coefficient, *U*, without heat transfer aids.		
[a] Use the set point of the applicable protective device (temperature limiter). [b] Use the set point of the applicable temperature controller.		

D.4.4 Requirements for protective device in Divisions 1 and 2

The requirements of 4.4 apply for trace heating to be used in areas classified using the Division method. For Division 1 equipment, the requirements of 4.5.3.2 also apply except that the trace heating is to be suitable for the appropriate Class. For Division 2 trace heating, the requirements of 4.5.3.3 also apply except that the trace heating is to be suitable for the appropriate Class.

D.5 Type tests

D.5.1 Division 1 trace heating equipment

D.5.1.1 General

Trace heaters shall be tested for increased impact energy and static mechanical load. The requirements for system components other than integral components are covered in other applicable standards for equipment for use in Class I, II or III, Division 1 locations. The following tests are intended to qualify trace heaters and integral components (if applicable) for application in these explosive atmospheres and are required in addition to all the type tests described in 5.1. The test samples needed for the type tests are summarized in Annex E.

D.5.1.2 Verification of sheath temperatures

The sheath temperature test described in 5.1.13 shall be conducted at the conditions defined in Tables D.2 and D.3, and the resultant sheath temperatures shall not exceed the declared temperature class or the maximum predicted sheath temperature.

D.5.1.3 Mechanical type tests

The deformation test as described in 5.1.6 shall be conducted at 2 000 N. The impact test as described in 5.1.5.2 shall be conducted retaining the same impact area at an impact energy of 27,1 J.

D.5.2 Division 2 equipment

D.5.2.1 General

The requirements for system components other than integral components are covered in other standards for equipment for use in the respective Class I, II, or III Division 2 locations. The following test is intended to qualify trace heaters for use in these explosive atmospheres and is required in addition to the type tests described in 5.1.

D.5.2.2 Verification of sheath temperatures

The sheath temperature test described in 5.1.13 shall be conducted at design conditions defined in Tables D.2 and D.3, and the resultant sheath temperature shall not exceed the declared temperature class or maximum sheath temperature.

D.6 Marking

This requirement supplements the requirements of 6.1.

Trace heaters shall be clearly and permanently surface marked to indicate Class, Division, Group(s), and Temperature Class.

D.7 Instructions – Installation requirements

In addition to the documentation requirements specified in Clause 7, the instructions and/or other documentation shall include the following information:

a) The person(s) responsible for installation shall verify that the installation and inspection are performed by personnel who are trained, qualified, and knowledgeable in trace heating systems when using the Division method of area classification. The installation and inspection shall be in accordance with the system manufacturer’s design documents, product recommendations, and installation instructions; the installation checklist (see Annex B) shall be followed rigorously.

b) The proposed installation shall be verified for the proper selection of trace heaters and component systems identified for the application; i.e. Division 1 or Division 2. The manufacturer’s documentation shall be reviewed for specific installation requirements and the proposed installation shall be verified that the heating system is compatible with the environment.

c) For Division 1 installations only, each seal fitting shall be limited to one trace heater or power lead. In addition, it is required that a seal fitting be installed in the power supply circuit cable, or conduit immediately adjacent to the trace heater power connection box.

d) Earth-fault equipment protective devices intended for use with trace heating circuits in Division areas shall be appropriately identified for use in Division areas.

e) For Division 1 installations only, the person(s) responsible for the installation shall complete and retain a document similar in format to the installation checklist in Annex B at the installation for future reference during maintenance and repair.

f) For Division installations, the minimum requirement for all insulation resistance tests according to 7.6 item d) shall be at least 20 MΩ.

Annex E
(normative)

Type test matrix for Division 1 and 2 explosive atmospheres

Table E.1 – Applicable trace heater and trace heater pads and panels tests by installation location

Clause	Type test	Division 1	Division 2
5.1.2	Dielectric test	X	X
5.1.3	Electrical insulation resistance test	X	X
5.1.4	Flammability test	X	X
5.1.5	Impact test		
5.1.5.1	Room temperature impact test	X	X
5.1.5.2	Minimum temperature impact test	X	X
5.1.6	Deformation test	X	X
5.1.7	Cold bend test	X	X
5.1.8	Water resistance test	X	X
5.1.9	Integral components resistance to water test	X	X
5.1.10	Verification of rated output	X	X
5.1.11	Thermal stability of electrical insulating material	X	X
5.1.12	Thermal	X	X
5.1.13.2	Product classification approach	X	X
5.1.13.4.2	Systems approach – pipe sculpture	X	X
5.1.13.4.3	Systems approach – vessels	X	X
5.1.13.4.4	Systems approach – tubing bundles	X	X
5.1.13.4.5	Systems approach – plate test	X	X
5.1.14	Verification of start-up current	X	X
5.1.15	Verification of the electrical resistance of electrically conductive covering	X	X
5.1.16	Outdoor exposure test	X	X
D.5.1	Class I, II and III Division 1 locations		
D.5.1.2	Verification of sheath temperatures	X	
D.5.1.3	Mechanical type tests	X	
D.5.2	Class I, II and III Division 2 locations		
D.5.2.2	Verification of sheath temperatures		X

Table E.2 – Applicable tests for integral components with trace heaters and trace heater pads and panels

Clause	Type test	Division 1	Division 2
5.1.2	Dielectric test	X	X
5.1.3	Electrical insulation resistance test	X	X
5.1.4	Flammability test	X	X
5.1.5	Impact test		
5.1.5.1	Room temperature impact test	X	X
5.1.5.2	Minimum temperature impact test		X
5.1.6	Deformation test		X
5.1.8	Water resistance test	X	X
5.1.9	Integral components resistance to water test	X	X
5.1.11	Thermal stability of electrical insulating material	X	X
5.1.15	Verification of the electrical resistance of electrically conductive covering	X	X
5.1.16	Outdoor exposure test	X	X
D.5.1	Class I, II and III Division 1 locations		
D.5.1.3	Mechanical type tests	X	

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