

IEEE Standard for the Testing, Design, Installation, and Maintenance of Electrical Resistance Trace Heating for Industrial Applications

IEEE Industry Applications Society

Sponsored by the
Petroleum and Chemical Industry Committee

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IEEE Standard for the Testing, Design, Installation, and Maintenance of Electrical Resistance Trace Heating for Industrial Applications

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Petroleum and Chemical Industry Committee
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IEEE Industry Applications Society

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Abstract: Specific testing requirements for qualifying electrical resistance trace heating for use in industrial applications in ordinary locations, as well as a basis for electrical and thermal design, are included in this standard.

Keywords: constant wattage trace heaters, electrical design, heat loss, heat tracing, heater pads, heater panels, heating cables, IEEE 515™, parallel trace heaters, pipelines, self-regulating trace heaters, series trace heaters, surface trace heating devices, thermal design, trace heaters, trace heating, vessel heater

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Introduction

This introduction is not part of IEEE Std 515-2017, IEEE Standard for the Testing, Design, Installation, and Maintenance of Electrical Resistance Trace Heating for Industrial Applications.

The scope of this standard includes specific testing requirements for qualifying electrical resistance trace heating for use in industrial applications in ordinary locations, as well as a basis for electrical and thermal design.

This document was first published as a recommended practice in 1983. In 1989, it was elevated to a standard, and Division 1 heating cables were added.

In 1997, this standard was expanded to include American classified zone heaters. A 32-week benchmark test was added to provide a thermal shock cycling test. This test established a minimum performance criteria for new products, offered a system to validate product temperature ratings claimed by manufacturers, and provided a minimum acceptable level of quality/performance by the trace heating devices.

The 2004 revision added a 12-week temperature cycling test as an alternative to the 32-week benchmark test. This revision also aligned the tolerance on sheath temperature for T-rating with the IEC 60079-30 5 K and 10 K tolerances (IEC 60079-30-1:2007 [B9] and IEC 60079-30-2:2007 [B10]).¹

The 2011 revision included subsequent harmonization with international standards and has expanded the sections on maximum sheath temperature determination and design.

This revision removes hazardous (classified) locations requirements and updates the standard for industrial applications for ordinary (unclassified) locations. The hazardous (classified) locations requirements in IEEE 515-2011 has been superseded by the requirements in IEC/IEEE 60079-30-1 [B9] and –2 [B10]. Several figures, definitions, text and methods have also been revised to align with IEC/IEEE 60079-30-1 [B9].

¹The numbers in brackets correspond to those of the bibliography in Annex A.

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IEEE Standard for the Testing, Design, Installation, and Maintenance of Electrical Resistance Trace Heating for Industrial Applications

1. Overview

1.1 Scope

This standard provides requirements for the testing, design, installation, and maintenance of electrical resistance trace heating in general industries as applied to pipelines, vessels, pre-traced and thermally insulated instrument tubing and piping, and mechanical equipment. The electrical resistance trace heating is in the form of series trace heaters, parallel trace heaters, and trace heater pads or panels. The requirements also include test criteria to determine the suitability of these trace heating devices utilized in industrial applications as applied in unclassified (ordinary) locations.

1.2 Purpose

The provisions of this standard should help ensure that process, fluid, or material temperatures are maintained and provide electrical, thermal, and mechanical durability to the trace heating system, such that in normal use, its performance is reliable and poses no danger to the user or surroundings. This standard is to serve as a complementary document to the current version of those national and international standards addressing electrical resistance trace heating.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

ANSI Z358.1, American National Standard for Emergency Eyewash and Shower Equipment.²

ASTM B193-02, Standard Test Method for Resistivity of Electrical Conductor Materials.³

²ANSI publications are available from the American National Standards Institute (<http://www.ansi.org/>)

³ASTM publications are available from the American Society for Testing and Materials (<http://www.astm.org/>).

ASTM D5025-05, Standard Specification for Laboratory Burner Used for Small-Scale Burning Tests on Plastic Materials.

IEC 60695-11-3, Fire hazard testing—Part 11-3: Test flames—500 W flames—Apparatus and confirmational test methods.⁴

NFPA 70®, National Electrical Code®(NEC®).⁵

3. Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.⁶

ambient temperature: Temperature surrounding the workpiece, including the trace heating device and any thermal insulation or weather barrier that may be applied.

branch circuit: Portion of the wiring installation between the overcurrent device protecting the circuit and the trace heating devices.

certifying agency: Organization that validates that equipment meets tests and standards.

cold lead: Electrically insulated conductor or conductors used to connect a trace heating device to a branch circuit and designed so that it does not produce significant heat.

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

dead leg: Segment of process piping segregated from the normal flow pattern for the purpose of providing a heat loss reference.

electrical insulation: A dielectric material that insulates each conductor from other conductors or from conductive parts at or near earth potential.

electrical resistance trace heating (heat tracing): The utilization of electric trace heaters and support components that are externally applied and used to maintain or increase the temperature of fluids/materials in piping, vessels, or other equipment. *Syn:* **trace heating**.

electrically conductive covering: Metallic sheath, metallic braid, or other conductive material.

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

factory fabricated: A trace heating device assembled by the manufacturer, including end terminations and connections.

field assembled: A trace heating device supplied in bulk form with terminating components, assembled on site.

heat loss: A quantitative value of energy flow from a pipe, vessel, or other equipment to the surrounding ambient temperature.

⁴IEC publications are available from the International Electrotechnical Commission (<http://www.iec.ch>) and the American National Standards Institute (<http://www.ansi.org/>).

⁵NFPA publications are available from the National Fire Protection Association (<http://www.nfpa.org>).

⁶*IEEE Standards Dictionary Online* is available at: <http://dictionary.ieee.org>.

heat sink: A part that conducts and dissipates heat away from the pipe, vessel, or other equipment such as supports and valve operators.

heat-transfer aids: Thermally conductive materials, such as metallic foils or heat-transfer compounds, used to increase the heat-transfer efficiency from the trace heating devices to the workpiece.

high-limit temperature: The maximum allowable temperature, including the piping, fluid, and heating system.

integral component: A component, such as heat shrink termination, cold lead connection, molded end seal, or splice, which may conform to the general shape of the trace heating device and is exposed to the same environment as the trace heating device, which may be factory fabricated or field assembled and which is not intended to be re-used in the event of a repair or modification.

maintain temperature: Specified temperature of the fluid or process material that the trace heating is designed to hold at equilibrium under specified design conditions.

maximum ambient temperature: Highest specified ambient temperature.

maximum continuous exposure temperature (trace heating device de-energized): The highest allowable continuous temperature to which the trace heating device may be continuously exposed as declared by the manufacturer.

maximum intermittent exposure temperature (trace heater energized or de-energized): The highest allowable intermittent temperature to which the trace heating device may be exposed as declared by the manufacturer.

maximum maintain temperature/maximum continuous operating temperature (trace heating device energized): Specified maximum workpiece temperature the trace heating device operates at continuously as declared by the manufacturer.

maximum sheath temperature: Maximum temperature of the outermost covering of a trace heating device.

maximum withstand temperature: Maximum operating or exposure temperature that does not adversely affect the thermal stability of the trace heater and its component parts.

MI (mineral insulated) trace heater: Mineral insulated metal sheathed trace heater typically containing one or two heating conductors.

minimum ambient temperature: Lowest ambient temperature specified at which trace heating is operable and performs according to specified requirements (and on which heat-loss calculations are based).

minimum installation temperature: Minimum temperature at which the trace heating system may be handled and installed as recommended by the manufacturer.

operating voltage: Actual voltage applied to the trace heater when in service.

ordinary (unclassified) location: A location or area not having a flammable gas, flammable liquid-produced vapor, combustible dusts, or fibers/flyings.

overjacket: A continuous layer of insulating material that may be applied over the electrically conductive covering used to protect against corrosion and enhance mechanical protection.

oversize insulation: A term applied to thermal insulation when the inside diameter of the thermal insulation must be larger than the nominal outside diameter of a particular pipe, vessel, or other equipment so as to accommodate the trace heater.

parallel trace heater: A device of linear geometry designed for the purpose of producing heat on the principal of electrical resistance, with its heating element being either continuous or in discrete zones, such that the power density per unit length is not substantially affected by any change in circuit length.

power connection: The connection between the trace heater and the branch circuit wiring.

rated output: Total power or power per unit length or unit surface area of a trace heating device, at rated voltage, temperature, and length or area.

rated voltage: Voltage assigned by the manufacturer to which operating and performance characteristics of trace heating devices are referred.

routine test: A test performed by the manufacturer on the trace heater and factory fabricated integral components during or after the production process.

runaway pipe temperature: The highest equilibrium pipe (workpiece) temperature that occurs when the trace heating device is continuously energized at the maximum ambient temperature.

series trace heater: A device of linear geometry designed for the purpose of producing heat on the principle of electrical resistance, with its heating element electrically connected in series, with a single current path and with a specific resistance at a given temperature for a given length.

sheath: A uniform and continuous metallic or nonmetallic covering enclosing components of the trace heating device to provide protection against influence from the surroundings (e.g., corrosion, moisture, abrasion).

sheath temperature: The temperature of the outermost continuous covering of a trace heater or surface heater that may be exposed to the surrounding atmosphere.

stabilized design: Design where the temperature of the trace heating device, by design and use, stabilizes below the high limit temperature, under the most unfavorable conditions, without the need for a protective system to limit the temperature.

start-up current: Current response of a trace heater following energization.

surface heater: A trace heater pad or trace heater panel.

surface heater unit: A surface heater suitably terminated in conformity with the manufacturer's instructions.

tee connection: Connection of trace heating devices, in series or parallel, to accommodate a branch on a pipe, vessel, or other equipment.

temperature control device: A device that serves to maintain the temperature within a specified temperature range.

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

temperature sensor (sensing element): A device that responds to temperature and provides an electrical signal or mechanical operation.

thermal insulation: Material having air- or gas-filled pockets, voids, or heat-reflective surfaces that, when properly applied, retards the transfer of heat.

trace heater pad: A heater intended for heating a surface by providing heat over an area, comprising series or parallel connected elements, and having sufficient flexibility to conform to the shape of the surface to be heated.

trace heater panel: A non-flexible heater intended for heating a surface by providing heat over an area, comprising series or parallel connected elements, and fabricated to conform to the general shape of the surface to be heated.

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.

trace heating: *See:* **electrical resistance trace heating (heat tracing).**

trace heating device (trace heater): A 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.

traced tube bundle: Pretraced and thermally insulated instrument tubing that is used for fluid transport, containment, or conditioning system. The bundle is factory fabricated and consists of tubing, trace heater, thermal insulation, and weatherproof jacket.

type test: A test or series of tests carried out on trace heaters and accessories, representative of a type, to determine compliance of the design, construction, and manufacturing methods within the requirements of this standard.

weather barrier (cladding): 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.

workpiece: Object to which the trace heating device is applied, such as piping, vessels, tanks, valves, instruments, and similar equipment.

4. General product testing

4.1 Type test—general purpose tests

Samples of a trace heater 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. [Annex E](#) provides a matrix of test requirements for each trace heating device application.

Integral components shall be subjected to the same tests as the trace heater, except where otherwise noted. System components other than those identified as integral shall be evaluated in accordance with national and international standards relevant to their construction and use.

Thermal measuring devices (thermometers, thermocouples, etc.) and the connecting cables shall be selected and so arranged that they do not significantly affect the thermal behavior of the trace heater.

4.1.1 Dielectric test

The dielectric test shall be performed on trace heaters in accordance with [Table 1](#) on test sample(s) prepared as described in [4.1](#).

Table 1—Dielectric test voltage

Rated voltage E	Test voltage V_{ac} (rms)
< 30 V ac (rms)	500
< 60 V dc	500
≥ 30 V ac (rms)	$2 \times E + 1000$
≥ 60 V dc	$\sqrt{2} \times E + 1000$

The test voltage, where E is the rated voltage, shall be applied between the conductors and the electrically conductive covering at a rate of rise 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 $\Omega \cdot m$). The electrically conductive covering shall be bonded to the water and the voltage shall be applied between conductors and the water.

For type tests 4.1.3, 4.1.5, and 4.1.7 through 4.1.9, and the routine test in 4.3.2 for MI trace heaters the required test voltage is reduced to $2 \times E + 500$ V ac for trace heaters rated over 30 V ac, or to $\sqrt{2} \times E + 500$ V dc for trace heaters rated over 60 V dc in type tests, due to the dielectric characteristics of the MI trace heater construction and electrical insulation materials.

4.1.2 Electrical insulation resistance test

The electrical insulation resistance test shall be conducted after the dielectric test specified in 4.1.1 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 source voltage of 500 V dc. The measured value shall not be less than 50 M Ω .

Alternatively the insulation resistance test may be conducted by submerging the trace heater in tap water at room temperature (resistivity typically 500 $\Omega \cdot m$). The electrically conductive covering shall be bonded to the water and the voltage shall be applied between the conductors and the water.

4.1.3 Water resistance test

A sample as described in 4.1, excluding integral components shall be immersed in tap water for a period of 14 d. 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 4.1.1 and the insulation resistance test outlined in 4.1.2.

4.1.4 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 1. For surface heaters, 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 dielectric test outlined in 4.1.1 and the insulation resistance test outlined in 4.1.2 shall be performed. The immersed connections of the trace heater shall be inspected to verify no evidence of water ingress.

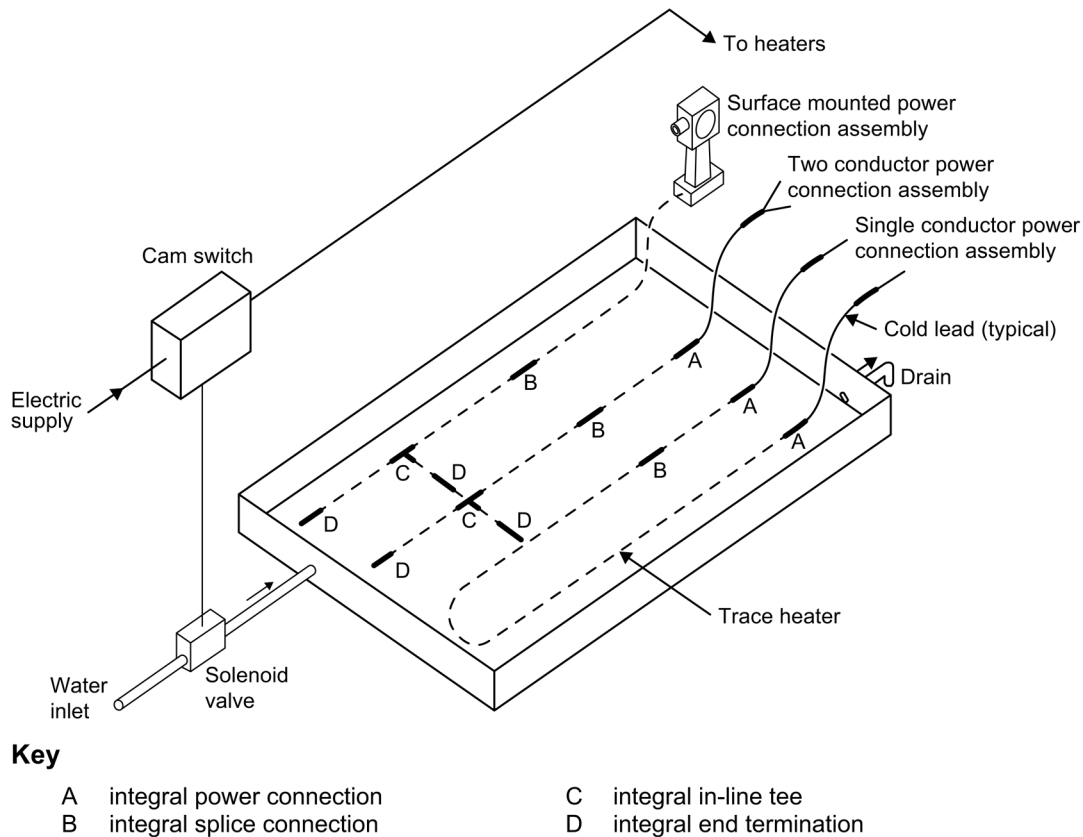


Figure 1—Integral components resistance to water test

4.1.5 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 °C 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 5 min. While still in the tap water, the dielectric test 4.1.1 and the insulation resistance test 4.1.2 shall be conducted. Upon completion of the test, the sample shall have no visible cracks when examined with normal vision.

Terminations that improve the vapor 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% relative humidity (R.H.). Compliance of the sample or prototype shall be verified by testing the electrical insulation in accordance with 4.1.1 and 4.1.2.

4.1.6 Thermal performance test

It is critical that the maximum sheath temperature of a trace heater is lower than the maximum ratings of the trace heater materials. 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 verify 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 improve 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 determined by 4.1.11 b). For trace heaters that are irregular in shape, and for surface heaters, 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, that 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):

- The lowest rated voltage level and the maximum rated power output
- 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 transition from the hot to the cold platen.

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 min and a transition time between extremes shall not exceed 15 min, with a cycle being one complete exposure at both temperature extremes.

The trace heater samples shall be subjected to a pre-conditioning period of five continuous temperature cycles. A minimum of 1500 cycles shall then be performed. The trace heater samples' power output shall be continuously monitored, with measurements recorded during the final 300 s 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 s 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 $\pm 25\%$ of the initial measured output. This applies at the end point as well as the intermediate measurements.

4.1.7 Deformation test

A sample approximately 450 mm in length is placed on a rigid flat steel plate. A crushing force of 1500 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 steel rod is laid flat on the sample at a right angle. In the case of a surface heater, the steel rod shall rest across the active element.

After the deformation load is applied for 30 s, conformity is verified by testing the electrical insulation in accordance with 4.1.1 and 4.1.2 while the horizontal steel rod is still in place on the sample and the load applied.

4.1.8 Impact tests

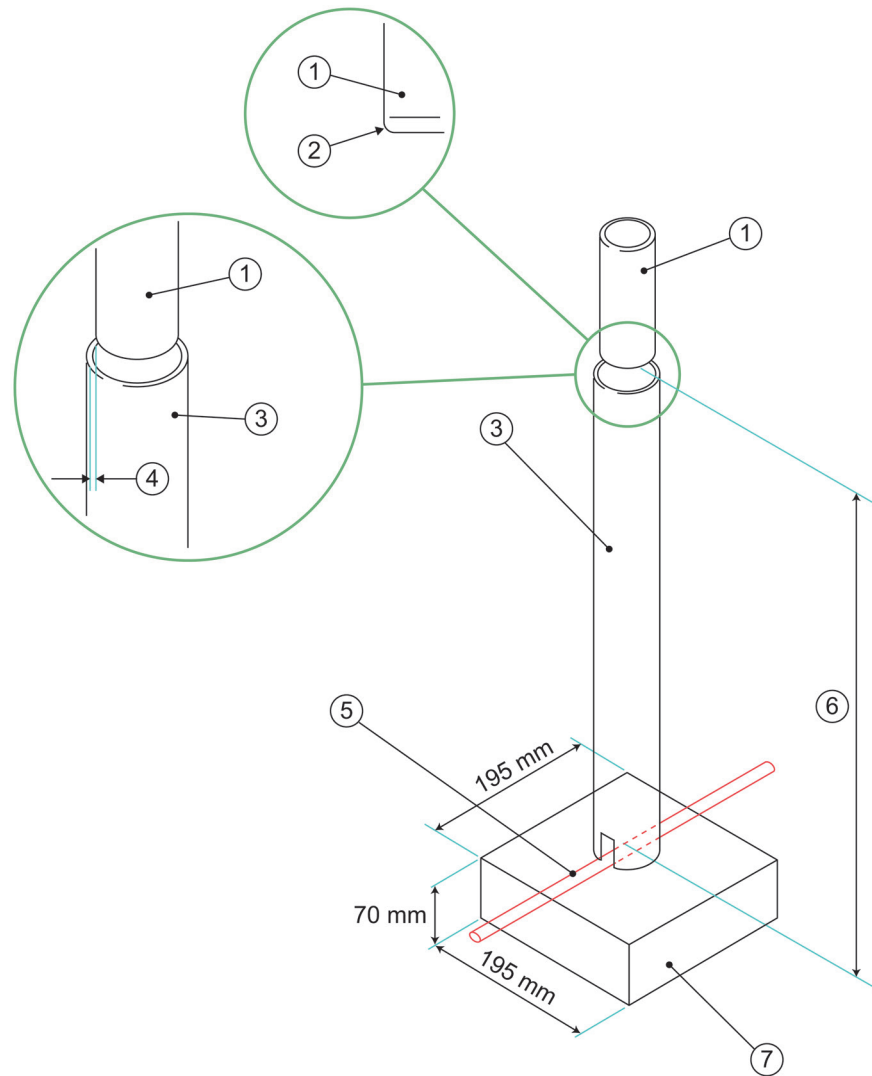
Both of the impact tests in 4.1.8.1 and 4.1.8.2 are required to be conducted on separate samples of trace heating devices approximately 450 mm in length and on any integral components assembled with the trace heating device.

4.1.8.1 Minimum temperature impact test

A sample is placed on a hardened steel plate (with a mass equal to or greater than 20 kg, 195 mm $\times$ 195 mm $\times$ 70 mm). The plate is positioned on a rigid substrate such that the impact energy absorbed by the substrate is negligible. The assembly is then conditioned for a minimum of 4 h at the manufacturer's minimum installation temperature. The apparatus used for this test is shown in Figure 2.

After conditioning, 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.

The impacted portion of the sample shall then be immersed in tap water at room temperature for at least 5 min, and the dielectric test 4.1.1 and insulation resistance test 4.1.2 shall be conducted. For surface heaters, both the heating region and cold leads shall be impacted.



Key

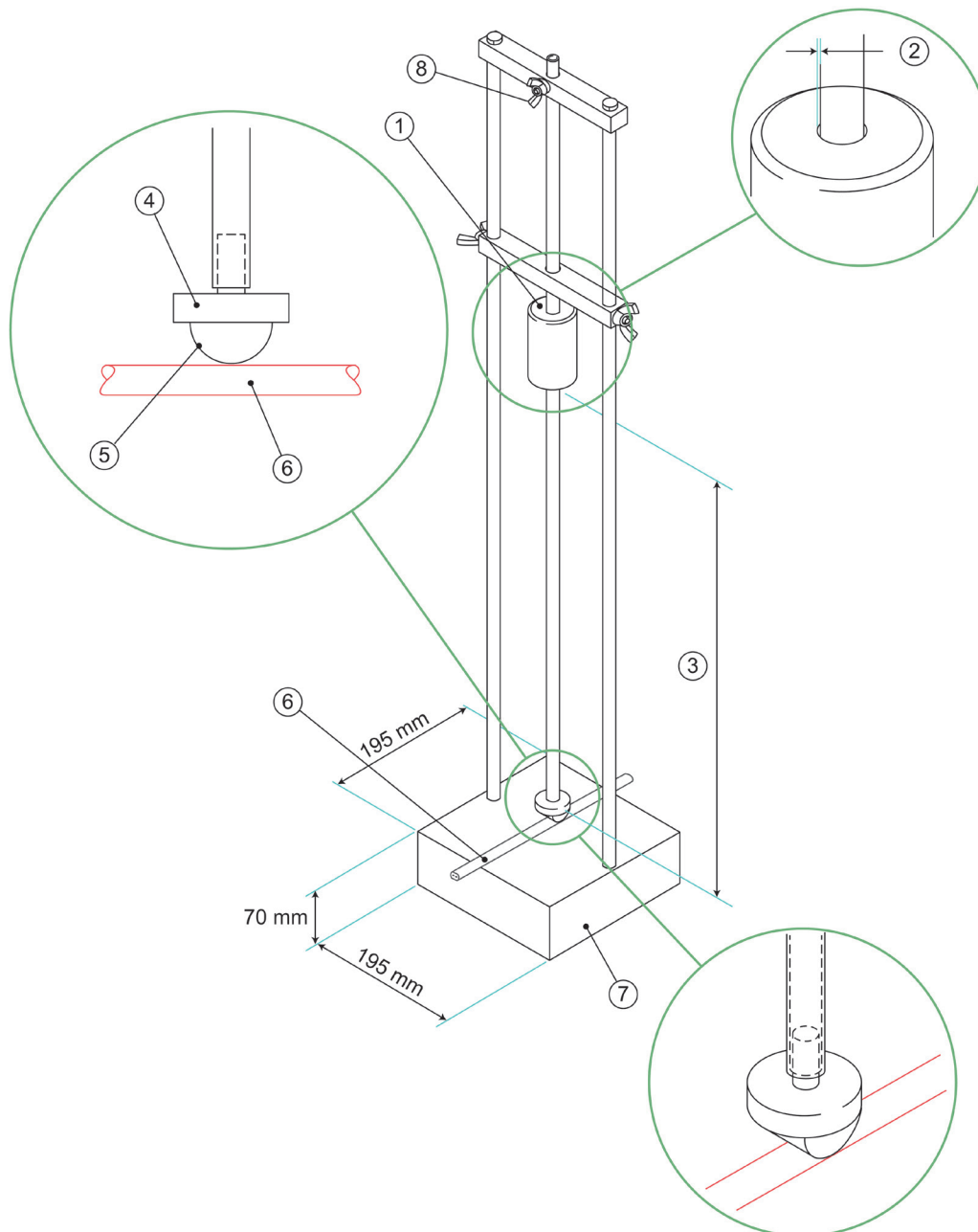
- | | |
|---|------------------------------------|
| 1 50.8 mm diameter hammer with mass of 1.8 kg | 5 trace heater sample |
| 2 smoothly rounded edges (~5 mm rounding) | 6 height of fall of hammer: 0.76 m |
| 3 guide tube | 7 base with minimum 20 kg mass |
| 4 sufficient clearance to allow for free-fall | |

Figure 2—Example of minimum temperature impact test

4.1.8.2 Room temperature impact test

Each sample is placed on a rigid flat 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 sample is then positioned underneath an intermediate piece of hardened steel in the shape of a horizontal cylinder with a diameter of 25 mm. This cylinder shall have a length of 25 mm with smoothly rounded edges to a radius of approximately 5 mm when used to test surface heaters (see Figure 3). For the test, the cylinder is laid horizontally on the sample. A trace heater having a noncircular 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).

A hammer with a mass of $1_{-0}^{+0.01}$ kg shall be allowed to fall once onto the horizontal cylinder from a height of $0.07_{-0}^{+0.01}$ m.



Key

- | | | | |
|---|---|---|--|
| 1 | hammer with mass of 1 kg | 6 | trace heater sample |
| 2 | sufficient clearance to allow for free-fall | 7 | base with minimum 20 kg mass |
| 3 | height of fall of hammer: 0.7m | 8 | set screw for guide tube—so guide tube does not rest on impact plate |
| 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 | | |

Figure 3—Example of room temperature impact test

Immediately after impact, conformity is verified by testing of the electrical insulation in accordance with 4.1.1 and 4.1.2 while the steel cylinder and hammer are still in place on the sample.

4.1.9 Cold bend test

This test applies only to flexible trace heating devices that have a stated minimum bending 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 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, 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 90° around one of the mandrels, then bent through 180° in the opposite direction over the second mandrel and 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.

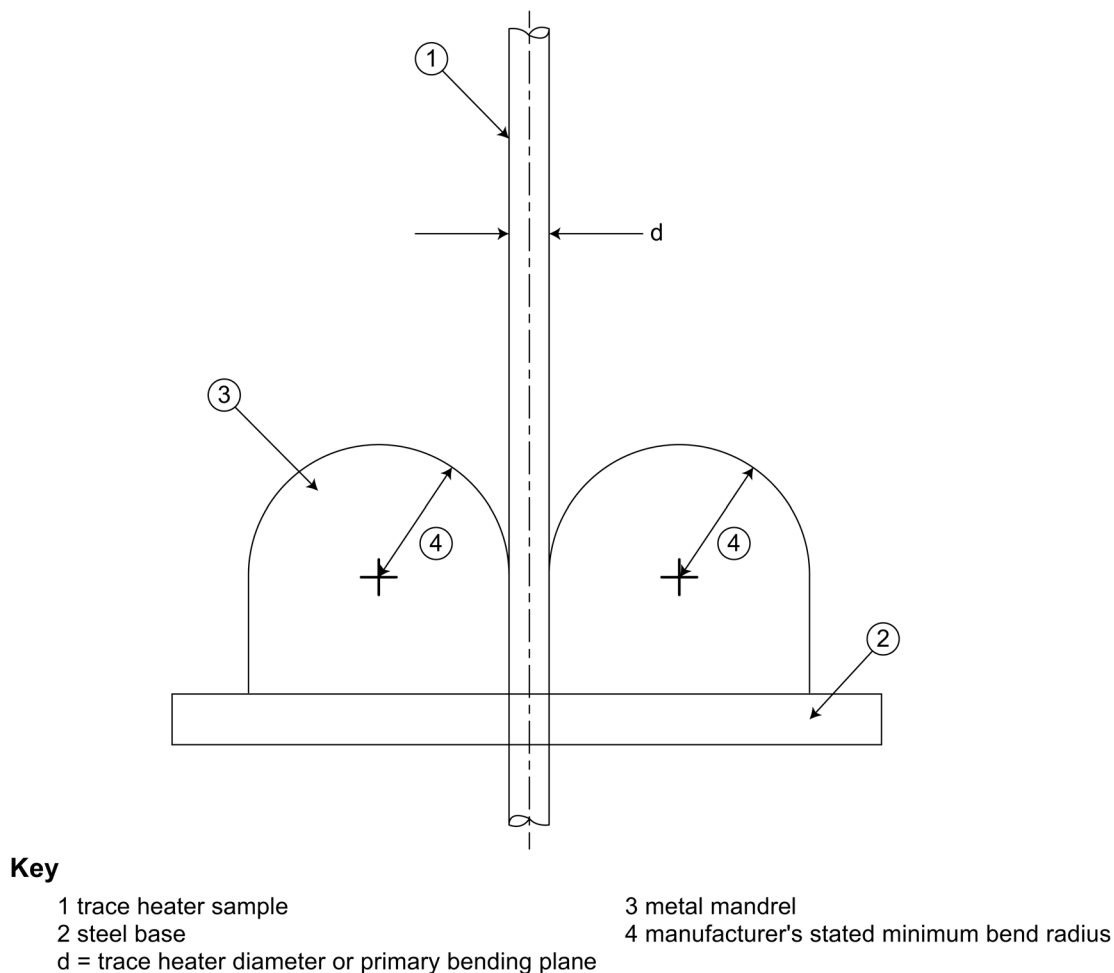


Figure 4—Cold bend test

Conformity is verified by testing the electrical insulation in accordance with 4.1.1 and 4.1.2.

4.1.10 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 drafts and in a flame chamber or fume hood with a minimum volume of 0.5 m³. For the trace heaters, the sample shall be at least 450 mm in length, and shall be supported in a vertical position. For surface heaters the sample 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 described in ASTM D5025-05⁷ or in IEC 60695-11-3 shall be used for the test. The fuel shall be methane, natural gas, propane, or butane with the following properties:

- *Methane or natural gas*: For methane: technical grade, 98% minimum purity; For methane or natural gas: heating value of 37 ± 1 MJ/m³ at 25 °C
- *Propane*: Technical grade, 98% minimum purity, heating value of 94 ± 2 MJ/m³ at 25 °C
- *Butane*: CP grade, 99% minimum purity, heating value of 120 ± 3 MJ/m³ at 25 °C

As shown in Figure 5, 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 surface heaters, 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 5.

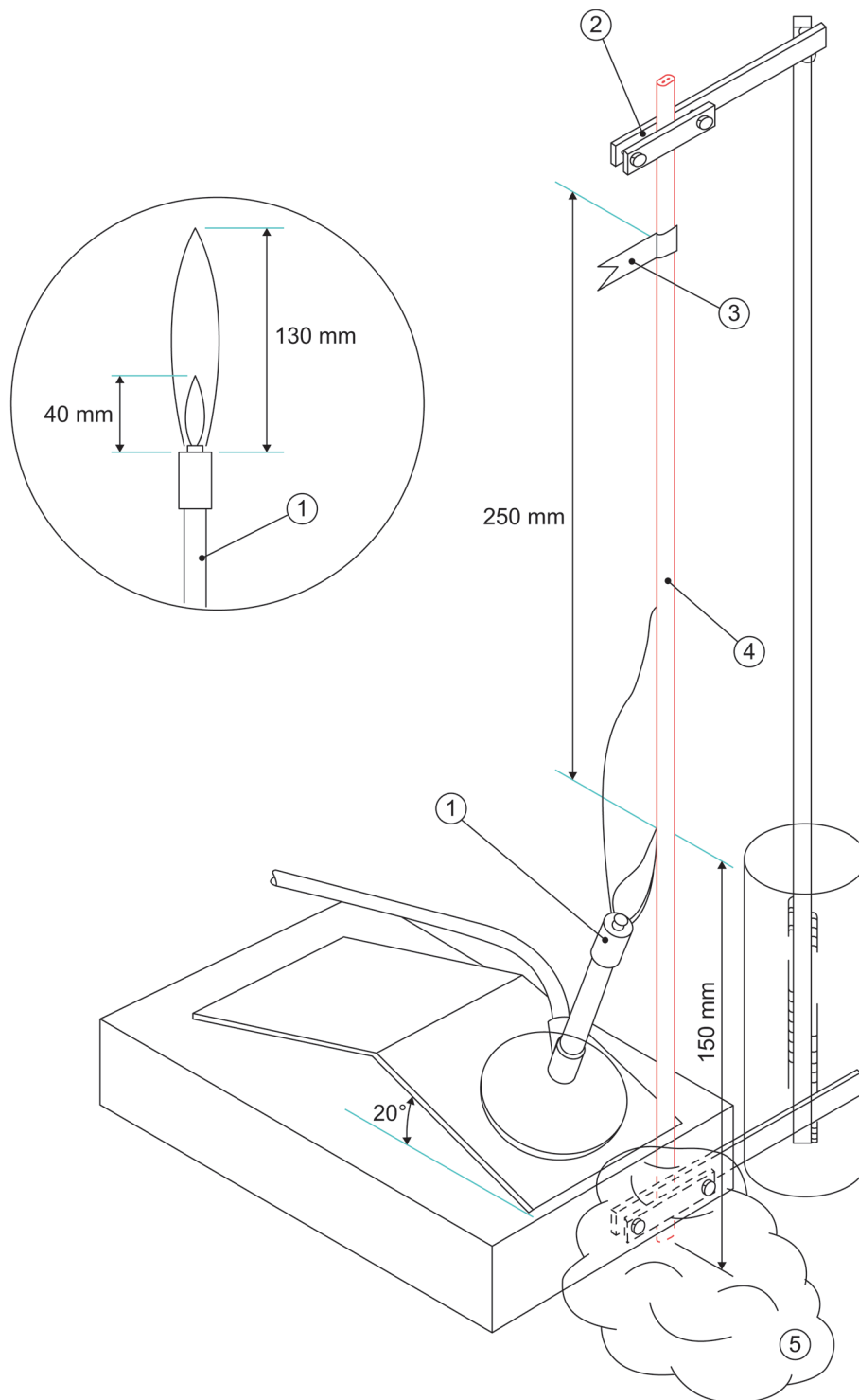
The laboratory burner shall be moved toward the sample until the inner blue cone touches the sample (see Figure 5). The flame shall be applied for 15 s, then removed for 15 s, until five such applications have been made.

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 D5027 standards.⁸

⁷Information on references can be found in Clause 2.

⁸Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.



Key

- 1 burner
- 2 support
- 3 unbleached paper flag

- 4 test sample
- 5 dry pure surgical cotton

Figure 5—Flammability test

4.1.11 Verification of rated output

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

- a) *Conductance*—The measured alternating current (ac) conductance or conductance per unit length, at a specified temperature, shall be within the manufacturer's declared tolerance.
- b) *Resistance*—The measured dc resistance or 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.

- c) *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 shall be completely covered with thermal insulation of 25 mm thickness.
 - 1) For surface heaters, the test is conducted on a liquid-cooled flat metal plate with 25 mm of thermal insulation installed over the surface heater.
 - 2) A suitable heat-transfer liquid is circulated through the pipe or metal plate at a sufficient rate to establish turbulent flow such that there is a negligible temperature difference between the fluid and the pipe or plate. 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 or plate. Flow velocity shall be such that the fluid temperature does not differ by more than 2 °C from end to end.
 - 3) 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, liquid temperature, 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.

4.1.12 Verification of start-up current

This test is applicable to trace heating devices that have a positive temperature coefficient of resistance greater than that of copper [See Section 7 in ASTM B193-02 (2014)]. 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 the manufacturer's instructions on a minimum 50 mm diameter, liquid-filled steel pipe or solid rod, or for heater panels or pads on a flat metal heat sink. The testing apparatus shall be completely covered in thermal insulation and conditioned at the designated temperature for at least 4 h.

NOTE—The apparatus described in item c) of 4.1.11 can be used for this test.

After the conditioning period, rated voltage shall be applied and the time/rms current characteristics shall be recorded from time 0 s 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.

4.1.13 Verification of the electrical resistance of electrically conductive covering

A metallic electrically conductive covering is required as part of the trace heater construction and shall cover at least 70% of the surface. For surface heaters, an integral metallic screen grid or equivalent electrically