

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 & Chemical Industry Committee



IEEE
3 Park Avenue
New York, NY 10016-5997
USA

9 September 2011

IEEE Std 515™-2011
(Revision of
IEEE Std 515-2004)

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

Sponsor

Petroleum & Chemical Industry Committee
of the
IEEE Industry Applications Society

Approved 16 June 2011

IEEE-SA Standards Board

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Abstract: Specific testing requirements for qualifying electrical resistance heating cables and heating devices for use in industrial applications, as well as a basis for electrical and thermal design, are included in this standard. Unclassified applications and explosive atmosphere applications that use both Divisions and Zone methods of classification are included.

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

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PDF: ISBN 978-0-7381-6681-0 STD97125
Print: ISBN 978-0-7381-6682-7 STDPD97125

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Introduction

This introduction is not part of IEEE Std 515-2011, 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 heating cables and heating devices for use in industrial applications, as well as a basis for electrical and thermal design. Applications include unclassified and both Division and Zone classified areas.

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 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 [B15]^a and IEC 60079-30-2:2007 [B16]).

This revision includes subsequent harmonization with international standards and has expanded the sections on maximum sheath temperature determination and design.

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

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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, pretraced 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 surface heating ~~devices-~~ units. In this standard, the terms *hazardous (classified) locations* and *potentially flammable atmospheres* refer to the same conditions. The requirements also include test criteria to determine the suitability of these heating devices utilized in industrial applications as applied in unclassified (ordinary) and hazardous (classified) locations.

1.2 Purpose

The provisions of this standard should 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 ~~heat tracing, such as the following:~~ [trace heating](#).

2. Normative references

~~This standard shall be used in conjunction with the following publications. When the following standards are superseded by an approved revision, the revision shall apply.~~

[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.](#)

ASTM D5025-05, Standard Specification for Laboratory Burner Used for Small-Scale Burning Tests on Plastic Materials.¹

ASTM D5207-09, Standard Practice for Confirmation of 20-mm (50-W) and 125-mm (500-W) Test Flames for Small-Scale Burning Tests on Plastic Materials.

~~NEPA 325-1994, Guide to Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids.~~

[IEC 60079-20-1, Explosive Atmospheres—Part 20-1: Material Characteristics for Gas and Vapour Classification—Test Methods and Data.](#)²

[IEC 60079-20-2, Explosive Atmospheres—Part 20-2: Material Characteristics—Combustible Dusts Test Methods.](#)

[NFPA 497, Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous \(Classified\) Locations for Electrical Installations in Chemical Process Areas.](#)³

[NFPA 499, Recommended Practice for the Classification of Combustive Dusts and of Hazardous \(Classified\) Locations for Electrical Installations in Chemical Process Areas.](#)

3. Definitions

[For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary: Glossary of Terms & Definitions*⁴ should be consulted for terms not defined in this clause.](#)

~~The following definitions apply to the subject matter presented in this standard.~~

ambient temperature: The temperature surrounding the object under consideration. Where an electrical heating device is enclosed in thermal insulation, the ambient temperature is the temperature exterior to the thermal insulation.

braid: [Interwoven metallic covering or other equivalent electrically conductive material surrounding the trace heater.](#)

certifying agency: [Organization that validates that equipment meets tests and standards.](#)

cold lead: [An electrically insulated conductor used to connect a heating conductor to the branch-circuit conductors and designed so as not to produce appreciable heat.](#)

connections: [Terminations and splices used to attach a heating device to power wiring or to connect sections of devices.](#)

¹ ASTM publications are available from the American Society for Testing and Materials, 100

Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA (<http://www.astm.org/>).

² IEC publications are available from the Sales Department of the International Electrotechnical Commission, Case Postale 131, 3 rue de Varembé, CH-1211, Genève 20, Switzerland/Suisse (<http://www.iec.ch/>).

IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

³ [NFPA publications are published by the National Fire Protection Association, Batterymarch Park, Quincy, MA 02269, USA \(<http://www.nfpa.org/>\).](http://www.nfpa.org/)

⁴ [The IEEE Standards Dictionary: Glossary of Terms and Definitions is available at <http://shop.ieee.org>.](http://shop.ieee.org)

~~**3.2 braid or sheath:** Metallic braid, metallic sheath, or other equivalent electrically conductive material intended to provide an electrical path to operate an~~

dead leg: [A segment of process piping that has a static flow condition at all times.](#)

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, other electric heating devices, and support components that are externally applied and used to maintain or increase the temperature of fluids/materials in piping and associated equipment.

end termination connection: The termination applied to the end of a trace heater that may be heat producing, opposite to where the power is supplied.

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

field assembled: A 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 equipment to the surrounding ambient [temperature](#).

heat sink: A part that conducts and dissipates heat away from the pipe or equipment such as ~~related to pipe heating systems, can be~~ pipe supports and valve operators.

heat-transfer aids: Thermally conductive materials, such as metallic foils or heat-transfer cements, used to increase the heat-transfer rates from the heating devices to the process piping or equipment.

[heating device:](#) Trace heater or surface heating unit.

[heating pad:](#) [Surface heating unit compromising series- or parallel-connected elements with sufficient flexibility to conform to the shape of the surface to be heated.](#)

[heating panel:](#) [Nonflexible surface heating unit compromising series- or parallel-connected elements fabricated to conform to general shape of the surface to be heated.](#)

[high-limit temperature:](#) [The maximum allowable temperature, including the piping, fluid, and heating system.](#)

[integral components:](#) [Factory fabricated or field installed electrical terminations and connections, such as heat shrink terminations, cold lead connections, molded-end seals, or splices, which may conform to the general shape of the heating device and are exposed to the same environments \(such as under the thermal insulation\) as the heating device.](#)

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 continuous exposure temperature: The highest temperature to which a component of the trace heating system may be continuously exposed (heater de-energized).

maximum intermittent temperature (energized or de-energized): Highest allowable temperature to which a heating device or components may be exposed for a period of time as declared by the manufacturer.

maximum maintain temperature: Specified maximum temperature of a surface or process that the heating device is capable of maintaining continuously.

mineral insulated (MI) trace heater: Metal tube (sheath), filled with metal oxide powder for dielectric insulation, typically containing one or two heating conductors.

operating voltage: The voltage applied to the heating device when in service.

overjacket: A continuous layer of insulating material applied over the sheath or braid 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 so as to accommodate the trace heater.

parallel trace heater: 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.

power connection: The connection between the heating device and ~~incoming power~~ the branch circuit wiring.

rated output: Power/unit length of heating device or total power, at rated voltage, and temperature (if required), normally expressed as W/m (W/ft) or kW.

rated voltage: The voltage to which operating and performance characteristics of a heating device is referred.

routine test: A test performed by the manufacturer of the heating device on all devices during or after the production process.

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

series trace heater: Heating elements that are electrically connected in series with a single current path and have a specific resistance at a given temperature for a given length.

sheath: Uniform and continuous covering, metallic or nonmetallic, enclosing the insulated conductor(s), used to protect the [cable trace heater](#) against mechanical damage and influences from the surroundings (corrosion, moisture, etc.).

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

start-up current: The current response of a heating device [following for the first 5 min after](#) energization.

surface heating unit: See: [heating pad](#), [heating panel](#).

tee connection: Connection of heater in series or parallel to accommodate a branch on a pipe or equipment.

temperature class (T-rating): One of the values of temperature allocated to electrical heating devices derived from a system of classification according to the maximum surface temperature of the heater. Also referred to as T-class, identification number, T-rating, and temperature code.

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, void spaces, or heat-reflective surfaces that, when properly applied, will retard the transfer of heat with reasonable effectiveness under ordinary conditions.

~~3.46 Zone 0: Terminology used for classification of an industrial area in which an explosive atmosphere is present continuously, or present for long periods of time during normal operation.~~

~~NOTE—See the NEC, Article 505, and IEC 60079-10:2002 [B17] for a detailed definition.~~

~~3.47 Zone 1: Terminology used for classification of an industrial area in which an explosive atmosphere is likely to exist under normal operation.~~

~~NOTE—See the NEC, Article 505, and IEC 60079-10:2002 [B17] for a detailed definition.~~

~~3.48 Zone 2: Terminology used for classification of an industrial area in which an explosive atmosphere is not likely to occur in normal operation, and if it does, it will exist only for a short period.~~

~~NOTE—See the NEC, Article 505, and IEC 60079-10:2002 [B17] for a detailed definition.~~

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

trace heating circuit: A trace heating circuit comprising one or more heating devices or segments connected to branch wiring of a single circuit protection device.

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 heating devices 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 insulation from water or other liquids; physical damage caused by sleet,

wind, or mechanical abuse; and deterioration caused by solar radiation or atmospheric contamination.

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

4. General product testing

4.1 Type test—general purpose tests

The following tests are intended to qualify heating devices for the applications within the scope of this standard for unclassified (ordinary locations). Samples of a trace heater at least 3 m in length or of a representative surface heater section, unless otherwise specified, shall be selected for testing. The tests shall be conducted at room temperature between 10 °C and 40 °C unless otherwise noted. Annex E provides a matrix of test requirements for each heating device application.

Connections and end terminations may be identified as integral components of a heating device or may be identified separately. Integral components, whether intended to be factory fabricated or field assembled, shall be subjected to the same type of tests as the heating device, 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 heating device.

4.1.1 Dielectric test

The dielectric test shall be performed in accordance with Table 1.

Table 1—Dielectric test voltage

Rated voltage	Test voltage (Vac rms)
<30 V rms	500
<60 Vdc	500
≥30 V rms	$2E + 1000$
≥60 Vdc	$\sqrt{2} E + 1000$

The test voltage where E = rated voltage shall be applied at a rate of rise neither less than 100 V/s nor more than 200 V/s and shall be maintained for 1 min without dielectric breakdown.

The test voltage waveform shall be essentially sinusoidal, with a frequency of 45 Hz to 65 Hz. The test voltage shall be applied between the heating device's conductors and the metallic braid, sheath, or equivalent electrically conductive material, or a specially applied conductive metal ground plane. Alternatively, the dielectric test may be conducted by submerging the heating device in tap water at room temperature (resistivity typically 50 000 $\Omega \cdot \text{cm}$). The test voltage shall be applied between the heating conductors and the water.

For MI trace heaters, the required test voltage in 4.1.1 is reduced to $2E + 500$ Vac in type tests, 4.1.3, 4.1.5, and 4.1.7 through 4.1.9. This is because of the dielectric characteristics of the MI trace heater construction and electrical insulation materials.

4.1.2 Insulation resistance test

The insulation resistance shall be measured on the preceding sample as described in 4.1, including integral components after the dielectric test specified in 4.1.1. The resistance of the insulation shall be measured between conductors and the metallic braid, sheath, or equivalent electrically conductive material, or a specially applied conductive metal ground plane, by means of direct current (dc) voltage of 500 Vdc. The measured value shall not be less than 50 M Ω .

4.1.3 Water-resistance test

A sample [as described in 4.1, excluding integral components](#), shall be immersed (except at [connections and end terminations](#)) in tap water at 10 °C to 25 °C for a period of 14 days. [Trace heater ends are not immersed.](#)

Within 1 h after conditioning [as discussed previously](#) and while still immersed in the water, the sample shall be subjected to the dielectric test outlined in 4.1.1 [and insulation resistance test outlined in 4.1.2](#).

4.1.4 Integral components resistance to water

A sample of the heating device with all integral components shall be placed in a tap water flow and drain apparatus as shown in Figure 1. For surface heating ~~devices~~[units](#), a unit with cold leads shall be used. The water flow shall be initiated, and the heating device and integral components shall be completely immersed. At that point, the water flow is stopped and the heating device 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 heating device shall continue to be energized for 30 s after the water has been drained. The heating device 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 in 4.1.2](#) shall be ~~performed~~ [successfully completed](#). The immersed connections of the heating device shall be inspected to verify no evidence of water ingress.

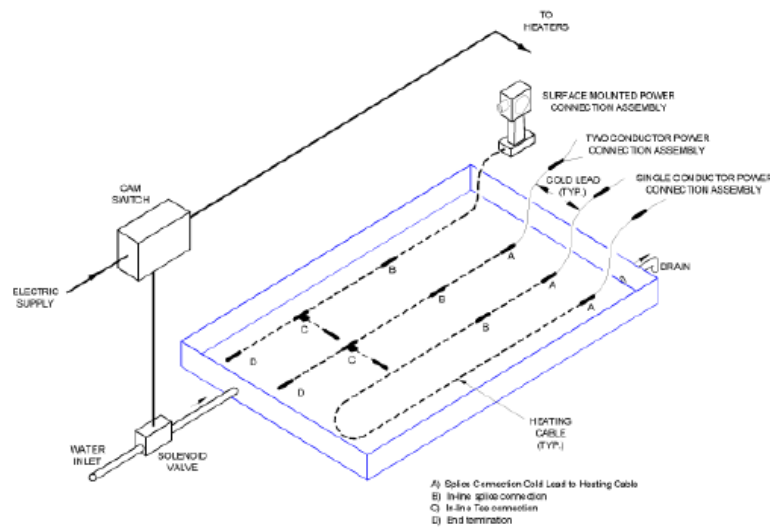


Figure 1—Trace heater termination and splice test apparatus

4.1.5 Elevated temperature exposure dielectric test

A sample of the heating device shall be placed in a forced-circulation air oven. The oven shall be heated to T_1 and maintained at a temperature of 20 °C above the highest exposure temperature declared by the manufacturer for a period of 4 weeks.

The sample shall be removed from the air oven and cooled to room temperature. Trace heater samples shall be wound six close turns around a mandrel having a radius equal to 12 times the radius of the primary bending plane or thickness of the trace heater. Integral components shall not be wound around the mandrel. Surface heating ~~cable. Surface heating devices, units,~~ if flexible, 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 at 10 °C to 25 °C for 5 min. While still in the tap water, the dielectric test ~~outlined in 4.1.1~~ and the insulation resistance test 4.1.2 shall be ~~performed~~ successfully completed. Rigid heating devices shall also be submerged in tap water and tested. After completion of the test, the sample shall have no visible cracks when examined with normal vision.

Terminations that insure the vapor tightness of trace heaters with electrical insulation that is a hygroscopic material (for example the cold end seals of MI trace heater sets) 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 4.1.1 and 4.1.2.

4.1.6 Thermal performance benchmark

One of the tests in 4.1.6.1 and 4.1.6.2 shall be used to verify the power output stability for all parallel heating devices.

4.1.6.1 Primary test

Three randomly selected samples representing the maximum output of all trace heaters or surface heating units under evaluation shall be tested. If the type of trace heater or surface heating unit has different levels of rated voltages and wattages, then three samples each shall be selected that represent 1) the lowest rated voltage level and the maximum rated output, and 2) the maximum rated voltage and the minimum rated output.

The samples shall be terminated according to the manufacturer's ~~specifications,~~ recommendations, such that a heating length of at least 600 mm or representative surface heating unit dimensions is provided. The aging temperature of the test shall be the maximum declared maintain temperature of the heating device. The samples shall be conditioned, while energized, at the aging temperature for $120 \text{ h} \pm 24 \text{ h}$. The initial output of the samples is then to be determined by one of the three methods given in 4.1.11, with the exceptions of sample length and number of test temperature points for item c) of 4.1.11. For this case, the samples shall be evaluated at rated voltage and at the manufacturer's stated reference temperature for the rated output. The output shall be within the manufacturer's stated output range.

The samples shall be attached to a fixture or suitable heat sink as described in item c) of 4.1.11 and insulated accordingly. The pipe or heat sink temperature shall be set to the specified aging temperature and maintained with $\pm 3\text{ }^{\circ}\text{C}$ plus 1% of the temperature reading in degrees Celsius. Circulating fluid or external heating may be used to raise the fixture to the aging temperature. The samples shall be operated at rated voltage. The power supply shall be attached to a 15 min cycle timer such that the samples are energized for 12 min and de-energized for 3 min. The samples shall be exposed to this conditioning for 32 weeks (5376 h).

For heating devices with an intermittent temperature exposure rating, the samples are exposed to the same conditioning for 32 weeks, except for an 8 h excursion once each week. At the beginning of the 8 h, the samples shall be disengaged from the cycle timer. The pipe or heat sink temperature shall be increased to a temperature equal to the manufacturer's stated intermittent exposure temperature. The time allowed to increase the temperature should be no greater than 1 h. After 7 h from the beginning of the excursion, the pipe or heat sink temperature shall be decreased back to the aging temperature, again allowing no more than 1 h for the operation. Where the intermittent temperature rating is based on the heating device being energized, then the heating device shall be continuously energized during this temperature excursion, except during cool down back to the maximum maintain temperature. Where the intermittent temperature rating is based on the heating device being de-energized, the exposure cycle is conducted in a de-energized condition. At the end of the 8 h excursion, the samples shall be reengaged to the cycle timer. The excursions should occur on the same day each week.

At the end of the 32 weeks of operation at the continuous rated temperature, the output of the samples shall be determined by the same procedure as used for the initial readings. The heating device samples shall maintain a power level within plus 20% or minus 25% of the initial measured output.

4.1.6.2 Alternative test

The test apparatus shall consist of a metal platen(s) with the ability to change temperature within specified levels. The platen(s) shall be sized to expose all parts of the heating device samples, which would be exposed under normal installation conditions, to the temperature

levels required by this procedure. The test apparatus shall insure that the heating device 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 heating device profile. The apparatus shall allow energizing of the heating device 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 heating device samples.

The temperature of the platen(s) shall be uniformly controlled to a maximum tolerance of $\pm 5\text{ }^{\circ}\text{C}$ for platen temperatures less than $100\text{ }^{\circ}\text{C}$ or 5% of the maximum continuous operating temperature if above $100\text{ }^{\circ}\text{C}$.

The platen described previously may be a flat metal plate, a metal pipe, or a metal surface typical of the majority of applications for the heating device being tested.

The heating device samples shall be randomly selected and shall be a minimum of 0.3 m in length. Where the heating device is irregular in shape, such as a surface heating unit, the heating device sample shall consist of at least one heating unit.

If the heating devices are part of a heating device product range, with common materials (with materials having the same performance ratings) and construction, which have different levels of rated voltages and power outputs, then three samples each shall be selected that represent the following:

- a) The lowest rated voltage level and the maximum rated power output
- b) The highest rated voltage and the minimum rated power output

Heating device 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 heating device samples shall be installed on the sample mounting fixture or directly applied to the platen. The samples shall be powered at the maximum rated voltage. The temperature of

the platen shall be $23\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$. The initial power output of the samples shall be determined by measuring voltage and current after the device has reached equilibrium.

The heating device 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 $23\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$ and the maximum continuous operating temperature. The samples may be de-energized during the cool-down period.

The heating device 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 $350\text{ }^{\circ}\text{C}$, then the lower temperature may be set at $350\text{ }^{\circ}\text{C}$ 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.

A minimum of 1500 cycles shall be performed.

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

Where the maximum exposure temperature is declared as “power ON,” the samples shall be energized at the maximum rated voltage.

After completion of the maximum exposure testing, the heating device samples power output shall be measured, using the same method and platen temperature as used during the initial measurements. The heating device samples shall maintain a power level within plus 20% or minus 25% of the initial measured output.

4.1.7 Deformation test

A sample of the heating device as well as a sample of each type of integral components and non heating lead (if applicable) shall be placed on a rigid 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, and in the case of a trace heater, it is placed across the specimen at right angles. For a trace heater that is oval or rectangular, the widest surface shall be the surface on which the load is applied. In the case of a surface heating unit, it is necessary to verify that the steel rod rests across the active element. After a minimum time of not less than 30 s and with the proof loading continuously applied, the dielectric test 4.1.1 [and insulation resistance test 4.1.2](#) shall be [successfully](#) completed. The test voltage shall be applied between the heating device conductors and its braid or sheath.

4.1.8 Impact test

[Both of the impact ~~test-shall~~tests in 4.1.8.1 and 4.1.8.2 are required to](#) be conducted on [separate samples of heating devices approximately 200 mm in length and on any integral components assembled with the heating device.](#)

[4.1.8.1 Minimum temperature test](#)

Each sample is positioned on a hardened ~~rigid~~-steel plate [\(with a mass equal to or greater than 20 kg, 195 mm × 195 mm × 70 mm\). The plate is positioned on a rigid substrate such that the impact energy absorbed by the substrate is negligible. The](#) assembly [is then](#) conditioned for a minimum of 4 h at the manufacturer's minimum recommended installation temperature. After conditioning and while still at the minimum recommended installation temperature, a sample shall be subjected to a 50.8 mm diameter cylindrical steel plunger with smoothly rounded edges to a ~~mass~~ [radius](#) of [approximately 5 mm, with a mass of](#) 1.8 kg and allowed to free fall from a height of 762 mm, resulting in an impact energy of 13.6 J. Then, the impacted portion of the sample shall be immersed in tap water at 10 °C to 25 °C for 5 min, and the dielectric test 4.1.1 [and insulation resistance test 4.1.2](#) shall be ~~conducted~~[successfully completed](#). For surface heating ~~devices~~[units](#), both the heating region and cold leads shall be impacted.

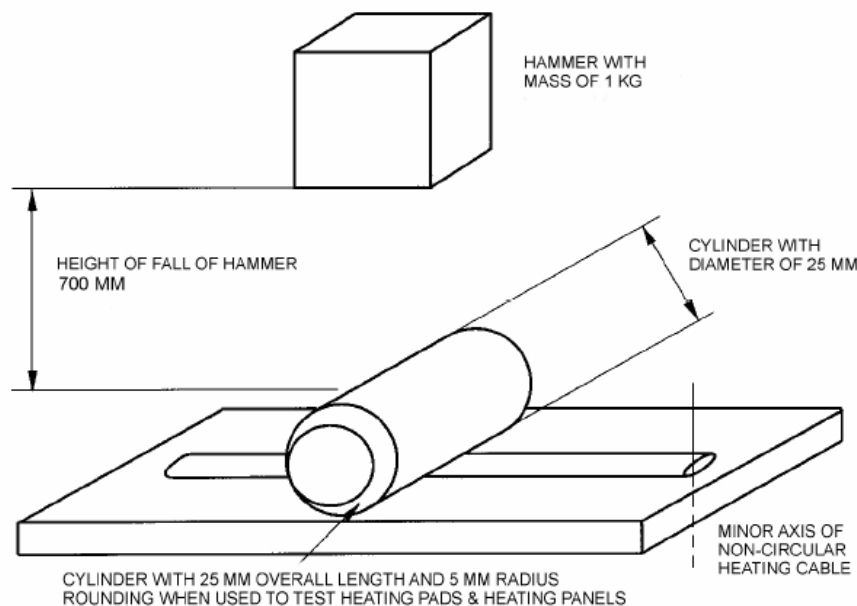


Figure 2—Trace heater room temperature impact test apparatus

4.1.8.2 Room temperature test

Each sample is positioned 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. 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 hardened steel cylinder with a diameter of 25 mm is then positioned horizontally across the top of the sample. This cylinder is required to have a length of 25 mm with smoothly rounded edges to a radius of approximately 5 mm when used to test heating pads and heating panels (Figure 2). A hammer with a mass of 1 kg shall be allowed to fall once onto the horizontal cylinder from a height of 700 mm (i.e., with an impact load of 7 J). 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 heating devices that have a stated minimum bending radius of less than 300 mm. The apparatus used for the bend test shall be as represented in Figure 3. A sample of trace heater or cold lead shall be fixed in the apparatus as shown in Figure 3. With the test sample in position, the apparatus shall be placed in a refrigerated compartment and maintained at the minimum recommended installation temperature for a period of not less than 4 h. At the end of this period and with the sample maintained at the minimum recommended installation temperature, the sample shall be bent through 90° around one of the bending mandrels, then bent through 180° in the opposite direction over the second bending 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. For heating devices, the heating region shall be bent around a mandrel equivalent to the manufacturer's minimum bending radius. When this has been completed, the sample shall be immersed in tap water at 10 °C to 25 °C for 5 min, and then the dielectric test 4.1.1 and insulation resistance test 4.1.2 shall be successfully completed.

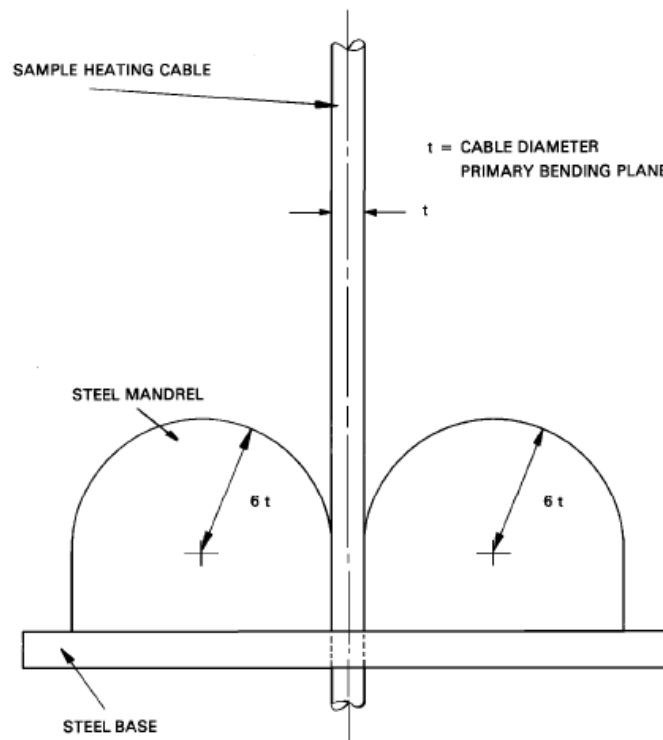


Figure 3—Cold bend test apparatus

4.1.10 Flammability test

A flammability test shall be performed on heating devices and on heating devices with integral components. The full range of sizes shall be capable of complying with the test. The test shall be made in a room free from drafts and carried out in a minimum volume of 0.5 m^3 flame chamber or fume hood. For the trace heater, the sample shall be at least 450 mm in length and shall be supported in a vertical position. For surface heating ~~devices~~units, 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 D 5025-05 shall be used for the test. The gas flame produced by the burner is to be calibrated as described in ASTM D 5207-09. The fuel shall be methane, propane, or natural gas, and shall be of a grade suitable for calibration to the ASTM D 5207-09 procedure. As shown in Figure 4, 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 heating device 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 will contact 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.

The flame shall be brought up to the heating device in such a manner that the vertical plane containing the major axis of the burner tube shall be at right angles to the sample. The flame shall be applied for 15 s and then removed for 15 s until five such applications have been made.

The test results shall be considered satisfactory if the heating device 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.

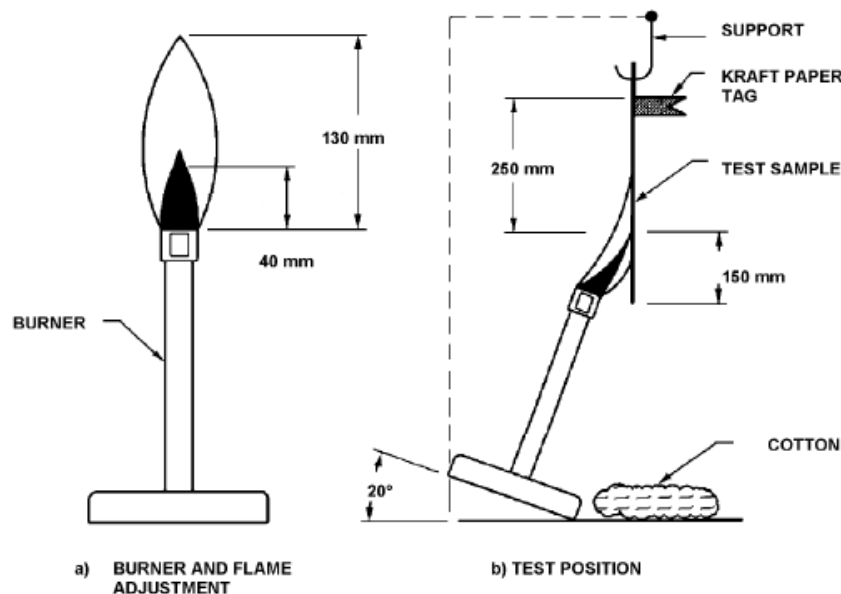


Figure 4—Flammability test

4.1.11 Verification of rated output

The rated output of the heating device 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.
- c) *Thermal*—For trace heaters, the thermal output shall be measured by installation of a single 3 m to 6 m sample of the trace heater on a schedule 40 carbon steel pipe of 50 mm diameter or greater, as shown in Figure 5. The heater shall be installed per the manufacturer's

instructions. The test apparatus shall be completely covered with a fiberglass thermal insulation of 25.4 mm or equivalent.

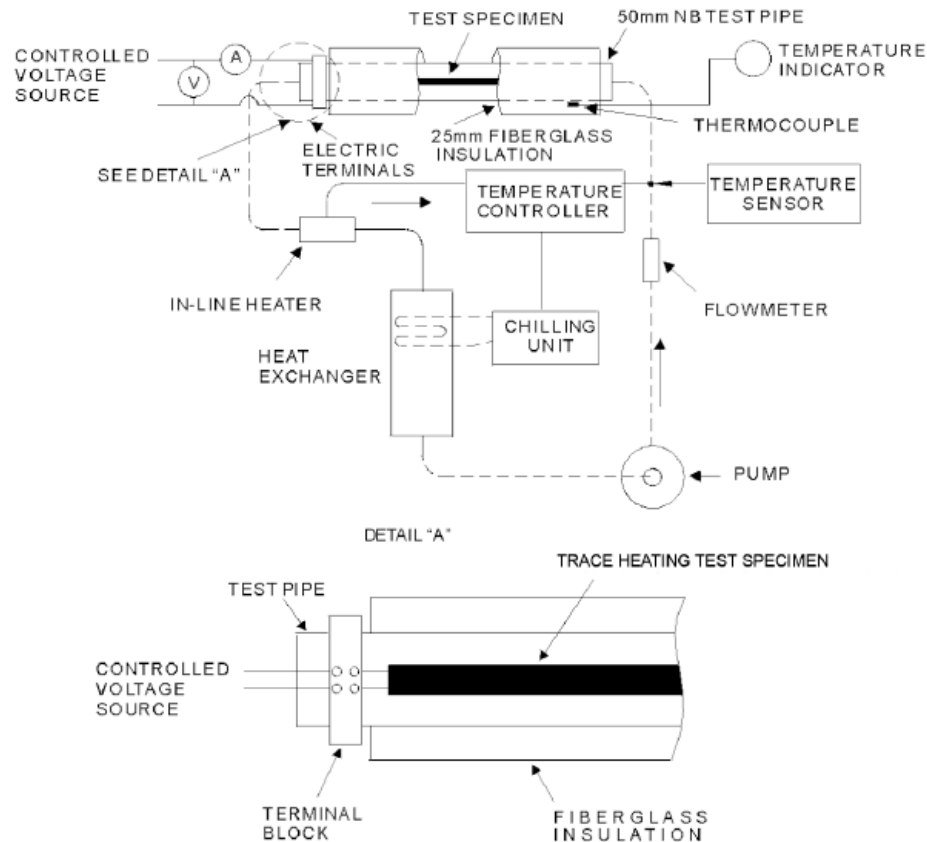


Figure 5—Verification of rated output

For surface heating units, the test shall be conducted on a flat metal plate with rapid heating and cooling capability. Fiberglass thermal insulation, 25.4 mm thick, shall be installed over the surface heating unit.

A suitable heat-transfer fluid in the liquid phase shall be circulated through the pipe or metal plate fixture at a sufficient rate to establish turbulent flow corresponding to a Reynolds number greater than 2300. This will establish negligible temperature difference between the fluid and the pipe temperature. Sufficient means should be utilized to maintain constant temperature of the heat-transfer fluid. These parameters shall be verified by thermocouples placed at the entry and exit ends of the pipe. Flow velocity shall be sufficient so that the fluid temperature does not

differ by more than 2 °C from end to end.

The thermal output of the heating device shall be measured at three pipe or plate temperatures over the heater operating range. The heating device shall be powered at its rated voltage and allowed to attain equilibrium. The voltage, current, fluid temperature, and sample length shall be recorded at each test temperature. Three separate determinations shall be made on separate samples. The resulting values shall be within the manufacturer's declared tolerance.

4.1.12 Verification of start-up current

The start-up current of the heating device shall be measured at the manufacturer's minimum designated ambient temperature.

A sample of the trace heater at least 1 m in length is installed per the manufacturer's instructions on a minimum 50 mm diameter fluid-filled steel pipe, solid rod, or for surface heating units, a flat metal heat sink. ~~The testing apparatus shall be completely covered with thermal insulation and conditioned at the test temperature for at least 4 h. The~~ [Thermal insulation shall be prepared to cover the testing apparatus.](#)

[To keep the cooling time to a minimum, the testing apparatus and the thermal insulation may be cooled down to the manufacturer's minimum designated ambient temperature separately. When the testing apparatus and the thermal insulation have cooled down to the minimum designated ambient temperature, the testing apparatus shall be completely covered with that thermal insulation and maintained at the test temperature for at least 4 h. Alternatively, 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/current characteristics shall be recorded from time 0 s to 300 s. The time current characteristic of any of the three samples shall not be more than the value declared by the manufacturer. The samples shall be in the upper 1/2 of the manufacturer's declared power output tolerances.

4.1.13 Verification of braid or sheath conductivity

A metallic braid, metallic sheath, or equivalent electrically conductive material is required as part of the ~~heating cable~~trace heater construction and shall cover at least 70% of the surface. For surface heating ~~devices (panels), units,~~ an integral metallic screen grid or equivalent electrically conductive covering ~~covering~~ at least 70% of the exposed surface opposite the surface to be heated shall be incorporated into the construction. The resistance of at least 3 m length of the trace heater shall be measured at room temperature using a four-wire resistance (Wheatstone bridge) method. A representative sample of a surface heating unit shall be used. The resistance shall be equal to or less than the manufacturer's declared value. Additional considerations shall be applied by the certifying agencies for evaluation of equivalent materials other than metallic braid or sheath.

4.2 Type test—verification of sheath temperatures

Maximum sheath temperatures of heating devices must be determined for the proper application of the heater. The ~~maximum~~ sheath temperature is dependent on the heater watt density, overall heat-transfer coefficient, and the ~~runaway pipe/tank/tube bundle~~ temperature of the surface being heated. These factors are used by the manufacturer to determine the sheath temperatures of the heating devices, as presented in 6.4. Table 2 and Table 3 defines the ~~operational and environmental~~ test conditions for each of the types of area classification.

Table 2—Sheath temperature test conditions for gases

Item	Class I, II, III		Class I			Unclassified (Ordinary)
	Div. 1	Div. 2	Zone 0	Zone 1	Zone 2	
Percent of operating voltage	110	110	— ^a	110	110	100
Maximum pipe temperature for calculation	— ^b	— ^b	— ^a	— ^b	— ^b	— ^b
Maximum wind speed for calculation	0	0	— ^a	0	0	0

^aElectric heating devices are not permitted in Zone 0 areas.

^bThe pipe temperature (T_{pe} or T_{pm} , whichever is greater) used to calculate the maximum sheath temperature—see 6.4.

Table 3—Sheath temperature test conditions for dusts

Item	Zone 20	Zone 21	Zone 22
Percent of operating voltage	— ^a	110	110
Maximum pipe temperature for calculation	— ^a	— ^b	— ^b
Maximum wind speed for calculation	— ^a	0	0

^aElectric heating devices are not permitted in Zone 20 areas.

^bThe pipe temperature (T_{pe} or T_{pm} , whichever is greater) used to calculate the maximum sheath temperature—see 6.4.

At least one of the following two methods shall be used for ~~determining the~~verifying a heating device's sheath ~~temperatures and the resultant sheath~~ temperature ~~shall not exceed the declared or~~ temperature class ~~or maximum surface temperature~~as declared by the manufacturer:

- Systems method in which the manufacturer demonstrates the ability to design and predict sheath temperatures by conducting tests on ~~specific representative~~ installations
- Product classification method in which the maximum sheath ~~temperatures are~~ enerated temperature is determined in an artificial environment intended to simulate worst-case conditions independent of the application

4.2.1 Systems method—design verification procedures

Either of these procedures is used to validate a manufacturer's design methodology and calculations. This test verification method may be 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

certifying agency and the manufacturer. These procedures are also used to validate a manufacturer's predicted maximum trace heater sheath temperatures when a high-temperature limiter is used (6.4.5.2.3.1).

This procedure shall be repeated with two varied parameters such as insulation type and thickness, to the satisfaction of the certifying agency.

4.2.1.1 Trace heaters

For trace heaters, the test apparatus as shown in Figure 6 shall consist of a minimum test section of 3 m horizontal run and a minimum 1.5 m vertical run of piping test section having a pipe size between 50 mm and 150 mm diameter. The pipe shall be empty. A flanged gate valve or equivalent (butterfly valve, globe valve, etc.) should be located in the center portion of the horizontal run. The vertical run should be so arranged that flanged pipe ends are in the center (refer to Figure 6). The trace heater shall be installed in a manner consistent with the manufacturer's installation instructions. ~~T/C shall be used to monitor the pipe~~ between 9 o'clock and 3 o'clock positions (upper portion of the pipe) on the pipe circumference. The sample shall be within the upper half of the heating device's thermal output tolerance or test conditions shall be considered to achieve similar results. Thermocouples shall be used to monitor the pipe, valve, and flange surface temperatures and cable corresponding heater sheath temperatures at each of these locations. 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 mm² or smaller size Type K thermocouples. The thermocouples should be spot welded to MI cable metallic sheaths and heated metallic surfaces. For metallic braid polymeric sheaths, or nonmetallic 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 certifying agency. The piping system should be insulated with a minimum of 25 mm thickness of soft thermal insulation, such as fiberglass or mineral wool (oversized to accommodate the trace heater), and installed in accordance with the manufacturer's installation procedures. The pipe ends should be plugged and thermally insulated. An additional length of piping may be added to the test section on either end to minimize end effects in the test section or additional trace heater may be added within the test section to achieve the same purpose.

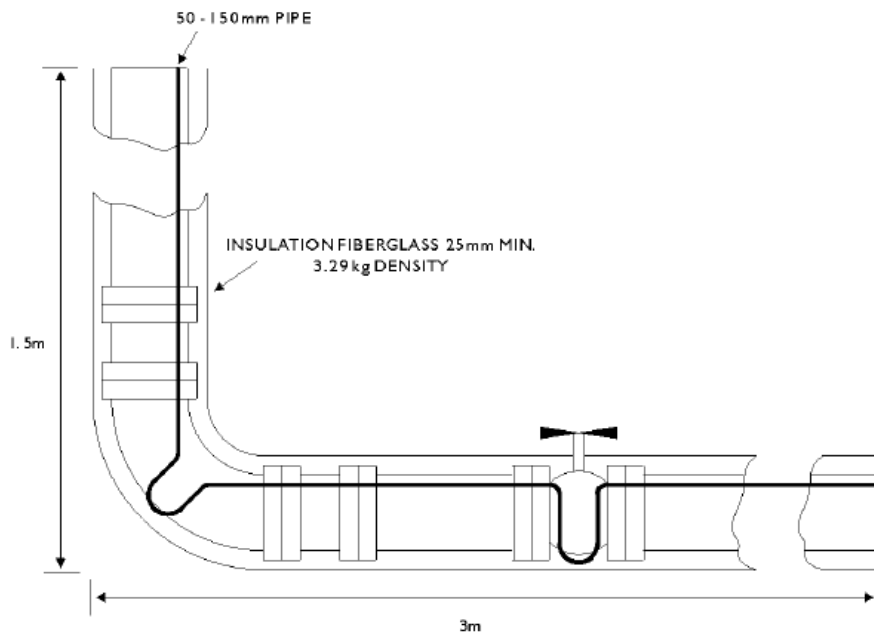


Figure 6—Verification of sheath temperature using systems approach

For tubing bundles, the test apparatus shall consist of 4.5 m of traced tube bundle. Thermocouples shall be used to monitor the tubes and corresponding trace 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 mm² or smaller size Type K thermocouples. The thermocouples shall be spot welded to metallic sheath and heated metallic surfaces and shall be attached with suitable adhesive/tape systems when installed on polymeric sheaths or nonmetallic heated surfaces. Additional thermocouples may be located at other anticipated hot spots at the discretion of the certifying agency.

The trace heater shall be powered at voltage conditions based on the area classification; see Table 2. ~~After stabilization, the thermocouple readings are recorded, including the local ambient temperature. The measured surface temperatures~~ The system temperatures shall be allowed to stabilize and thermocouple readings recorded. When using the temperature limiter technique, the high-limit sensor shall be installed per the manufacturer's instructions midspan on the horizontal piping, midway between the valve and the vertical run. The predicted maximum sheath temperatures based on the set point of the high-temperature limiter shall be compared to the measured maximum trace heater sheath temperatures. The measured sheath temperatures minus the measurement uncertainty (no more than 10 °C) shall not exceed the manufacturer's calculated value.

4.2.1.2 Surface heaters

For surface heaters, a representative section shall be applied to a 6-mm-thick steel plate in accordance with the manufacturer's installation instructions. The steel plate shall not extend more than 25 mm from any edge of the surface heater. Thermocouples shall be used to monitor the plate temperatures and the corresponding heating device surface temperature at locations in the centermost region of the heating device. The heating device sample shall be within the upper half of the heating device's 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 thermocouples. The thermocouples should be spot welded to MI cable metallic sheaths and heated metallic surfaces. For metallic braid, polymeric sheaths, or nonmetallic 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 certifying agency. The heated side of the plate shall be insulated with a minimum of 25 mm of thermal insulation. The plate is then located in a stable room temperature environment. The surface heater shall be powered at voltage conditions based on the area classification according to Table 2. After stabilization, the thermocouple readings are recorded, including the local ambient temperature. The measured heating device surface temperatures minus the measurement uncertainty (no more than 10 °C) shall not exceed the manufacturer's calculated value.