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IEEE Standard for the Testing, Design, Installation, and Maintenance of Electrical Resistance Heat Tracing for Industrial Applications

IEEE Industry Applications Society

Sponsored by the
Petroleum and Chemical Industry Committee



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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. Applications include unclassified, and both North American and Zone classified areas.

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

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Introduction

(This introduction is not part of IEEE Std 515-2004, IEEE Standard for the Testing, Design, Installation, and Maintenance of Electrical Resistance Heat Tracing 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 North American 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 added Division 1 heating cables.

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

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IEEE Standard for the Testing, Design, Installation, and Maintenance of Electrical Resistance Heat Tracing for Industrial Applications

1. Overview

1.1 Scope

This standard provides requirements for the testing, design, installation, and maintenance of electrical resistance heat tracing in general industries as applied to pipelines, vessels, pretraced and thermally insulated instrument tubing and piping, and mechanical equipment. The electrical resistance heat tracing is in the form of series heating cables, parallel heating cables, and surface heating devices. 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 as follows:

Class I¹

- Division 1

- Division 2

- Zone 1

- Zone 2

Class II

- Division 1

- Division 2

Class III

- Division 1

- Division 2

Unclassified (ordinary)

¹Class I is a term used with zone locations in the USA and Canada.

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 heat-tracing 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 standard to those national and international standards addressing electrical resistance heat tracing, such as the following:

NFPA 70-2002, National Electrical Code[®], NEC[®], Article 427.

EN 50019-2000 [B8].²

IEC 62086-1:2001 [B18].

IEC 62086-2:2001 [B19].

IEC 60079-0:2004 [B14].

IEC 60079-7:2001 [B16].

2. 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.

ASTM D 5025-1999, A Laboratory Burner Used for Small-Scale Burning Tests on Plastic Materials.³

ASTM D 5207-2003, Standard Practice for Confirmation of 20-mm (50-w) and 125-mm (500-w) Test Flames for Small-Scale Burning Tests on Plastic Materials.

NFPA 70-2002, National Electrical Code[®] (NEC[®]).⁴

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

NFPA 497M-1991, Classification of Gases, Vapors, and Dusts for Electrical Equipment in Hazardous (Classified) Locations.

3. Definitions

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

3.1 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.

²The numbers in brackets correspond to those of the bibliography in Annex A.

³ASTM 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/>).

⁴The NEC is published by the National Fire Protection Association, Batterymarch Park, Quincy, MA 02269, USA (<http://www.nfpa.org/>). Copies are also available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (<http://standards.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 electrical protection device.

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

3.4 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.

3.5 connections: Terminations and splices used to attach a heating device to power wiring or to connect sections of devices.

3.6 dead leg: A segment of process piping that is not in the normal flow pattern.

3.7 Division 1: Terminology used for classification of an industrial area in which flammable gases or vapors, flammable liquids, combustible dusts, or ignitable fibers or flyings can be present under normal conditions, or from frequent breakdowns, or where failure of equipment could release materials and create simultaneous failure of electrical equipment.

NOTE—See the NEC for a detailed definition.⁵

3.8 Division 2: Terminology used for classification of an industrial area in which flammable gases or vapors, flammable liquids, combustible dusts, or ignitable fibers or flyings will only be present under abnormal conditions.

NOTE—See the NEC for a detailed definition.

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

3.10 electrical resistance heat tracing: The utilization of electric heating cables, other electric heating devices, and support components that are externally applied and used to maintain or raise the temperature of fluids/materials in piping and associated equipment.

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

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

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

3.14 heating device: Heating cable or surface heating unit.

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

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

3.17 heat-tracing circuit: A heat-tracing circuit is comprised of one or more heating devices or segments connected to branch wiring of a single-circuit protection device.

⁵Information on references can be found in Clause 2.

3.18 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.

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

3.20 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 conform to the general shape of the heating device and are exposed to the same environments as the heating device.

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

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

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

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

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

3.26 overjacket: The outermost continuous layer of insulating material applied to protect against corrosion and enhance mechanical protection.

3.27 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 heating cable.

3.28 parallel heating cable: Heating elements that are electrically connected in parallel, either continuously or in zones, so that the watt density per lineal length is maintained, irrespective of any change in length for the continuous type or for any number of discrete zones.

3.29 power connection: The connection between the heating device and incoming power.

3.30 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.

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

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

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

3.34 series heating cable: 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.

3.35 sheath: A uniform and continuous covering, metallic or nonmetallic, enclosing the insulated conductor(s), used to protect the cable against mechanical damage and influences from the surroundings (corrosion, moisture, etc.). *See: overjacket.*

3.36 sheath temperature: The temperature of the outermost continuous covering of a heating cable or surface heating device that may be exposed to the surrounding atmosphere.

3.37 start-up current: The current response of a heating device following energization.

3.38 surface heating device (heating panel): A heater comprising series or parallel connected elements having sufficient flexibility to conform to the shape of the surface to be heated.

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

3.40 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.

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

3.42 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.

3.43 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, heating cable, thermal insulation, and weatherproof jacket.

3.44 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, IEEE Std 515-2004.

3.45 weather barrier: 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.

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.

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 heating cable at least 3 m in length or representative surface heater section, unless otherwise specified, shall be selected for testing. Tests shall be conducted at room temperature between 10 °C–40 °C unless otherwise noted. Annex F 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 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.

4.1.1 Dielectric test

The dielectric test shall be performed on the heating device in accordance with Table 1.

Table 1—Dielectric test values

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 maintained for 1 min without dielectric breakdown.

The test voltage waveform shall be essentially sinusoidal, with a frequency of 45–65 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 Ω·cm). The test voltage shall be applied between the heating conductors and the water.

4.1.2 Insulation resistance test

The insulation resistance shall be measured on the above sample 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 dc voltage of 1000 Vdc for mineral insulated heaters and 2500 Vdc for polymer insulated heaters. The measured value shall not be less than 50 MΩ.

4.1.3 Water-resistance test

A sample shall be immersed (except at terminations, or ends where the conductors are exposed) in tap water at 10 °C–25 °C for a period of 14 days.

Within 1 h after this conditioning and while still immersed in the water, the sample shall be subjected to the dielectric test outlined in 4.1.1.

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, a unit with cold leads shall be used. 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 shall be performed. The immersed connections of the heating device shall be inspected to verify no evidence of water ingress.

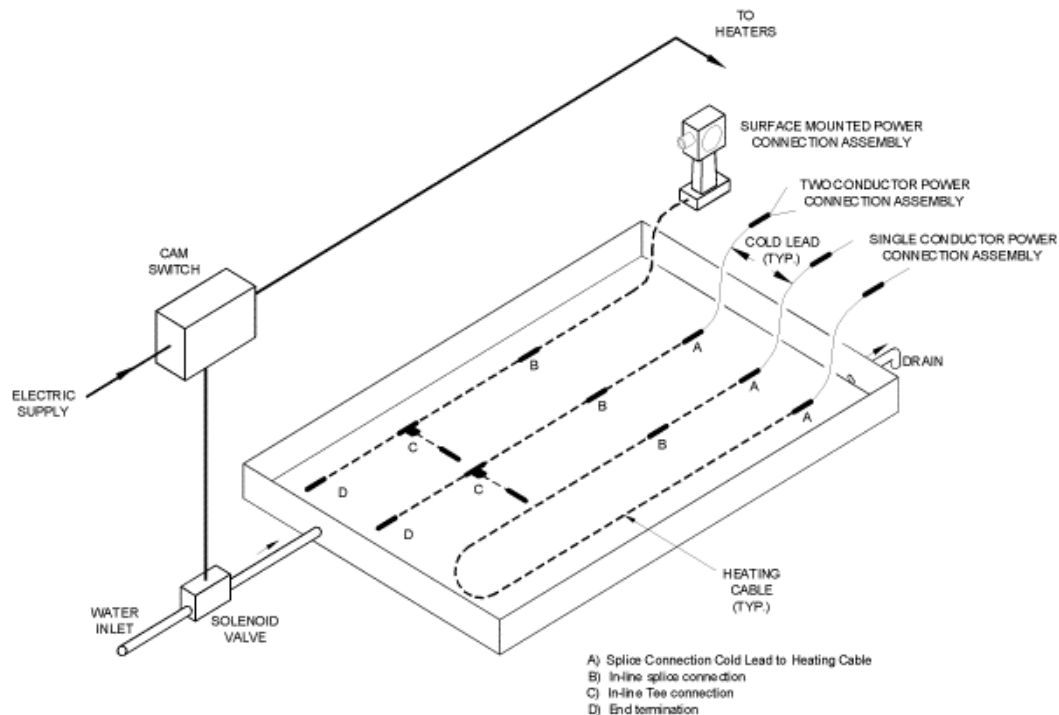


Figure 1—Heating cable termination and splice test apparatus

4.1.5 Elevated temperature exposure dielectric test

A sample of a heating device shall be placed in a forced-circulation air oven. The oven shall be heated to, and maintained at, a temperature of 25 °C ± 5 °C above the highest exposure temperature declared by the manufacturer for a period of 14 days.

The sample shall be removed from the air oven and cooled to room temperature. Heating cable samples shall be wound six close turns around a mandrel having a radius equal to twelve times the radius of the primary

bending plane or thickness of the heating cable. Surface heating devices, 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–25 °C for 5 min. While still in the tap water, the dielectric test outlined in 4.1.1 shall be performed. Rigid heating devices shall also be submerged in tap water and tested. Upon completion of the test, the sample shall have no visible cracks when examined with normal vision.

4.1.6 Thermal performance benchmark

One of the following tests shall be used to verify power output stability for all parallel heating devices.

4.1.6.1 Primary test

Three randomly selected samples representing the maximum output of all cables or surface heating devices under evaluation shall be tested. If the type of cable or surface heating device has different levels of rated voltages and wattages, then three samples each shall be selected that represent the following:

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

Samples shall be terminated according to the manufacturer's specifications, such that a heating length of at least 600 mm or representative surface heating device dimensions are 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 h $\pm$ 24 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 the procedure in item c) in 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) in 4.1.11 and insulated accordingly. The pipe or heat sink temperature shall be set to the specified aging temperature and maintained with ± 3 °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 utilized 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 ensure 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 previously described 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 device, 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 $350\text{ }^{\circ}\text{C}$, 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.

Following 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 Newton (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 heating cable, it is placed across the specimen at right angles. For a cable that is oval or rectangular in shape, the widest surface shall be the surface on which the load is applied. In the case of a surface heating device, it is necessary to ensure 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 outlined in 4.1.1 shall be conducted. The test voltage shall be applied between the heating device conductors and its braid or sheath.

4.1.8 Impact test

The impact test shall be conducted on a sample that is positioned on a hardened rigid steel plate and the assembly 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, having 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 Joule (J). Then the impacted portion of the sample shall be immersed in tap water at 10 °C–25 °C for 5 min, and the dielectric test outlined in 4.1.1 shall be conducted. For surface heating devices, both the heating region and cold leads shall be impacted. After testing, the sheath or dielectric insulation shall have no visible cracks when examined with normal vision.

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 2. A sample of heating cable or cold lead shall be fixed in the apparatus as shown in Figure 2. 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 panels, 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–25 °C for 5 min, and then the dielectric test outlined in 4.1.1 shall be conducted.

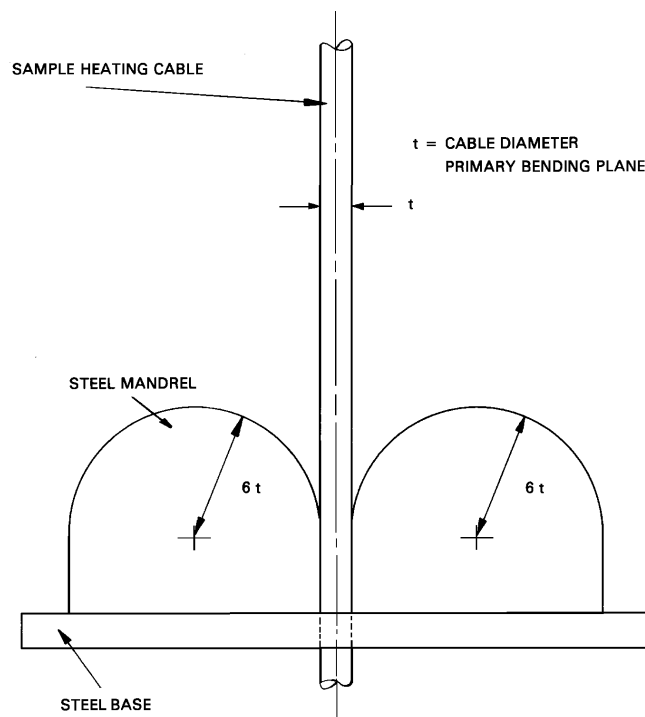


Figure 2—Cold-bend test apparatus

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 m³ flame chamber or fume hood. For heating cable, the sample shall be at least 450 mm in length and shall be supported in a vertical position. For surface heating devices, 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 5025-1999 shall be used for the test. The gas flame produced by the burner is to be calibrated as described in ASTM D 5207-2003. The fuel shall be methane, propane, or natural gas, and shall be of a grade suitable for calibration to the ASTM D 5207-2003 procedure. As shown in Figure 3, 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, 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.

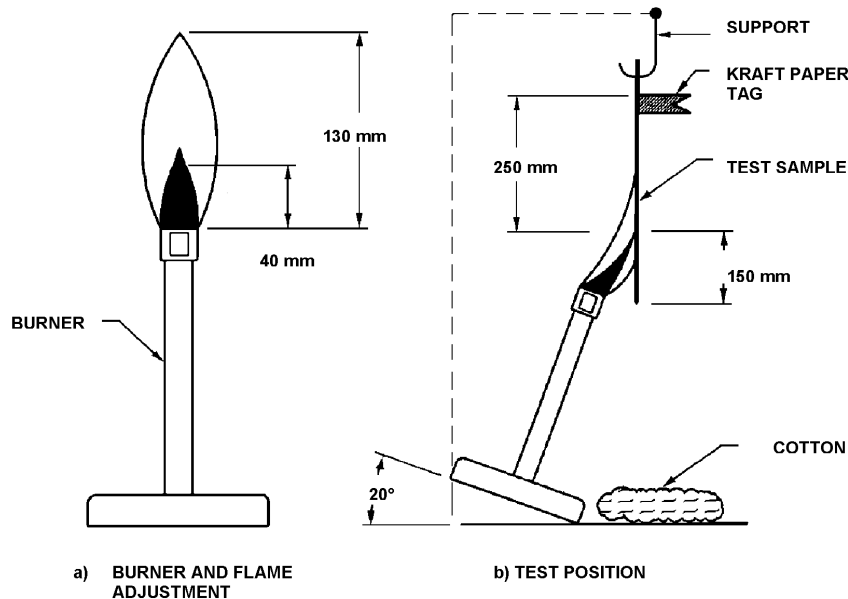


Figure 3—Flammability test

4.1.11 Verification of rated output

The rated output of the heating device shall be verified by one of the following three methods:

- Conductance*—The measured ac conductance or conductance per unit length, at a specified temperature, shall be within the manufacturer's declared tolerance.
- Resistance*—The measured dc resistance or resistance per unit length, at a specified temperature, shall be within the manufacturer's declared tolerance.
- Thermal*—For heating cables, the thermal output shall be measured by installation of a single 3–6 m sample of heating cable on a schedule 40 carbon steel pipe of 50 mm diameter or greater, as shown in Figure 4. The cable 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.

For surface heating devices, 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 device.

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 (T/C) 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.

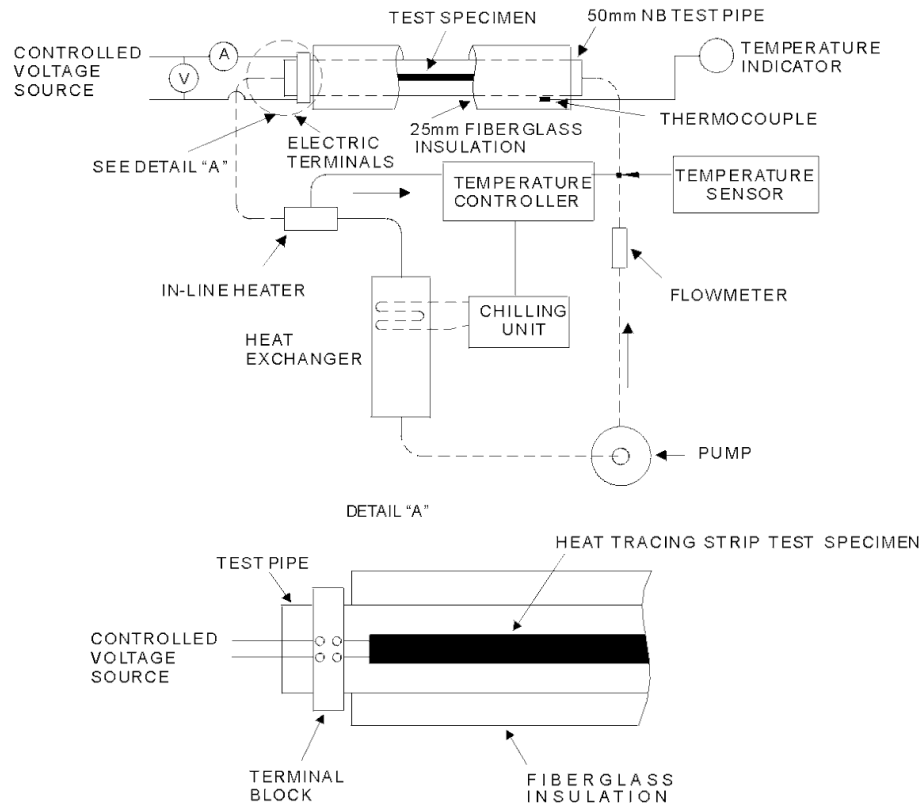


Figure 4—Verification of rated output

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 heating cable at least 1 m in length is installed per manufacturer's instructions on a minimum 50 mm diameter fluid-filled steel pipe, solid rod, or for surface heating devices, 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 apparatus described in item c) in 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 zero 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 one third of the manufacturer's declared power output tolerances.

4.1.13 Verification of braid or sheath conductivity

An electrically grounding metallic braid, metallic sheath, or equivalent electrically conductive material is required as part of the heating cable construction and shall cover at least 80% of the surface. For surface heating devices (panels), an integral metallic screen grid or equivalent electrically conductive covering covering at least 80% 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 heating cable shall be measured at room temperature using a four-wire resistance (Wheatstone bridge) method. A representative sample of a surface heating device 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 to ensure 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. These factors are used by the manufacturer to determine the sheath temperatures of the heating device, as illustrated in Equation (4). Table 2 defines the operational and environmental conditions for the test for each of the types of area classifications. The maximum allowable watt density and sheath temperatures declared by the manufacturer shall be verified.

Table 2—Sheath temperature test conditions

Item	Class I, II, III		Class I			Unclassified (ordinary)
	Div. 1	Div. 2	Zone 0	Zone 1	Zone 2	
Percent of rated voltage	120	110	Note 2	110	110	100
Maximum pipe temperature for calculation	Note 1	Note 1	Note 2	Note 1, 3	Note 1, 3	Note 1
Maximum wind speed for calculation	0	0	Note 2	0	0	0
NOTES 1—The pipe temperature (T_{pr} or T_{pm} , whichever is greater) used to calculate the maximum sheath temperature (see 6.4). 2—Electric heating devices are not permitted in Zone 0 areas. 3—Maximum sheath temperature determination for both systems approach and product classification methods—test values for maximum surface temperature will have 5 °C added for test values below T3 (200 °C) and 10 °C for test values over T3 (200 °C).						

One of the following two methods shall be used for determining the heating device's sheath temperatures and the resultant sheath temperature shall not exceed the declared temperature class or maximum surface temperature:

- A systems approach, in which the product is subjected to a test condition, where the manufacturer demonstrates the ability to design and predict sheath temperatures by conducting tests on specific installations
- A product classification approach, in which maximum sheath temperatures are generated in an artificial environment simulating worst-case conditions

4.2.1 Systems approach—design verification method

This procedure is used to validate a manufacturer's design methodology and calculations. This procedure may be repeated with varied parameters, such as insulation type and thickness, to the satisfaction of the certifying agency.

For heating cables, the test apparatus, as shown in Figure 5, shall consist of a 3 m horizontal run and 1.5 m vertical run of piping having a pipe size between 50 mm and 150 mm diameter. A flanged gate valve or equivalent (butterfly valve, globe valve, etc.) would be located in the center of the horizontal run. The vertical run should be so arranged that flanged pipe ends are in the center (see Figure 5). The heating cable shall be installed in a manner consistent with the manufacturer's installation instructions. T/C shall be used to monitor the pipe and valve surface temperatures and cable sheath temperatures. The T/C should be located at anticipated hot spots at the discretion of the certifying agency. The piping system should be insulated with a minimum of 25 mm thickness of thermal insulation and installed in accordance with the

manufacturer's installation procedures. Pipe ends should be plugged and thermally insulated. For tubing bundles, the test apparatus shall consist of 4.5 m of traced tube bundle, with T/C located at the discretion of the certifying agency. The heating cable shall be powered at voltage conditions based on the area classification (see Table 2). System temperatures shall be allowed to stabilize and thermocouple readings recorded. The measured sheath temperatures minus the measurement uncertainty (no more than 10 °C) shall not exceed the manufacturer's calculated value.

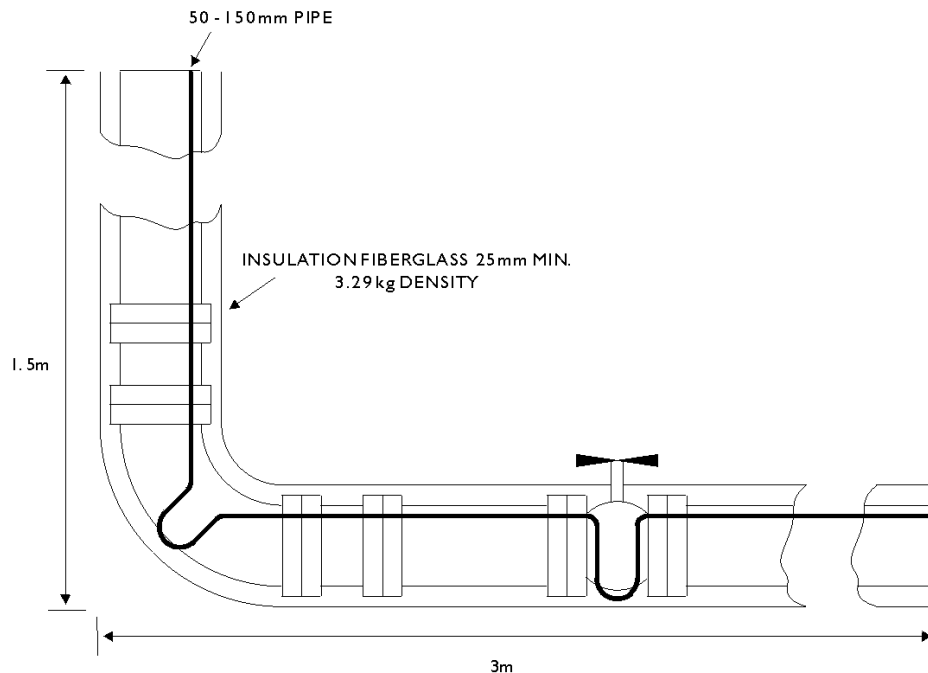


Figure 5—Verification of sheath temperature using systems approach

For surface heaters, a representative section shall be applied to a 6 mm 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. T/C shall be used to monitor the temperature of the external surface of the heater. The T/C should be located at 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 surface temperatures minus the measurement uncertainty (no more than 10 °C) shall not exceed the manufacturer's calculated value.

4.2.2 Product classification approach

A sample of heating cable at least 1500 mm in length is placed loosely coiled in a forced air circulation oven. For a surface heater, a representative section is placed horizontally in the oven. The sample shall be within the upper half of the heating device's thermal output tolerance. Representative T/C are used to monitor sample sheath temperatures and are placed 500 mm from each end. One additional thermocouple is used to monitor oven ambient. The heating device shall be powered at voltage conditions based on the area classification (see Table 2). The oven ambient temperature is incrementally raised from room ambient in 15 °C increments. Sufficient time is permitted at each temperature for the oven ambient and heater sheath temperatures to stabilize and attain thermal equilibrium. Oven ambient and heater sheath temperatures are recorded at each successive level until the temperature difference between the two approaches is 5 °C or less. A curve is drawn from the test data, and a straight line is drawn tangent to the curve at 5 °C temperature

difference point and extended to the X axis (oven temperature). The temperature read at this intercept is taken as the maximum sheath temperature, as shown in Figure 6.

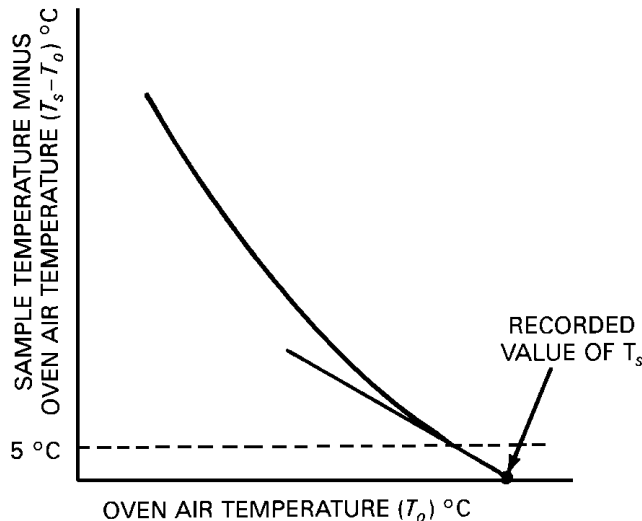


Figure 6—Maximum sheath temperature using product classification approach

4.3 Specific type test requirements for hazardous (classified) locations

Test values for certain of the type tests listed in 4.1 and 4.2 shall be adjusted for the different hazardous (classified) locations.

4.3.1 Class I, Division 1 locations

Heating devices recommended for these areas shall be tested for severe chemical exposure, impact, and static mechanical loads. Additional type testing shall be required for system components. The requirements for system components are covered in other applicable standards for equipment for use in Class I, Division 1 hazardous (classified) locations. The following tests are intended to qualify heating devices for application in these hazardous (classified) areas and are required in addition to all the type tests described in 4.1.

4.3.1.1 Verification of sheath temperatures

The sheath temperature test described in 4.2 shall be conducted in accordance with design conditions detailed in Table 2, and the resultant sheath temperature shall not exceed the declared temperature class or maximum surface temperature.

4.3.1.2 Mechanical type tests

The deformation test as described in 4.1.7 shall be conducted at 204 kg (2000 N). The impact test as described in 4.1.8 shall be conducted retaining the same impact area, however, with an increased impact energy of 27.1 J.

4.3.1.3 Chemical exposure tests

The heating device and any integral components shall be exposed (completely immersed except for the connections) to the following chemicals: acetone, ethyl acetate, isooctane, hexane, methanol, methyl ethyl ketone, methylene chloride, and toluene. The exposure duration shall be 24 h. The chemical shall be maintained at a temperature not less than 5 °C below the boiling point. Boiling points shall be obtained from NFPA 325-1994.