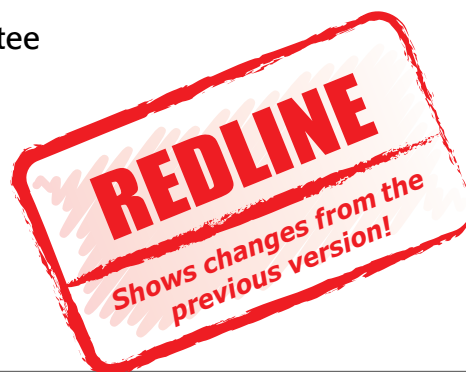


IEEE Standard for the Testing, Design, Installation, and Maintenance of Electrical Resistance Trace Heating for Commercial Applications

IEEE Industry Applications Society

Sponsored by the
Petroleum and Chemical Industry Committee



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3 Park Avenue
New York, NY 10016-5997
USA

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

Sponsor

**Petroleum and Chemical Industry Committee
of the
IEEE Industry Applications Society**

Approved 19 October 2012

IEEE-SA Standards Board

Abstract: Specific test requirements for qualifying electrical resistance trace heating for commercial service are provided in this standard. A basis for electrical and thermal design is included, heating device characteristics are addressed, and installation and maintenance requirements are detailed. Recommendations and requirements for unclassified heating device applications are provided.

Keywords: deicing, design, electrical resistance, floor warming, freeze protection, frost heave, heat tracing, heater, heating cable, heating device, IEEE 515.1, installation, maintenance, snow melting, trace heater, trace heating.

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Introduction

This introduction is not part of IEEE Std 515.1-2012, IEEE Standard for the Testing, Design, Installation, and Maintenance of Electrical Resistance Trace Heating for Commercial Applications.

The utilization of electrical resistance trace heating in the commercial construction industry has increased steadily due to the availability of more reliable products and more efficient operation. The need exists for broad-based technical information about electrical resistance trace heating systems. In the construction industry, these systems are used for temperature maintenance of domestic hot water, general freeze protection of piping and drain lines, roof and gutter deicing, snow melting of concrete and asphalt embankments, frost heave protection of freezer floors in cold storage warehouses, and floor warming as an enhancement for the comfort of office personnel. The approval process for these systems provides the basis for this standard.

This standard provides specific test requirements for qualifying electrical resistance heating devices for commercial construction and a basis for electrical and thermal design. Type and routine production tests are outlined in this standard and address such subjects as mechanical durability, resistance to moisture, and electrical and thermal ratings. This standard outlines specific recommendations dealing with the installation of electrical resistance trace heating systems for the intended use.

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

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1. Overview

1.1 Scope

This standard provides test criteria to determine the suitability of heating devices and fittings that are used for commercial applications. The standard also includes detailed recommendations for the design, installation, and maintenance of electrical resistance trace heating in these applications.

Commercial applications include installations both inside and outside commercial business buildings, such as office buildings, hospitals, and airports. Typical applications include freeze protection of water pipes; temperature maintenance of hot water piping and other lines and tubing; protection of sprinkler systems; roof, gutter, and pavement deicing; and other applications as shown in Table 1 in 4.1.

Commercial applications involving hazardous (classified) locations shall also meet the relevant hazardous location requirements in IEEE Std 515^{TM 1} as well as any other applicable codes and standards.

1.2 Purpose

The provisions of this standard provide requirements to ~~should~~ ensure that adequate material temperatures are maintained and that electrical, thermal, mechanical, and water-exclusion durability are provided to the trace heating system. In addition, the requirements ~~it should~~ provide that under normal use the products will exhibit long-term performance reliability to reduce the potential for ~~without~~ damage to the user or surroundings. This standard is a supplement to those provisions outlined in National Electrical Code[®] (NEC[®]) (NFPA 70), Articles 426 and 427.

2. Normative references

The following referenced documents are indispensable for the application of this ~~standard~~ 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.

¹ Information on references can be found in Clause 2.

ANSI Z358.1-1990, Emergency Eyewash and Shower Equipment.²

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

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

ASTM D5207, Practice for Calibration for 20 mm and 125 mm Test Flames for Small-Scale Burning Tests on Plastic Materials.

[ASTM G151, Standard Practice for Exposing Non-Metallic Materials in Accelerated Test Devices that Use Laboratory Light Sources.](#)

ASTM [G155](#) ~~G26~~, [Standard](#) Practice for Operating Xenon Arc Light ~~Exposure~~ Apparatus ~~With and Without Water~~ for Exposure of Non-Metallic Materials.

CFR (Code of Federal Regulations) Publication 29, Part 1910 (OSHA) § 1910.151 (c).⁴

² ANSI publications are available from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

³ ASTM publications are available from the Customer Service Department, American society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103, USA (<http://www.astm.org>).

⁴ CFR publications are available from the Superintendent of Documents, U.S. Government Printing Office, P.O. Box 37082, Washington, DC 20013-7082, USA (<http://www.access.gpo.gov/>).

IEEE Std 515, IEEE Standard for the Testing, Design, Installation, and Maintenance of Electrical Resistance Trace Heating for Industrial Applications.⁵

~~NEMA 250, Enclosures for Electrical Equipment (1000 Volts Maximum).⁵~~

~~[NFPA 13, Standard for the Installation of Sprinkler Systems.](#)⁶~~

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

~~UL 50, Enclosures for Electrical Equipment.⁷~~

⁵ IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08855-1331, USA (<http://standards/ieee.org/>).

~~⁵ NEMA publications are available from the National Electrical Manufacturers Association, 2101 L Street NW, Suite 300, Washington, DC 20037, USA (<http://global.ihs.com/nema>).~~

⁶ NFPA publications are available from Publication Sales, National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101, USA (<http://nfpa.org/codes/index.htm>).

~~⁷ UL publications are available from Underwriters Laboratories, Inc., 333 Pfingsten Road, Northbrook, IL 60062-2096, USA. Standards information is available at <http://ulstandardsinfo.net.ul.com>. Publications are available at <http://global.ihs.com>.~~

3. Definitions

~~Annex B~~

~~(informative)~~

~~Glossary~~

For the purposes of this document, the following terms and definitions apply. ~~These and other~~
~~within IEEE standards are found in~~ *Authoritative of* The IEEE Standards ~~Terms~~¹⁹ Dictionary *Online*
should be consulted for terms not defined in this clause.⁷

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.

certifying agency: The organization that validates that equipment meets tests and standards.

conductive layer: Metallic braid, metallic sheath, or other equivalent electrically conductive material
intended to provide an electrical path to operate an electrical protection device.

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

⁷ IEEE Standards Dictionary Online subscription is available at:
http://www.ieee.org/portal/innovate/products/standard/standards/standards_dictionary.html

¹⁹ ~~IEEE publications are available from the Institute of Electrical and Electronics Engineers, Inc., 445 Hoes Lane, Piscataway, NJ~~
~~08854, USA (<http://standards.ieee.org/>).~~

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

end termination: The termination applied to the end of the heating [device cable](#), opposite the power supply end.

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 and connections to be assembled by field personnel.

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

heating device: A [trace cable](#) heater or surface heating [unit device](#).

[heating pad:](#) A surface heating unit comprised of series or parallel connected elements having sufficient flexibility to conform to the shape of the surface to be heated.

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

integral components: Factory fabricated or field installed electrical terminations and connections, such as heat shrink terminations, 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.

maintain temperature: [The](#) specified temperature of the fluid or process material that the heating device is designed to hold at equilibrium under specified design conditions.

maximum exposure temperature: The highest temperature to which a component of the heating device system may be exposed either continuously or for a specified period of time.

maximum maintain temperature: [The](#) specified maximum temperature of a surface or process, which the heating device is capable of maintaining continuously.

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

overjacket: A polymeric sheath, sometimes fabric reinforced, applied over the conductive layer.

parallel [trace](#) ~~cable~~ heater: Heating elements that are electrically connected in parallel, either continuously or in zones, so that 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.

rated output: Total power or power/unit length of the heating device, at rated voltage or current, maintain temperature, and length, normally expressed as W/m ~~or~~ (W/ft).

rated voltage: The voltage to which the operating characteristics of the heating device are referred.

routine test: A test that is carried out by the manufacturer of the heating device on all heating devices during or after the production process.

series [trace](#) ~~cable~~ 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: A continuous covering for a heating device.

sheath temperature: The temperature of the outermost sheath that may be exposed to the surrounding atmosphere.

startup current: The transient current of a heating device immediately following energization.

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

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

trace heater: A parallel trace heater or series trace heater that generates heat by electrical resistance.

~~electrical-resistance~~ **trace heating:** The utilization of heating devices that generate heat by electrical resistance and support components that are applied and used to reduce or eliminate ice build-up to help prevent the freezing of pipes or surfaces or to help maintain a pipe or surface at a prescribed temperature.

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 to the requirements of this standard.

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.

4. General product testing

4.1 Type test—general requirements

Products intended for use in commercial applications, as defined in Table 1, shall meet the applicable tests as listed in Table 2. Products intended for use on sprinkler systems shall also meet the requirements of 4.6.

Table 1 — Commercial heating device installation type

Installation type	Type definition	Examples of type	Reference clause for general testing requirements
A	Insulated surfaces (including pipe)	Hot water lines Freeze protection Sprinkler systems Grease lines Fuel oil lines Pre-insulated pipe Below grade trace heating	4.1 and 4.2 Additionally 4.6 for sprinkler systems
B	Outdoor exposed areas	Roof deicing Gutter and down spouts deicing Catch basins and drains	4.1, 4.2, and 4.3
C	Installations with embedded trace heating	Embedded snow melting Embedded frost heave protection Embedded floor warming Embedded energy storage systems Embedded door frames	4.1, 4.2, and 4.4

Installation type	Type definition	Examples of type	Reference clause for general testing requirements
D	Installations with trace heater inside ~~of~~ conduit or piping	Snow melting ~~cable~~ trace heater in conduit Frost heave protection in conduit Floor warming in conduit Energy storage systems in conduit Enclosed drains and culverts	4.1, 4.2, and 4.5

Table 2 — Applicable tests for heating device and integral components of heating device by installation type

Type test	Subclause	Installation type			
		Type A	Type B	Type C	Type D
Dielectric	4.2.1	X	X	X	X
Insulation resistance	4.2.2	X	X	X	X
Water resistance	4.2.3	X	X	X	X
Integral components— resistance to water	4.2.4	X	X	X	X
Elevated temperature exposure	4.2.5	X	X	X	X
Thermal performance benchmark	4.2.6	X	X	X	X
Flammability	4.2.7	X	X	X	X
Deformation	4.2.8	X	X	X	X
Impact	4.2.9	X	X	X	X
Cold bend	4.2.10	X	X	X	X

Type test	Subclause	Installation type			
		Type A	Type B	Type C	Type D
Verification of rated output	4.2.11	X	X	X	X
Verification of startup current	4.2.12	X	X	X	X
Verification of sheath temperatures	4.2.13	X	X	X	X
Verification of conductive layer conductivity	4.2.14	X	X	X	X
Strain relief test for fittings	4.2.15	X	X	X	X
Enclosure considerations	4.2.16	X	X	X	X
Increased moisture resistance	4.3.1		X		
UV and condensation	4.3.2		X		
Resistance to cutting	4.3.3		X		
Abrasion	4.3.4		X		
Tension	4.3.5		X		
Resistance to cutting	4.4.1			X	
Resistance to crushing	4.4.2			X	
Increased moisture resistance	4.5.1				X
Pull-strength	4.5.2				X
Sprinklers	4.6.1	X			

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

Tests shall be conducted at 100% of rated voltage and room temperature between 10 °C and 40 °C unless otherwise noted.

~~NOTE 1~~ Heating devices and integral components of heating devices for hazardous (classified) locations shall meet the relevant hazardous location requirements in IEEE Std 515 in addition to the requirements in this standard.

~~NOTE 2~~ System components other than those identified as integral components shall be tested in accordance with applicable national and international standards.

4.2 Type test—insulated surfaces

Trace heating systems intended for installations on thermally insulated surfaces, such as insulated pipes, tanks, and tubing (Type A applications as defined in Table 1), shall meet the requirements of 4.2.1 through 4.2.16.

4.2.1 Dielectric test

The following dielectric test in Table 3 shall be performed on a sample of the heating device including integral components. For a trace heater cable, a minimum 3 m sample length shall be used.

Table 3 – Dielectric test

Rated voltage	Test voltage (V ac rms)
≤ 30 V rms	500
≤ 60 V dc	500
> 30 V rms	$2E + 1000$
> 60 V dc	$\sqrt{2} E + 1000$

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 V ac rms test voltage waveform shall be essentially sinusoidal with a frequency of 45 Hz to 65 Hz.

The test voltage shall be applied between the conductor(s) and the conductive layer. Alternatively, the dielectric test may be conducted by submerging the [trace heater cable](#) in tap water at room temperature (resistivity of tap water is typically 50 000 Ωcm). The test voltage shall be applied between the conductor(s) and the water.

4.2.2 Insulation resistance test

The insulation resistance of the sample shall be measured after the dielectric test specified in 4.2.1 is completed. The resistance of the insulation shall be measured between conductors and the conductive layer by means of dc voltage of 500 V. The measured value shall be greater than 50 M Ω .

4.2.3 Water resistance test

A sample of the heating device with integral components (at least 3 m in length for [trace](#) heater [cable](#)) shall be immersed in water at 10 °C to 25 °C for a period of 336 h (14 days).⁸ After the conditioning period, the sample shall be subjected to the dielectric voltage outlined in 4.2.1 for 1 min without dielectric breakdown.

4.2.4 Integral components resistance to water test

A sample of the heating device with integral components (at least 3 m in length for [trace](#) heater [cable](#)) shall be placed in a water flow and drain apparatus as shown in Figure 1.⁹ 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. At that point, water flow is initiated for the second cycle, and the heating device is simultaneously de-energized. The test shall be continued for 300 cycles. After completion, the dielectric voltage outlined in 4.2.1 shall be performed. The immersed connections of the heating device shall be inspected to verify no evidence of water ingress.

⁸ End terminations and connections for systems intended strictly for use in dry and accessible locations are not subject to this test.

⁹ End terminations and connections for systems intended strictly for use in dry and accessible locations are not subject to this test.

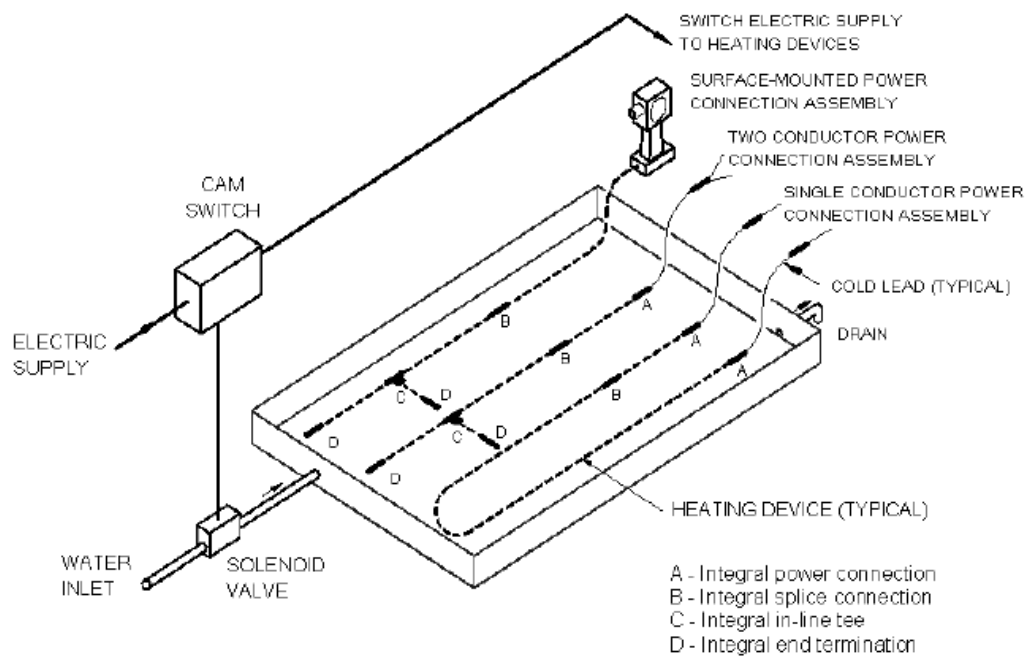


Figure 1— Water flow and drain apparatus

4.2.5 Elevated temperature exposure test

A sample of a heating device with integral components (at least 3 m in length for [trace](#) heater ~~cable~~) shall be placed in a forced-circulation air oven. The oven shall be heated to and maintained at a temperature of $25\text{ }^{\circ}\text{C} \pm 5\text{ K}$ 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. Trace heater ~~cable~~ 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 ~~cable~~. Heating pads ~~Surface devices~~ that have a stated minimum bending radius of less than 300 mm 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 in the tap water, the dielectric test outlined in 4.2.1 shall be performed. Rigid heating panels ~~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.

4.2.6 Thermal performance benchmark

When tested as described in either 4.2.6.1 or 4.2.6.2, the heating device samples shall maintain a power level within + 20% or - 25% of the initial measured output.

These tests are applicable to parallel constructed heating devices only. They do not apply to series heating devices.

4.2.6.1 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 voltage and wattage, then three samples each shall be selected that represent:

- 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 a representative surface heating [unit](#) ~~device~~ dimension 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 4.2.11, with the exceptions of sample length and number of test temperature points for procedure 4.2.11.3. 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 4.2.11.3 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 output for series [trace heaters](#) ~~cables~~ or rated voltage for parallel [trace heaters](#) ~~cable~~. Surface heating [units](#) ~~devices~~ shall be operated at rated output. 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 maximum exposure temperatures (either continuous or intermittent) higher than the maximum maintain temperatures, 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 maximum 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 maximum exposure 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 maximum exposure 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 re-engaged to the cycle timer. The excursions should occur on the same day each week.

At the end of the 32 weeks of testing, the output of the samples shall be determined by the same procedure as used for the initial readings. The percent change to the initial output shall be calculated.

4.2.6.2 Alternative test

This alternative test was developed to reduce the testing time of 4.2.6.1 for parallel heating device constructions with polymeric elements, but it may be used for any parallel construction.

Products that do not pass the requirements of this test shall comply with the requirements of 4.2.6.1.

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 ensure 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 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 ± 5 °C for platen temperatures less than 100 °C or 5% of the maximum continuous operating temperature if above 100 °C.

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

Three 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 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:

- 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 conditioned⁷ at the maximum rated voltage for up to 150 h at the manufacturer's declared maximum continuous operating temperature before 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 $23 \text{ °C} \pm 5 \text{ °C}$. 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 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.

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 ($\pm 1\text{ }^{\circ}\text{C}$) as used during the initial measurements.

4.2.7 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 draughts and carried out in a minimum volume of 0.5 m^3 flame chamber or fume hood. For [a trace](#) heater ~~eable~~, the sample shall be at least 450 mm in length and shall be supported in a vertical position. For surface heating [units](#) ~~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 D5025 shall be used for the test. The gas flame produced by the burner is to be calibrated as described in ASTM D5207. The fuel shall be methane, propane, or natural gas, and it shall be of a grade suitable for calibration to the ASTM D5207 procedure. As shown in Figure 2, 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 [200](#) ~~20°~~ from the vertical and the flame applied to the heating device so that the tip of [the](#) 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. 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.

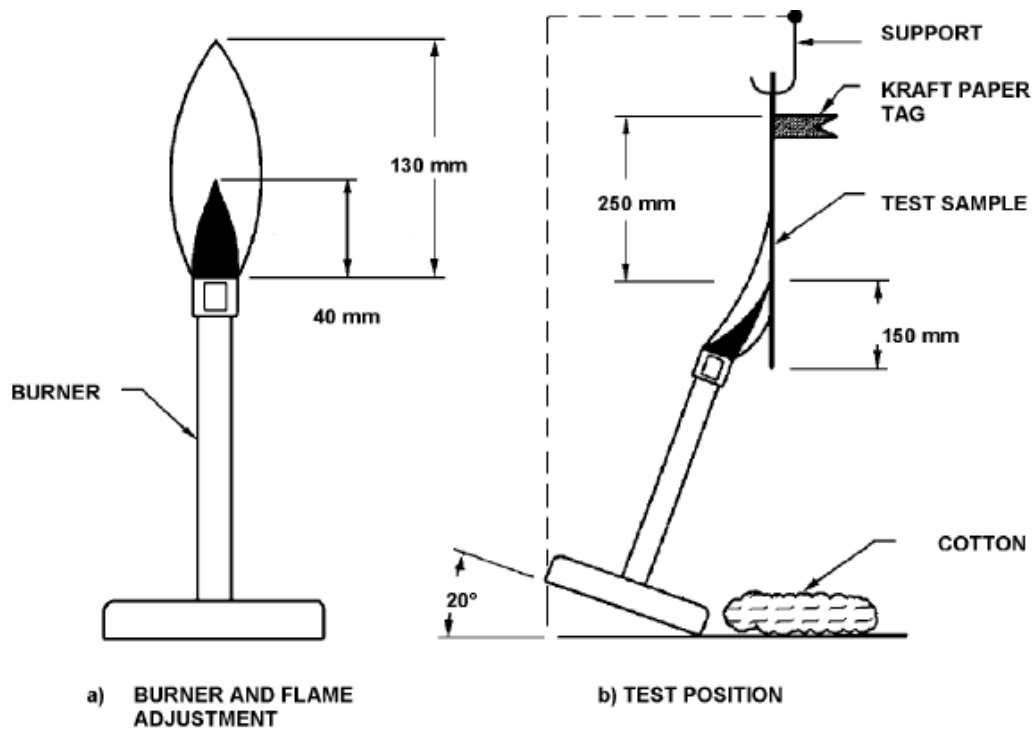


Figure 2 — Flammability test

4.2.8 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 ~~eable~~ it is placed across the specimen at right angles. For [trace heaters](#) ~~eable~~ that ~~are 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 [unit](#) ~~device~~, it is necessary to ensure that the steel rod rests across the active element. The test voltage shall be applied between the heating device conductor(s) and its conductive layer.

Conformity is verified by testing the electrical insulation in accordance with 4.2.1, where the horizontal steel rod is still in place on the sample and the load is applied.

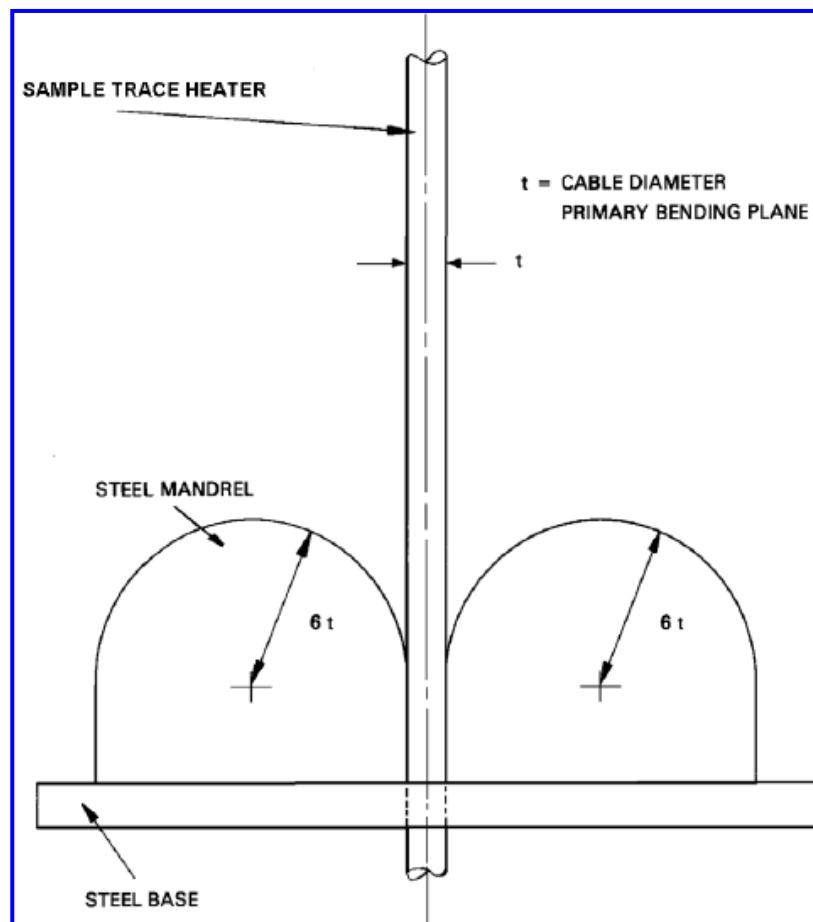
4.2.9 Impact test

The impact test shall be conducted on a sample of the heating device and a sample of each type of integral component, which are conditioned along with a hardened steel plate for a minimum of 4 h at the manufacturer's minimum recommended installation temperature.

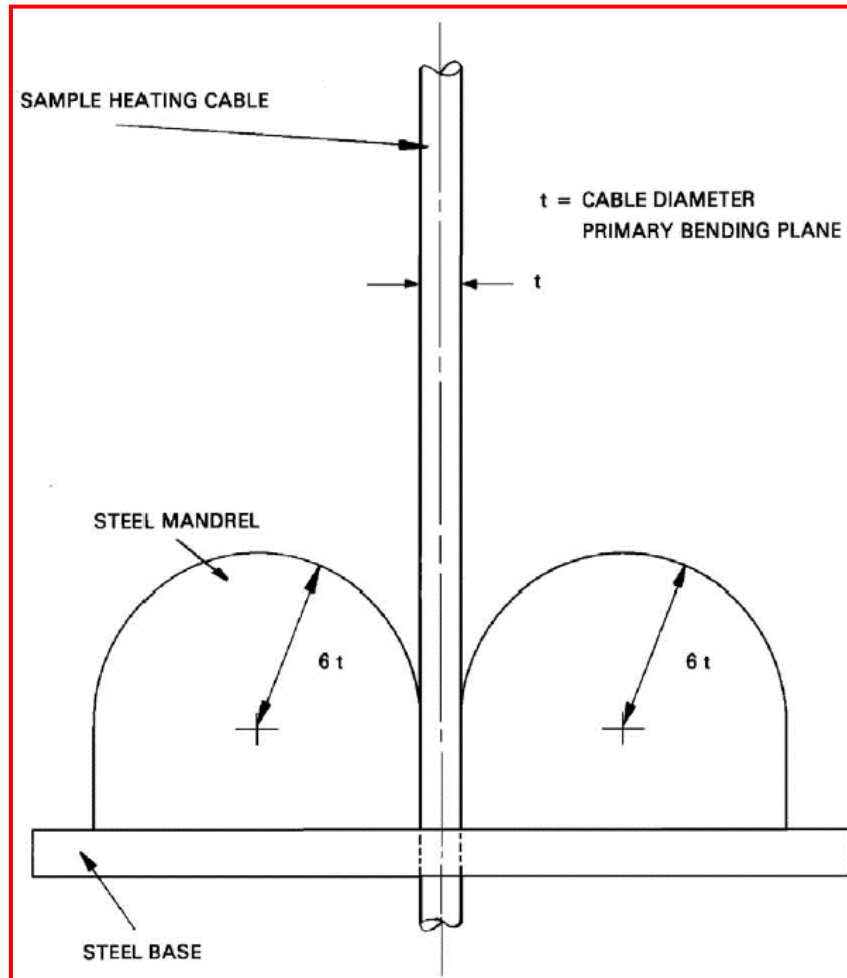
After conditioning and while at the minimum recommended installation temperature, each component of the sample shall be individually positioned on the steel plate. A 51 mm diameter cylindrical steel plunger with smoothly rounded edges having a mass of 1.8 kg shall be allowed to free fall from a height of 760 mm, which results in an impact energy of 13.6 J. The impacted portion of each sample shall be immersed in tap water at room temperature for 5 min, and the dielectric voltage outlined in 4.2.1 shall be applied for 1 min without dielectric breakdown. Overjackets subjected to this procedure shall have a dielectric voltage of 500 V ac applied between the conductive layer and water for 1 min without dielectric breakdown.

4.2.10 Cold bend test

This test applies only to 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 3₇ with the radius of the steel mandrels as shown or with the radius equal to the manufacturer's stated minimum bend radius.



(New)



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Figure 3— Cold bend test apparatus

A sample of [trace](#) heater ~~cable~~ without integral connections 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, the sample shall be fixed in the apparatus as shown in Figure 3. The sample shall then be bent 90° around one of the bending mandrels, then bent through 180° in the opposite direction over the second bending mandrel, and then straightened to its original position. All bending operations shall be carried out in the same plane. This cycle of operations shall be performed three times. Upon completion, the sample shall be immersed in tap water at room temperature for 5 min, and then the dielectric voltage outlined in 4.2.1 shall be conducted.

For surface heating [units](#) ~~devices~~, the heating region shall be bent around a mandrel equivalent to the manufacturer's minimum bending radius. When this process has been completed, the sample shall be immersed in tap water at room temperature for 5 min, and then the dielectric test outlined in 4.2.1 shall be conducted.

4.2.11 Verification of rated output

The rated output of the heating devices shall be verified by one of the following methods described in 4.2.11.1, 4.2.11.2, and 4.2.11.3.

4.2.11.1 Conductance method

The measured ac conductance or conductance per unit length, at a specified temperature, shall be within the manufacturer's declared tolerance.

4.2.11.2 Resistance method

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

4.2.11.3 Thermal method

The thermal output of the heating device shall be measured at three maintenance temperatures over the heater operating range with the heating device installed per the manufacturer's instructions. The heating device shall be powered at its rated voltage and allowed to attain equilibrium. The voltage, current, maintenance 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. The test apparatus for the various installation types are as described in 4.2.11.3.1 through 4.2.11.3.4.

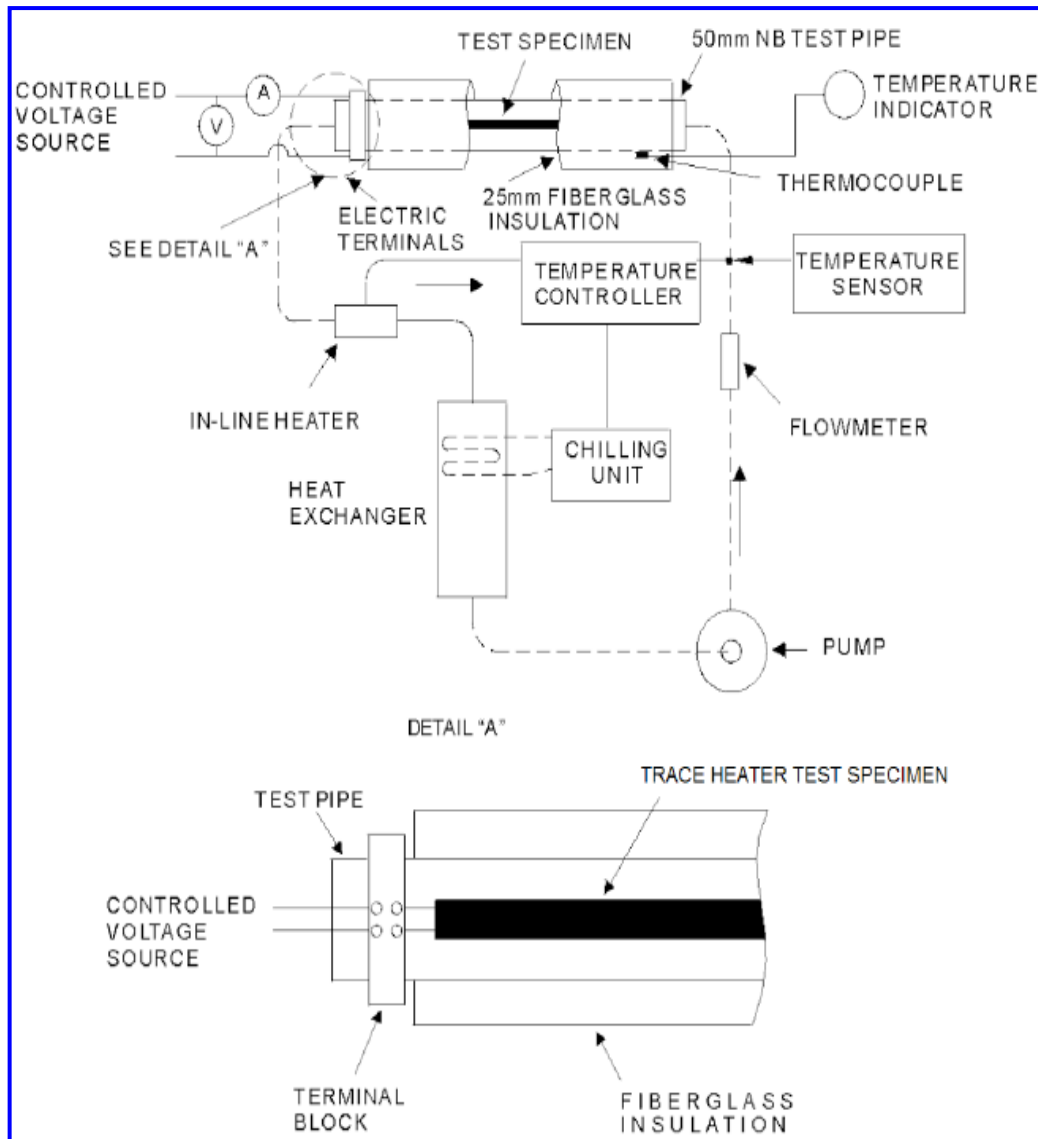
For installation types other than those described in 4.2.11.3.1 through 4.2.11.3.4, the certifying agency and the manufacturer shall agree on an appropriate test apparatus.

Rated power output values may be correlated between any of the tests described in 4.2.11.3.1 through 4.2.11.3.4 to eliminate the need to set up and run specialized test procedures for follow-up retesting.

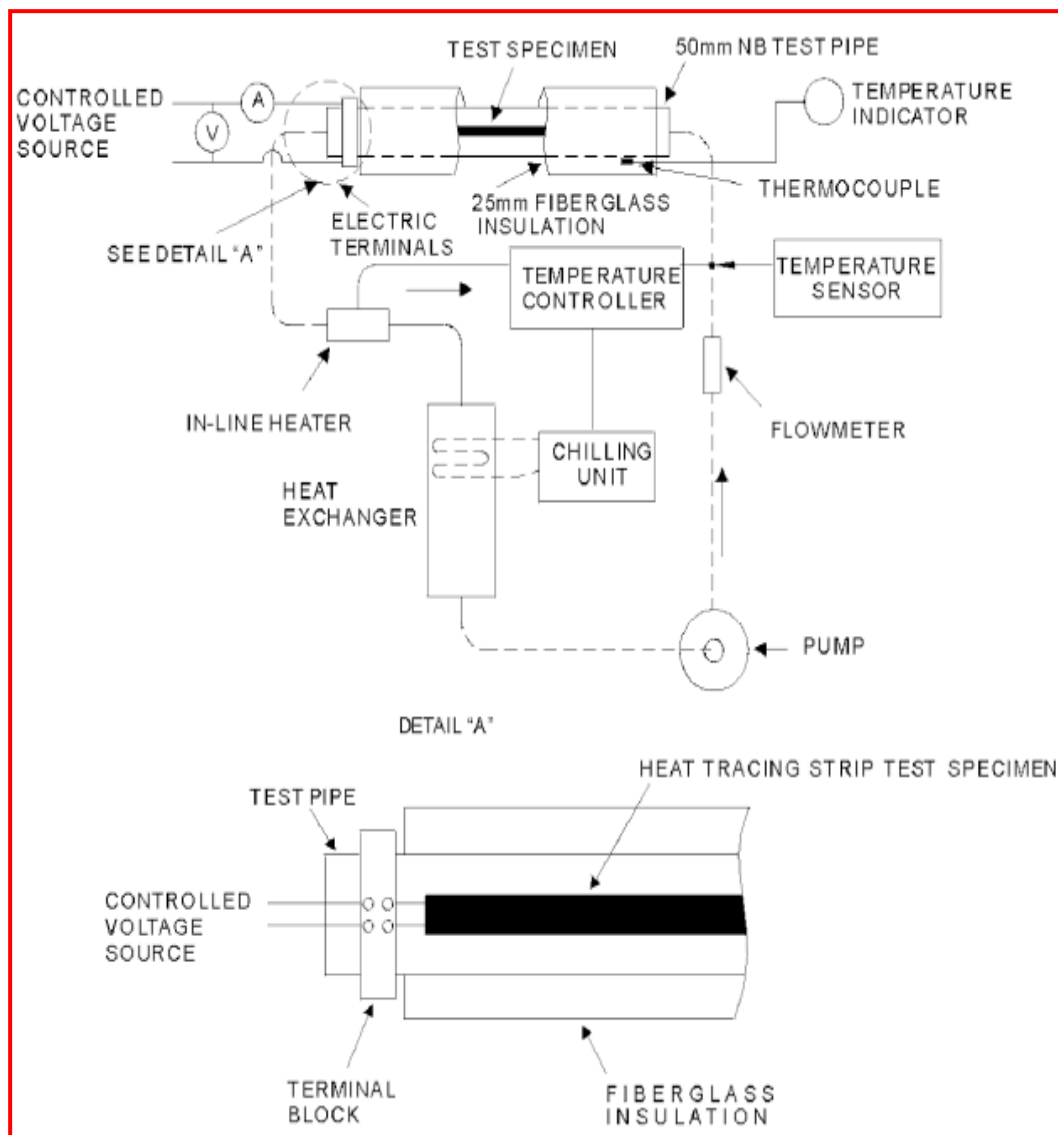
4.2.11.3.1 Insulated surfaces (including pipe)

For [trace](#) heaters [cables](#), the thermal output shall be measured by installation of a single 3 m to 6 m sample of [trace](#) heater [cable](#) on a Schedule 40 carbon steel pipe of 2 in (or metric equivalent) diameter or greater, as shown in Figure 4. The [trace heater cable](#) shall be installed in accordance with the manufacturer's instructions. The test apparatus shall be completely covered with a fiberglass thermal insulation of 25.4 mm or equivalent. A suitable heat transfer fluid in the liquid phase shall be circulated through the pipe at a sufficient rate to establish turbulent flow such that there is negligible temperature difference between the fluid and the pipe. The heat transfer medium shall be maintained at a constant temperature. 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 will not differ by more than 2 °C from end to end.

For surface heating [units](#) [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 [unit](#) [device](#).



(New)



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Figure 4— Verification of rated output

4.2.11.3.2 Outdoor exposed surface heating

For heating devices intended for outdoor exposed surface heating, the test apparatus shall be constructed and placed in an environmental chamber as described in 4.2.13.2.2, with the exception that the [trace heater cable](#) crossover need not be included in the construction. Alternatively, if the heating device is intended for ice/snow melting, the heating device may be placed in an ice bath to simulate the operation of the heating device.

4.2.11.3.3 Embedded heating

For heating devices intended for embedded heating, the test apparatus shall be constructed and placed in an environmental chamber as described in 4.2.13.2.3, with the exception that the control joint and [trace heater cable](#) crossover need not be included in the construction.

4.2.11.3.4 Heating inside of conduit/pipe

For heating devices intended for heating inside of conduit/pipe, the test apparatus shall be constructed and placed in an environmental chamber as described in 4.2.13.2.4, with the exception that the vertical run of conduit/pipe and [trace heater cable](#) crossover need not be included in the construction.

4.2.12 Verification of startup current

This test is applicable to heating devices that have a positive temperature coefficient of resistance greater than that of copper (ASTM Standard B193, Section 7).

The startup current of the heating device shall be measured at the manufacturer's minimum designated startup temperature. A sample of [trace](#) heater ~~cable~~, at least 1 m in length is installed in accordance with the manufacturer's instructions on a minimum 2 in diameter fluid-filled steel pipe or solid metal rod, or a sample of the surface heating [unit](#) ~~pad or panel~~ shall be installed on a flat metal plate. 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 4.2.11.3.1 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 at least 300 s. The startup current reported shall be the highest current response of three samples. This time-current characteristic shall not be more than the value declared by the manufacturer.

4.2.13 Verification of sheath temperatures

The sheath temperatures of heating devices must be constrained to prevent overheating during worst-case conditions. Factors limiting the sheath temperature include the maximum allowable exposure temperature of the heating device, the maximum allowable exposure temperature of the surface to be heated, and, for hazardous locations, the auto-ignition temperature of the potential hazard.

At least one of the following three methods must be used to demonstrate that the maximum sheath temperature of the heating device will not exceed temperature limitations of the application:

- a) *Product classification*: The maximum sheath temperatures are generated in an artificial environment simulating worst-case conditions. See 4.2.13.1.

- b) *Stabilized design*: The maximum sheath temperatures are determined by calculation of the energy balance of the system under worst-case conditions, without thermostatic control. The manufacturer must demonstrate the ability to predict maximum sheath temperatures by conducting tests on specific installations, in accordance with 4.2.13.2.
- c) *Controlled design*: The system temperatures are limited by the use of thermostats or controllers where the sensing element is used to monitor the temperature of the surface of the device, the temperature of the surface to be heated, or the ambient temperature. The manufacturer must demonstrate that the sheath temperatures will be adequately constrained by the function of the controller and where applicable by limitation of use through surface markings or instructions.

For hazardous locations, the test conditions and the determination of the test results are defined by IEEE Std 515.

4.2.13.1 Product classification approach

A sample of [trace](#) heater [cable](#) at least 1.5 m in length is placed loosely coiled in a forced air circulation oven. For a surface heating [unit](#), 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 thermocouples 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 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 difference (AT) between the two approaches 5 °C or less. A curve is drawn from the test data, and a straight line is drawn tangent to the curve at the 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 5.

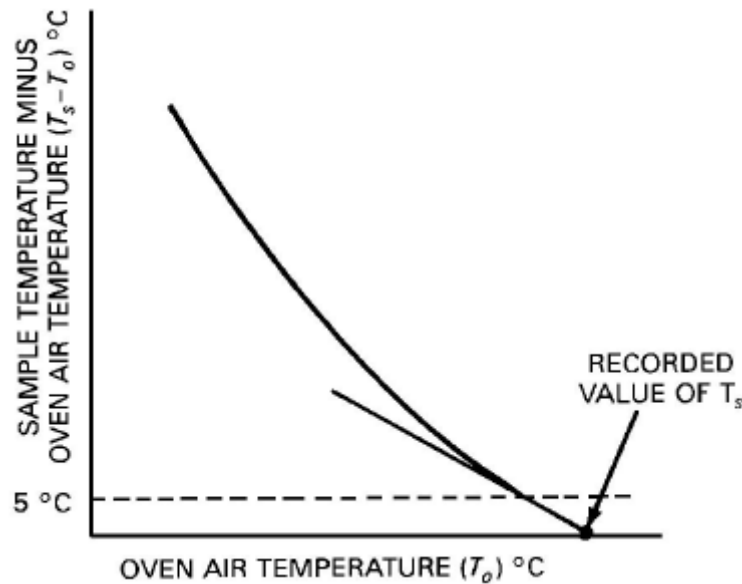


Figure 5 — Maximum sheath temperature using the product classification approach

4.2.13.2 Stabilized design approach

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

The procedures outlined in 4.2.13.2.1 through 4.2.13.2.4 are applied according to the installation type defined in Table 1. The measured sheath temperatures shall not exceed the manufacturer's calculated values by more than 10 °C.

Alternative simulated operating conditions may be agreed [upon](#) between the certifying agency and the manufacturer.

4.2.13.2.1 Insulated surfaces (including pipe)

For [trace](#) heaters ~~cables~~, the test apparatus as shown in Figure 6 shall consist of a 3 m horizontal run and [a](#) 1.5 m vertical run of piping having a pipe size between 50 mm and 150 mm [in](#) diameter. A flanged gate valve or equivalent (butterfly valve, globe valve, etc.) shall be located in the center of the horizontal run. The vertical run should be so arranged that the flanged pipe ends are in the center. The [trace](#) heater ~~cable~~ shall be installed in a manner consistent with the manufacturer's installation instructions. The [trace](#) heater ~~device~~ shall cross over itself at the valve if the manufacturer's installation instructions allow it. Thermocouples shall be used to monitor the pipe and valve surface temperatures and [trace heater](#) ~~cable~~ sheath temperatures. The thermocouples 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 thermocouples located at the discretion of the certifying agency. System temperatures shall be allowed to stabilize and thermocouple readings recorded.

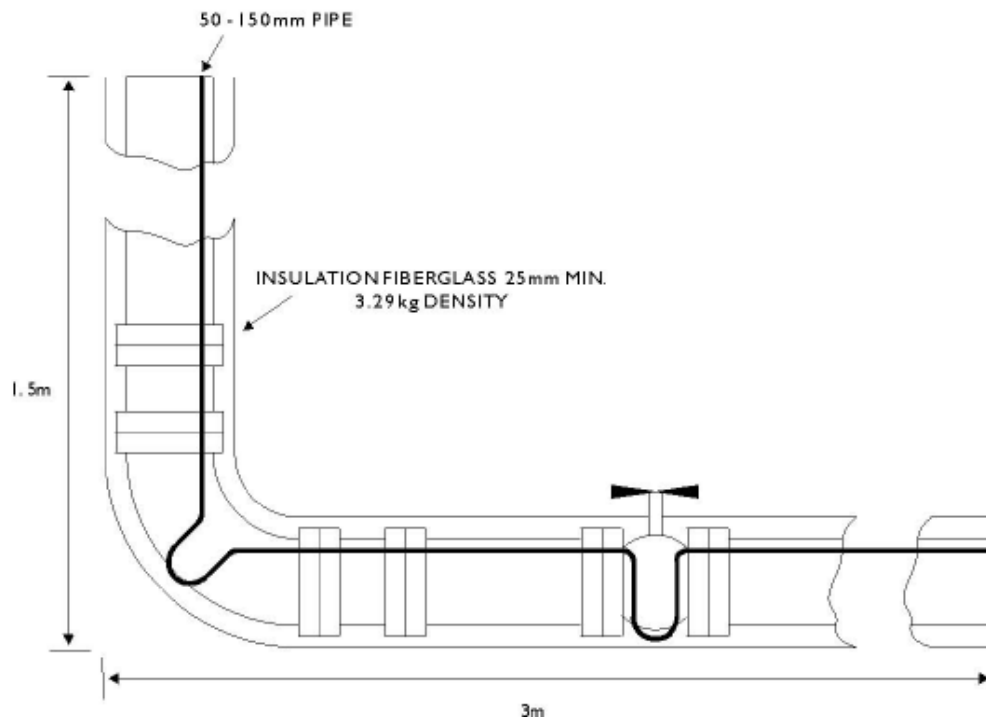


Figure 6 — Verification of sheath temperature using the stabilized design approach

For surface heating [units devices](#), a representative section shall be applied to a 6 mm steel plate, representative of the application in accordance with the manufacturer's installation instructions. The steel plate shall not extend more than 2.5 mm from any edge of the surface heating [unit](#). Thermocouples shall be used to monitor the temperature of the external surface of the [surface heating unit](#). The thermocouples 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 shall then be located in a stable room temperature environment in a vertical orientation. After stabilization, the thermocouple readings are recorded, including the local ambient temperature.

4.2.13.2.2 Outdoor exposed surface heating

For heating devices in roof and gutter applications, the test apparatus shall consist of a simulated roof consisting of a fir plywood panel 1.2 m x 1.8 m mounted at an angle of 45° to the horizontal. In addition, the fixture shall include a 1.8 m horizontal run of gutter and a 2 m vertical rise of downspout. The section of gutter shall have a single pass of the heating device, and the downspout shall have a dual pass of the heating device. Installation shall be made on the roof and gutter with attachment devices in accordance with the manufacturer's instructions. The heating device shall cross over itself on the roof if the manufacturer's installation drawing allows it. The sheath of the heating device shall have thermocouples installed at the midpoints of both the vertical and the horizontal runs as well as in the midpoint of the roof run (and the crossover if applicable). The gutter, roof, and downspout heating devices shall be energized in no wind conditions. The highest sheath temperature shall be recorded.

For heating devices intended for surface heating applications, such as the deicing of rails and metal structures, the test apparatus shall consist of a steel plate, rail, or other mounting surface having a thickness of at least 6 mm. The heating device shall be installed on the mounting surface, with expansion loops where applicable, along with any accessories in accordance with the manufacturer's installation instructions. Thermocouples shall be used to monitor the mounting surface as well as the heating device sheath. Thermocouples shall also be located at any anticipated hot spots to the discretion of the certifying agency. For maximum temperature testing, the apparatus shall be placed in an environmental chamber at the maximum ambient temperature and the maximum heating device sheath temperature shall be recorded.

4.2.13.2.3 Embedded heating

For heating device applications embedded in media such as ~~in~~ concrete, the test apparatus shall consist of a 1 m x 1 m x 90 mm minimum thickness slab (no reinforcing steel) and one control joint (3 mm deep) across the width. The heating device shall be installed per the manufacturer's installation instructions at the maximum watt density and minimum spacing. The heating device shall cross over itself if the manufacturer's installation instructions allow it.

Where insulated coverings are applied to the surface(s) of the embedding media in the application, a covering of material of equivalent *R*-value shall be applied to each surface during the test. Thermocouples shall be installed in the embedding media between two successive heating device passes, on the heating device sheath in the center-most area, and on the sheath of the heating device where the heating element or [trace heater](#) ~~cable~~ comes out of the concrete. Thermocouples shall also be located at any other anticipated hot spots at the discretion of the certifying agency.

The test apparatus shall be placed in an environmental chamber on 50 mm of rigid polyurethane insulation. The environmental chamber shall be raised to the maximum ambient temperature, and the maximum sheath temperature shall be recorded.

For heating device applications on or under floors, the test apparatus shall be at least a 1 m x 1 m section of floor constructed to be representative of the intended installation. The heating device shall be installed as per the manufacturer's installation instructions with any accompanying floor coverings at the maximum watt density and minimum spacing. The heating device shall cross over itself if the manufacturer's installation instructions allow it. Thermocouples shall be installed in the floor between two successive heating device passes and on the heating device sheath in the center-most area. Thermocouples shall also be located at any anticipated hot spots at the discretion of the certifying agency.