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

IEEE Industry Applications Society

Sponsored by the
Petroleum and Chemical Industry Committee

515.1™

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Abstract: Specific test requirements for qualifying electrical resistance heat tracing for commercial service. 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, installation, maintenance, snow melting, testing

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Introduction

This introduction is not part of IEEE Std 515.1-2005, IEEE Standard for the Testing, Design, Installation, and Maintenance of Electrical Resistance Heat Tracing for Commercial Applications.

The utilization of electrical resistance heat tracing 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 heat tracing 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 heat tracing systems for the intended use.

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Participants

This standard was developed by members of the 515.1 Working Group, with technical input from a panel of invited experts. The expertise of the panel members within their respective engineering firms includes the development of specifications and circuit designs for electrical resistance heat tracing for one or all of the applications included herein. At the time this standard was completed, the IEEE Industrial Application Society Working Group had the following membership:

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Contents

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

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 heat tracing 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™[1] as well as any other applicable codes and standards.

1.2 Purpose

The provisions of this standard should ensure that adequate material temperatures are maintained and that electrical, thermal, mechanical, and water-exclusion durability are provided to the heat tracing system. In addition, it should provide that under normal use, the products will exhibit long-term performance reliability 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.

[1] Information on references can be found in Clause 2.

2. Normative references

The following referenced documents are indispensable for the application of this standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

ASTM B193, Standard Test Method for Resistivity of Electrical Conductor Materials. [2]

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 G26, Practice for Operating Light-Exposure Apparatus (Xenon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials.

CFR (Code of Federal Regulations) Publication 29, Part 1910 (OSHA) § 1910.151 (c).[3]

IEEE Std 515, IEEE Standard for the Testing, Design, Installation, and Maintenance of Electrical Resistance Heat Tracing for Industrial Applications. [4]

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

NFPA 70, National Electrical Code® (NEC®).[6]

UL 50, Enclosures for Electrical Equipment.[7]

3. Definitions

For the purposes of this standard, the following terms and definitions apply. The glossary in Annex B and *The Authoritative Dictionary of IEEE Standards* [B10][8] should be referenced for terms not defined in this clause.

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

[1] 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/).
[2] 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).
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[5] NEMA publications are available from the National Electrical manufacture 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.html).
[7] UL publications are available from Underwriters Laboratories, Inc., 333 Pfingsten Road, Northbrock, IL 60062-2096, USA. Standards information is available at http://ulstandardsinfonet.ul.com. Publications are available at http://global.ihs.com.
[8] The numbers in brackets correspond to those of the bibliography in Annex A.

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

3.3 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.

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 tracing	4.1 and 4.2 Sprinklers—4.6
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 Tracing	Embedded snow melting Embedded frost heave protection Embedded floor warming Embedded energy storage systems Embedded door frames	4.1, 4.2, and 4.4
D	Installations with tracing inside of conduit or piping	Snow melting cable 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
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.[9]

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

[9] Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the standard.

4.2 Type test—insulated surfaces

Heat tracing 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 heating 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 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 MΩ.

4.2.3 Water resistance test

A sample of the heating device with integral components (at least 3 m in length for heating cable) shall be immersed in water at 10 °C to 25 °C for a period of 336 h (14 days).[10] 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 heating cable) shall be placed in a water flow and drain apparatus as shown in Figure 1.[11] 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

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

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 simultaneously the heating device is 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.

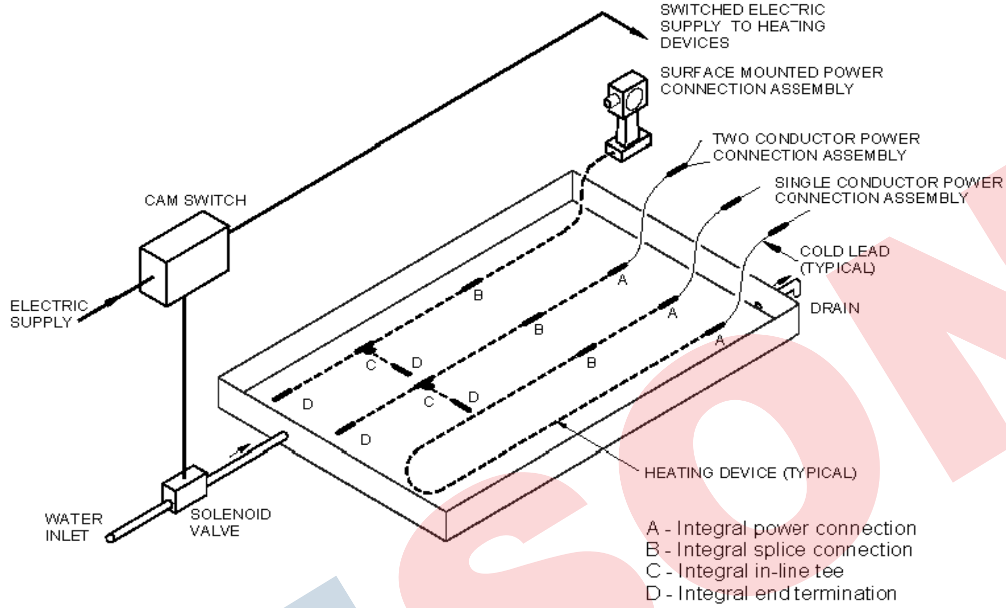

Figure 1—Water flow and drain apparatus

4.2.5 Elevated temperature exposure test

A sample of a heating device with integral components (at least 3 m in length for heating cable) shall be placed in a forced-circulation air oven. The oven shall be heated to, and maintained at, a temperature of 25 °C ± 5 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. Heating 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 heating cable. Surface heating 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 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 plus 20% or minus 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 (1) the lowest rated voltage level and the maximum rated output, and (2) 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 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 h ± 24 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 ±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 output for series cables or rated voltage for parallel cable. Surface heating 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 plus or minus 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 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 conditioned, 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 °C ± 5 °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 °C ± 5 °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 °C, the lower temperature may be set at 350 °C below the maximum continuous operating temperature.

The energized samples shall be exposed to each of these temperature extremes for a minimum of 15 min, and a transition time between extremes shall not exceed 15 min, with a cycle being one complete exposure at both temperature extremes.

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 (plus or minus 1 °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 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 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 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. 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.

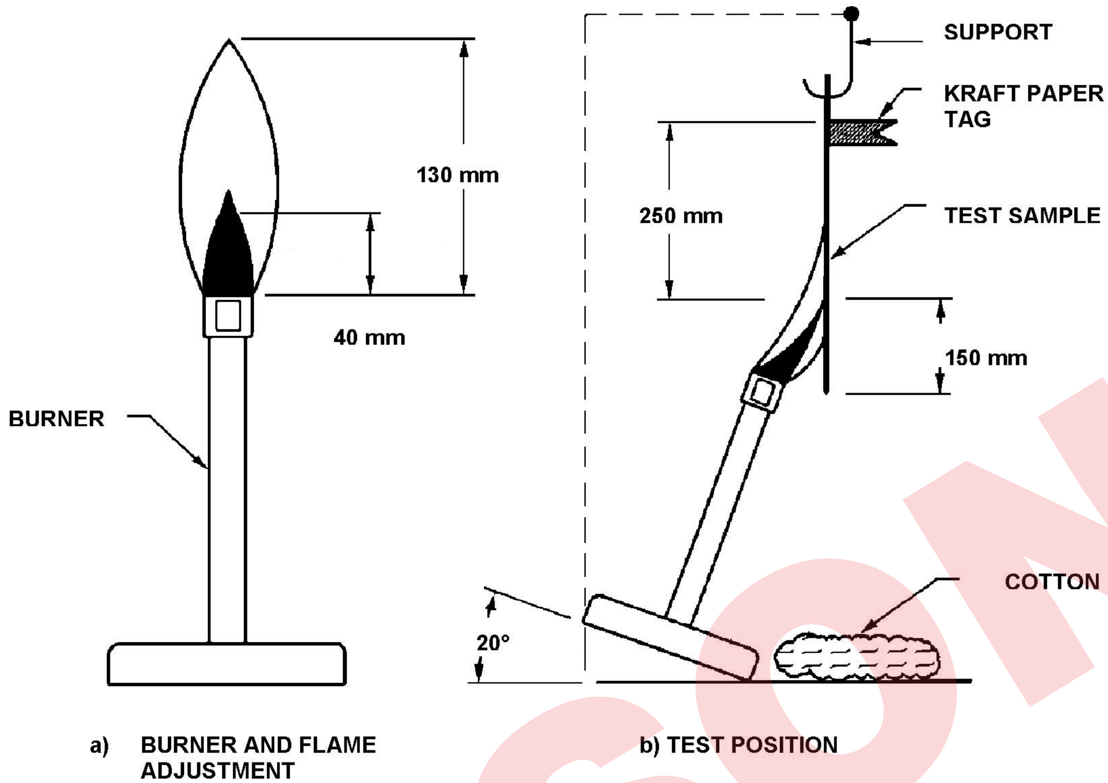

Figure 2—Flammability test

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 heating cable, it is placed across the specimen at right angles. For 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. 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, whereas 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 3, with the radius of the steel mandrels as shown, or with the radius equal to the manufacturer's stated minimum bend radius.

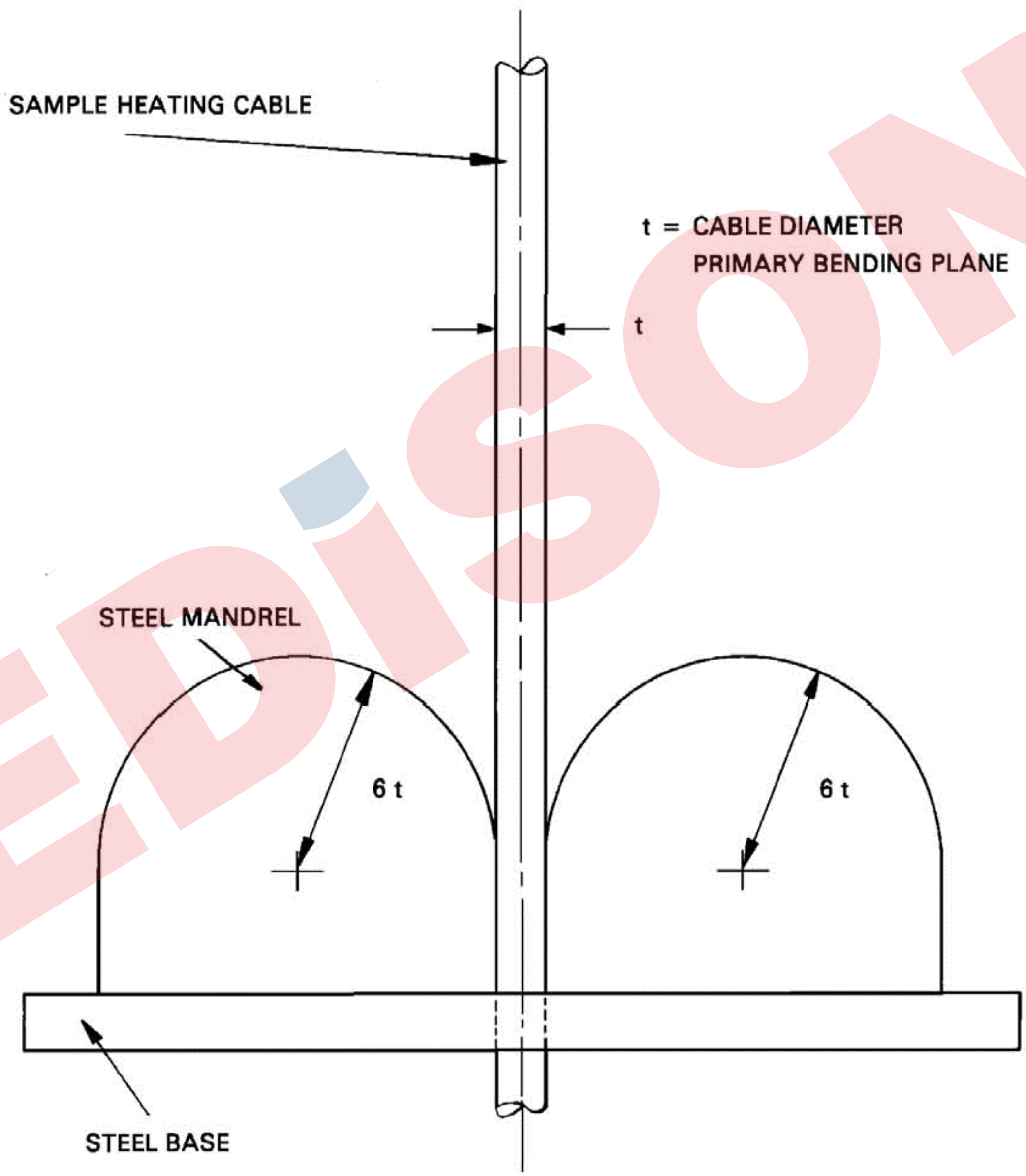

Figure 3—Cold bend test apparatus

A sample of heating 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 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 heating cables, the thermal output shall be measured by installation of a single 3 m to 6 m sample of heating cable on a schedule 40 carbon steel pipe of 2 in. (or metric equivalent) diameter or greater, as shown in Figure 4. The 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 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.

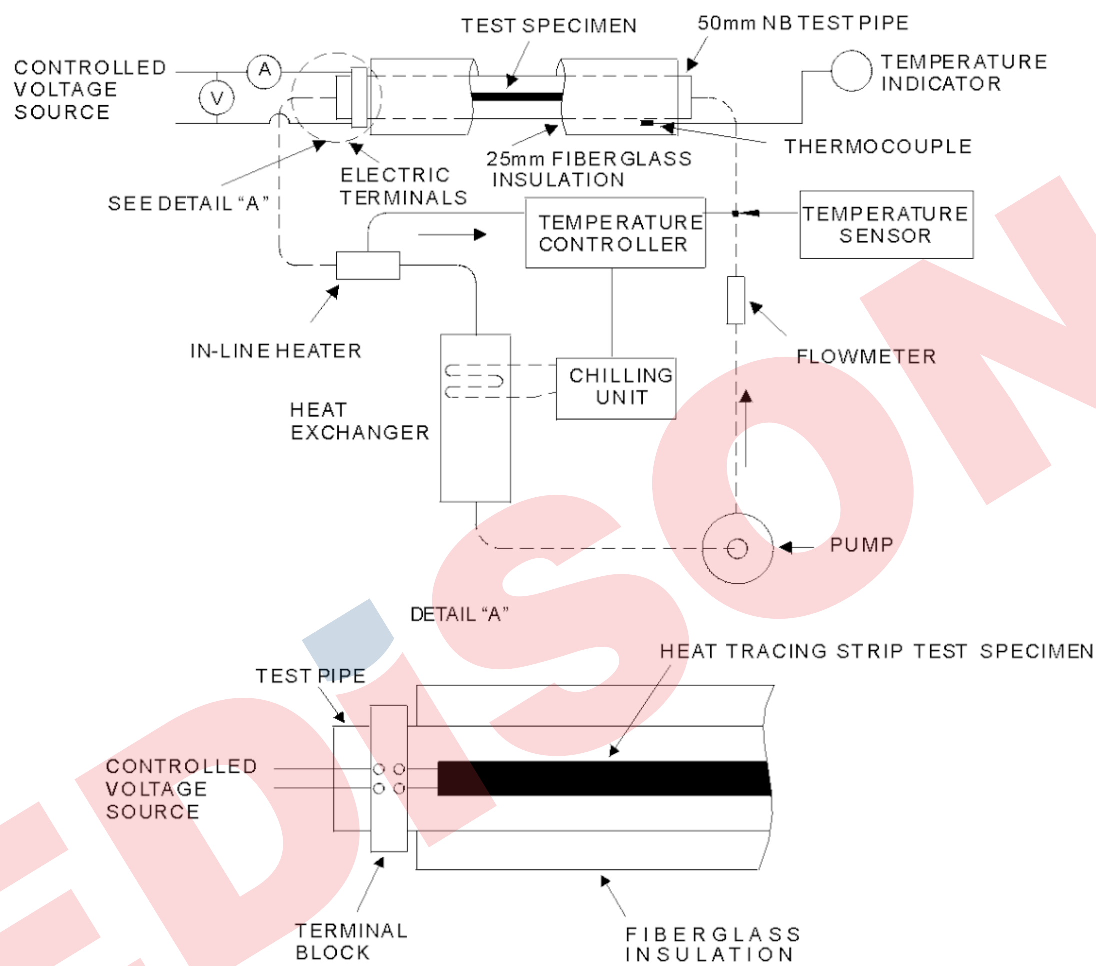

Figure 4—Verification of rated output

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 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 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 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 B-193, section 7).

The startup current of the heating device shall be measured at the manufacturer's minimum designated startup temperature. A sample of heating 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 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 heating cable at least 1.5 m 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 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 (ΔT) 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.

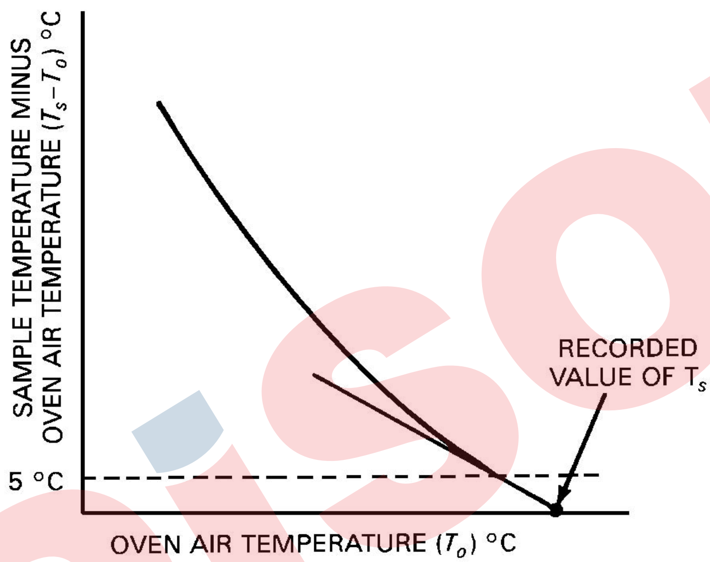

Figure 5—Maximum sheath temperature using the product classification approach

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 between the certifying agency and the manufacturer.

4.2.13.2.1 Insulated surfaces (including pipe)

For heating cables, the test apparatus as shown in Figure 6 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.) 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 heating cable shall be installed in a manner consistent with the manufacturer's installation instructions. The heating 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 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.

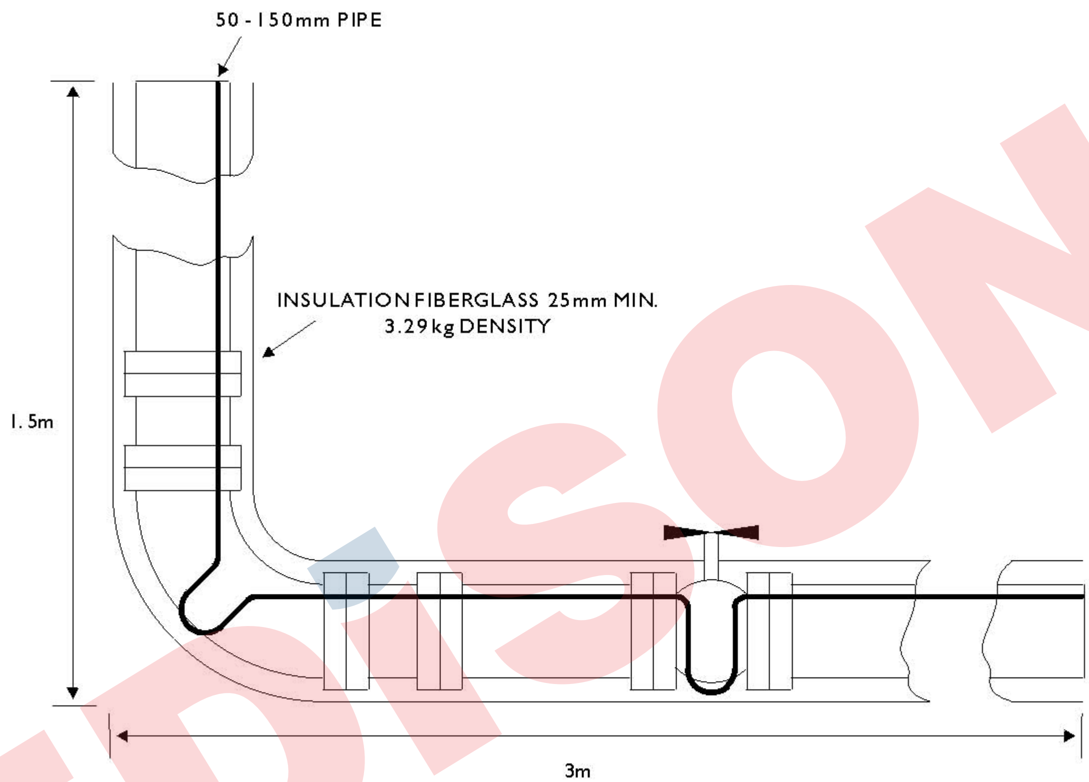

Figure 6—Verification of sheath temperature using the stabilized design approach

For surface heating 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 heater. Thermocouples shall be used to monitor the temperature of the external surface of the heater. 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 × 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 de-icing 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 × 1 m × 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 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 × 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.

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.

4.2.13.2.4 Heating inside of conduit/pipe

For internal heating devices in conduit/pipe, the test apparatus shall consist of a 3 m horizontal run and a 1.5 m vertical run of conduit/pipe of a size representative for the application. The heating device shall be installed in accordance with the manufacturer's installation procedures. The heating device shall cross over itself if the manufacturer's installation instructions allow it. Thermocouples shall be used to monitor the fittings as well as the heater sheath and the conduit/pipe. Thermocouples shall be located at anticipated hot spots at the discretion of the certifying agency.

The test apparatus shall be placed in an environmental chamber, and the chamber ambient shall be raised to the maximum ambient temperature. The maximum sheath temperature in free air shall be recorded.

4.2.14 Verification of conductive layer conductivity

A conductive layer is required as part of the heating cable construction and shall cover at least 70% of the surface. For surface heating devices (panels), an integral metallic screen, grid, or equivalent conductive layer on the exposed surface opposite the surface to be heated shall be incorporated into the construction.

Additional consideration shall be applied by the certifying agency for evaluation of equivalent materials other than metallic braid or sheath.

4.2.14.1 Operating ground-fault sensing or interrupting devices

If the conductive layer is intended for providing an electric path to operate a ground-fault sensing or interrupting device, 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. For surface heating devices, a representative sample shall be used. The resistance shall be equal to or less than the manufacturer's declared value and shall be capable of activating a ground-fault device or sensing and relaying device as intended by the NEC (NFPA 70) on the maximum recommended length of the heating cable or largest area surface heating device.

4.2.14.2 Operating conventional circuit breakers

If the conductive layer is intended for providing a ground path to operate a conventional circuit breaker without ground-fault sensing or interrupting devices, the conductive layer shall meet the requirements of 4.2.14.2.1 or 4.2.14.2.2.

4.2.14.2.1 Grounded conductive layer—low impedance

If a conductive layer is intended to be a ground path, then the dc conductance shall not be less than the conductance of the largest conductor under evaluation, based on the resistance of an equivalent squared millimeter copper conductor, but in no case less than 0.81 mm^2. This measurement shall be performed with an ohmmeter and a specimen of sufficient length to provide an accurate reading within the meter's capability. The conductance per unit length shall be established by taking the reciprocal of the resistance measured and multiplying it by the specimen length

4.2.14.2.2 Grounded conductive layer—other than low impedance

Alternatively, the conductive layer may be evaluated by installing a 3 m long sample of heating cable on a flat horizontal surface that is both noncombustible and electrically nonconductive. The heating cable shall be installed in three parallel runs and shall not be kinked or crossed over itself. The distance between parallel runs shall be 150 mm. A thermocouple shall be affixed to the surface of the sample in the middle run to measure the sheath temperature. Four layers of cheesecloth shall then be laid over the entire heating cable and thermocouple installation.

A 50 Hz or 60 Hz variable voltage source shall be connected across the ends of the conductive layer. A voltmeter and ammeter shall be connected to measure the voltage and current of the test circuit. The variable voltage supply shall be adjusted so that a three-stage test current, equal to the multiplier shown below times the maximum allowable branch circuit overcurrent protection specified by the manufacturer to which the unit can be connected in use, will flow through the conductive layer for the times specified as follows (Table 4):

Test current = multiplier $\times$ maximum branch circuit overcurrent protection

Table 4—Test current multiplier stroke test time

Stage	Multiplier	Test time
1	1.10	7 h
2	1.35	1 h
3	2.00	2 min

The results of the test shall be acceptable based on all of the following criteria:

a) The cheesecloth does not ignite or smolder

b) The cable insulation has no visible damage

c) The sheath temperature does not exceed 200 °C as measured by the surface thermocouple

4.2.14.3 Bonding of metallic coverings

Metallic coverings not intended as a grounding path (high resistance metallic sheath) shall be bonded to ground. Furthermore, the installation instructions for the heating device shall conform to item f) in 5.3.

4.2.15 Strain relief test for fittings

Fittings designed to terminate exposed heating cables directly to an exposed enclosure shall be subjected to strain relief testing. One sample of each strain relief fitting will be subjected to the test. The specimens will consist of at least 300 mm of heating cable attached to the subject fitting according to the manufacturer's instructions. A steady load of 9 kg for conductors smaller than 0.81 mm^2 and 16 kg for all other cases is to be gradually applied between the heating cable and the fitting. The load shall be maintained for a period of 1 min. As a result of this test, the heating cable shall not loosen or separate by more than 1 mm from the fitting, and there shall be no damage to the conductors, insulation, or fitting.

4.2.16 Enclosure considerations

Enclosures, mounting brackets, and associated components shall be evaluated for their intended environments in accordance with applicable national or international standards, or they shall be approved for use with the heating device by a certifying agency.

4.3 Type test—outdoor exposed surfaces

Deicing of outdoor exposed surfaces (such as roof surfaces, gutters, and downspouts) requires the use of electric heat tracing systems that can meet severe environmental constraints. In addition to the type tests described in 4.2, systems for use in outdoor locations (type B applications as defined in Table 1) shall also meet the requirements of 4.3.1 through 4.3.5.

4.3.1 Increased moisture resistance test

A sample of the heating device with integral components (at least 3 m in length for heating cable) shall be immersed in water at 10–25 °C for a period of 2000 h (12 weeks).

After conditioning, the sample shall be subjected to the dielectric voltage outlined in 4.2.1 for 1 min without dielectric breakdown.

4.3.2 UV and condensation test

A sample of the heating device, approximately 300 mm in length, including integral components, shall be hung vertically in the drum of a xenon-arc light-exposure apparatus as described in ASTM G150-00a.

The procedure shall be as described in ASTM G151 and ASTM G155 for a total period of 500 h. The cycle shall be set for 102 min of light and 18 min of combined light and water spray. At the end of this time, the sample shall be removed from the chamber and subjected to the impact test in 4.2.9 and cold bend test in 4.2.10. The outermost sheath shall be subjected to a dielectric voltage of 500 V ac, applied between the conductive layer and water for 1 min without dielectric breakdown.

Heating devices and integral components having a continuous metal sheath with no outer jacket shall be exempt from this test.

4.3.3 Resistance to cutting test

A sample of heating device, at least 200 mm in length, shall be used for testing. The sample shall be placed on top of a rigid flat steel support. A cutting surface with a 0.25 mm radius edge shall be mounted to a piston hanging above the sample such that the cutting surface is at a right angle to the sample. An ohmmeter shall be attached to the heating device conductors shorted together, and to the metal cutting surface.

A proof load of 445 N is to be gradually applied to the sample. The cutting edge shall not cut through to the conductors of the heating device, as indicated by the ohmmeter.

4.3.4 Abrasion test

Six straight samples of the heating device, approximately 910 mm, shall be prepared. The metallic covering shall be evaluated initially for electrical resistance of the shield with an ohmmeter having an accuracy of ±1%. The average resistance for the samples shall be calculated. The samples shall be attached to a horizontal reciprocating table while the table is at one end of its travel. The other end of each specimen shall be attached to a weight of 340 g. Each specimen shall be laid over a 90 mm radius cylinder covered with an unused layer of grade 1/2 (medium) emery cloth, or 120 grit silicon carbide/resin bond sand paper, as shown in Figure 7. The longitudinal axis of the cylinder shall be horizontal and perpendicular to each of the vertical planes that contain the specimens as they are rubbed against the abrasive cloth.

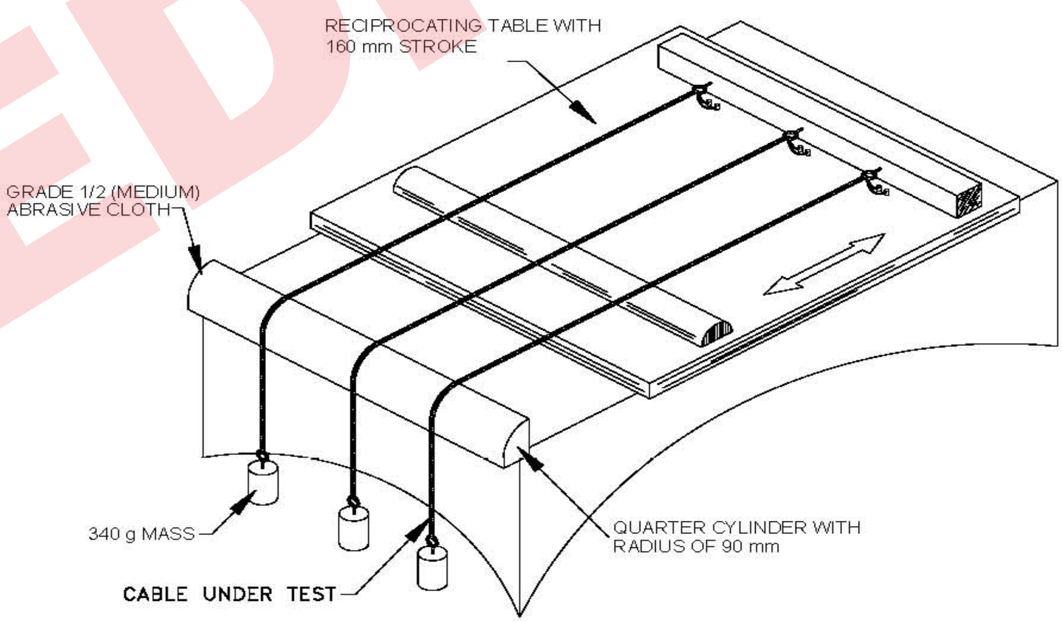

Figure 7—Abrasion test

The table shall be started in its horizontal reciprocating motion at the rate of approximately 30 cycles per minute. Each cycle shall consist of one complete back and forth motion with a stroke of approximately 160 mm. The table shall be stopped every 50 cycles, and the abrasive cloth shall be slightly shifted to one side so that in subsequent cycles, each specimen shall be subject to wear by a fresh surface of the cloth. After 2500 cycles, the test shall be stopped and the resistance of the conductive layer shall be measured again. The average conductive layer resistance shall be calculated and compared with the initial value. There shall be no broken strands, and the resistance value shall not exceed 125% of the initial value. For overjacketed cables, the underlying conductive layer shall not be exposed.

4.3.5 Tension test

A 32 kg weight (intended to simulate the weight of a 50 mm × 100 mm × 6 m long section of ice) shall be suspended from the free end of the heating section, whereas the other end of a 900 mm portion shall be secured tightly. The test duration shall be 1 h. There shall be no breakage of the conductors or conductive layer, and there shall be no damage to the insulation.

4.4 Type test—installations with embedded tracing

Embedded tracing applications are typically subject to crushing forces during installation. In addition to the tests in 4.2, heating device systems intended for embedding (type C applications as defined in Table 1) shall also meet the requirements of 4.4.1 and 4.4.2.

4.4.1 Resistance to cutting test

This test is described in 4.3.3.

4.4.2 Resistance to crushing test

A minimum 200 mm sample shall be placed in a compression device, between the flat rigid steel plates mounted horizontally and parallel to each other. As shown in Figure 8, the dimensions of each plate shall be 51 mm in the horizontal direction (width) parallel to the longitudinal axis of the heating cable.

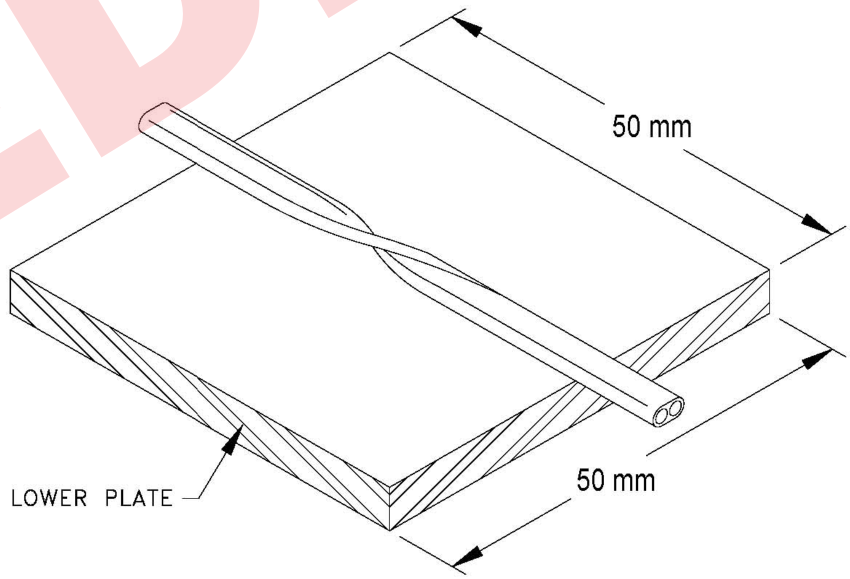

Figure 8—Resistance to crushing test

If applicable, the sample shall be twisted 180° between the plates, to cause the conductors to overlap during the compression. A force of 8900 N shall be applied gradually to the plates. There shall be no electrical contact between the two conductors, or between the conductors and the conductive layer and plates. The measurement shall be evaluated by monitoring for conductance with an ohmmeter.

4.5 Type test—tracing inside of piping or conduit

Tracing for installation inside of piping or conduit shall meet the requirements of 4.5.1 and 4.5.2, in addition to the requirements of 4.2 (type D applications as defined in Table 1).

4.5.1 Increased moisture resistance test

The procedures in 4.5.1.1 or 4.5.1.2 are applicable, depending on whether the intended use is a nonpressurized or pressurized application.

4.5.1.1 Nonpressurized systems

A sample of the heating device with integral components (at least 3 m in length for heating cable) shall be immersed in water at 10–25 °C for a period of 2000 h (12 weeks).

After conditioning, the sample shall be subjected to the dielectric voltage outlined in 4.2.1 for 1 min without dielectric breakdown.

4.5.1.2 Pressurized systems

A sample of the heating device with integral components (at least 3 m in length for heating cable) shall be immersed in pressurized water for a period of 2000 h (12 weeks). The manufacturer's declared pressure rating plus 20% or 700 kPa (101 psi), whichever is greater, shall be applied continuously during the test. The water shall be maintained at 10 °C to 25 °C or at the manufacturer's declared maximum maintain temperature, whichever is higher.

After conditioning, the heating device shall be subjected to the dielectric voltage test as outlined in 4.2.1 for 1 min without dielectric breakdown. Additionally, there shall be no evidence of water leakage from any device components.

4.5.2 Pull-strength test

A 68 kg weight, or a weight equivalent to the manufacturer's stated maximum conduit pull strength value, whichever is greater, shall be suspended from the free end of a 1 m length of heating cable, while the other end is secured tightly. The test duration shall be 1 min. The weight shall then be removed, and the sample subjected to the dielectric voltage outlined in 4.2.1 for 1 min without dielectric breakdown. In addition, there shall be no breakage of the conductors or conductive layer and there shall be no damage to the insulation.

4.6 Sprinkler tests[12]

The heating device and its associated components shall meet all the applicable type tests in 4.1 and 4.2. These tests will validate the heating device's functioning on mains and supply piping. In addition, they

[12] Use of this section to certify heating devices and their associated components for use in the United States is restricted until NFPA 13-1994 [B11] is modified to cover the expanded use of these systems. Certifying agencies may then consider certifying the heating devices and their associated components for use on branch lines containing sprinkler heads.

shall pass the following tests in 4.6.1 through 4.7 to validate their use on branch lines containing sprinkler heads.

4.6.1 Sprinkler head over and under temperature test

The heating device shall be installed on the pipe fixture shown in Figure 9.

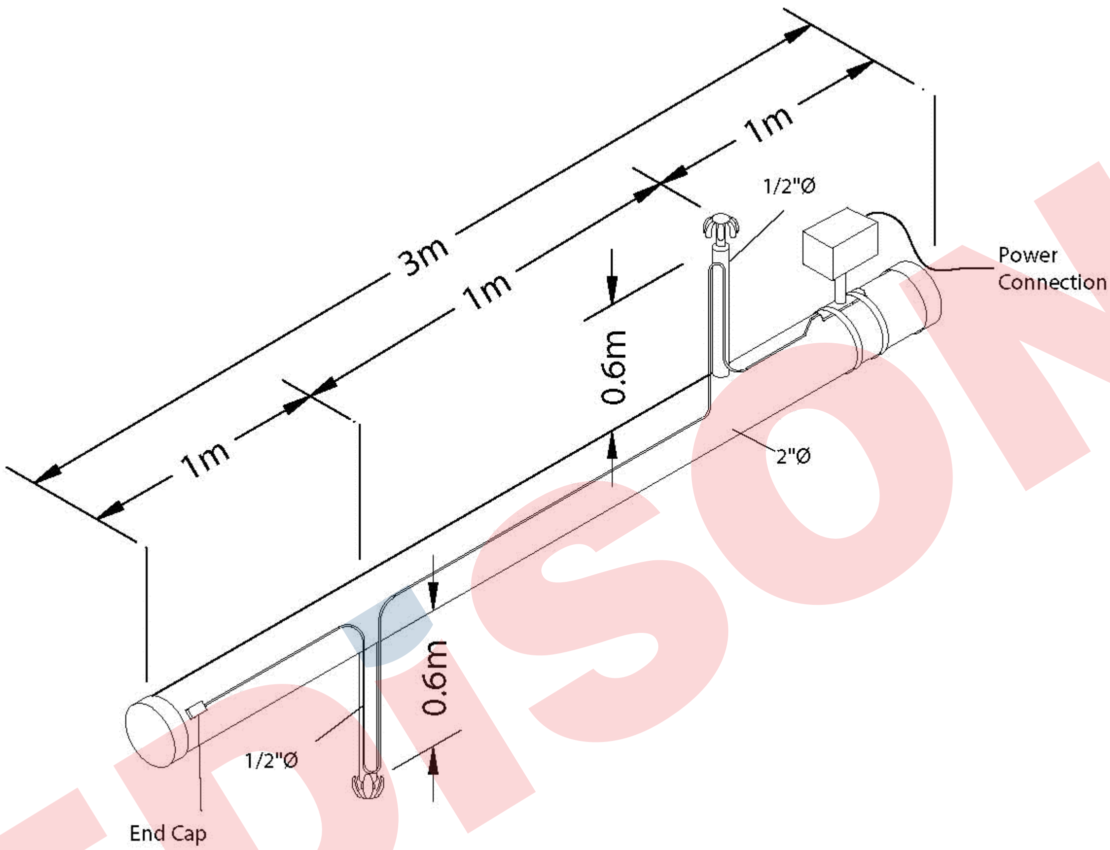

Figure 9—Sprinkler head over-temperature and under-temperature test

To simulate worst-case temperature conditions, no temperature control will be allowed to validate the reliability of the heating system in the event of a control system failure.

The branch line shall have one 0.5 in. pipe tee extended upward approximately 0.6 m from the branch line with a sprinkler head mounted at the end of it (to simulate the highest temperature condition, including chimney effects). The heat device shall be installed per the installation instructions provided by the manufacturer. Consideration should be given to likely over-insulation of this tee. This test will verify the maximum possible temperature for the head to verify the heat tracing will not falsely trigger the sprinkler head.

The branch line shall have the second sprinkler head installed on the bottom of the branch line from a tee fitting (to simulate low-temperature worst case). That sprinkler head will be heat traced per the manufacturer's recommended installation instructions, including exact location of thermal insulation in relationship to the sprinkler head. Thermal insulation must be installed in compliance with the applicable installation standard (e.g., NFPA 13-1994 [B11]) so as not to impede the sprinkler spray pattern. This sprinkler head will verify that no part of the sprinkler head that touches fluid will drop below freezing during minimum ambient temperatures. Indoor systems shall be exposed to 1–2 m per s and outdoor systems to 10 m per s air movement. If the system will be exposed to moving air, the sculpture shall be exposed to 1–2 m per s air movement during the minimum temperature portion of the test.

Each sprinkler head shall be monitored at the further most extremity of the body that is in contact with the fluid and at the activation bulb (that will trigger the sprinkler head).

The heating device shall be powered at the two design temperature extremes and allowed to stabilize before taking final temperature readings. The minimum design temperature and temperature readings shall verify that no fluid temperatures below 4 °C will occur in the head. Then the heating device shall be powered at its maximum declared ambient temperature and allowed to stabilize. The temperature readings from this portion of the test will verify that no false triggering will be caused by the heat tracing system.

The specific sprinkler head activation temperature ratings must be declared as part of the product ratings.

4.7 Routine testing

These tests shall be carried out during production or before shipment.

4.7.1 Output rating

The output rating for each shipped length of electric heating cable and for each surface heating device shall be verified by measurement of the dc resistance, conductance, or current at a given voltage and temperature. The value shall be within the manufacturer’s tolerance.

4.7.2 Dielectric test

The primary electrical insulation jacket of the heating device shall withstand a dry-spark test[13] at a minimum of 6000 V ac. As an alternative to the dry-spark test, the dielectric test in 4.2.1 may be conducted.

Nonmetallic overjackets shall withstand an additional dry-spark test with a minimum test voltage of 3000 V ac. As an alternative to the dry-spark test, the dielectric test in 4.2.1 may be conducted.

5. Markings and installation instructions

5.1 Product markings for heating devices

Heating devices intended for field fabrication shall be clearly and permanently surface marked with the following information. For heating devices with factory fabricated terminations, or surfaces where legible printing cannot be applied, this information shall be on a durable tag/label permanently affixed to the non-heating sheath within 75 mm of the power connection fitting or gland:

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

b) The catalog number, reference number, or model.

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[13] The dry-spark test shall have a substantially sinusoidal waveform at 2500 Hz to 3500 Hz. For a 3000 Hz supply, the speed of the wire in meters per second shall not be more than 33 times the length of the electrode in centimeters; this requirement is proportional to frequency.

c) The month and year of manufacture, date coding, applicable serial number, or equivalent.

d) The rated voltage for parallel heating devices or maximum operating voltage for series heating devices.

e) The rated power output in watts per unit length at the rated voltage (and at a stated temperature for devices that change output with temperature), the resistance in ohms per unit length for series cable, or the operating current or total wattage, as applicable.

f) Agency listing or approval.

g) If applicable, hazardous (classified) location markings, including temperature class or maximum surface temperature (where applicable).

5.2 Markings for field-assembled components

Field-assembled components shall be marked with the following information. In the case of components with small surface areas, or surfaces where legible printing cannot be applied, the markings may be placed on the smallest unit container in lieu of the component itself:

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

b) The catalogue number, reference number, or model.

c) The month and year of manufacture, date coding, applicable serial number, or equivalent.

d) Agency listing or approval.

e) Applicable environmental or area use requirements, such as NEMA 4, Type 4, IP ratings, and hazardous (classified) locations markings including temperature rating.

f) Any applicable warning/caution statements, e.g., "WARNING: De-energize circuit before removing cover."

5.3 Installation Instructions

The manufacturer shall provide specific installation instructions for heating devices and components. Instructions for various components and heaters may be combined where terminations/installation instructions are identical. The instructions shall be clearly identified as to the products and locations that apply, and they shall include the following information or equivalent:

a) The intended use(s) as shown in Table 1, by specific use as given in the column labeled "Examples."

b) The statement "Suitable for use with" and a listing of applicable heating devices, or a listing of applicable connection fittings.

c) The statement "Ground fault equipment protection is required for each circuit," unless applicable codes permit otherwise.

d) The statement "De-energise all power circuits before installation or servicing."

e) The statement "Keep ends of heating devices and kit components dry before and during installation."

f) The statement "The conductive layer of this heating device must be connected to a suitable grounding/earthing terminal." For conductive layers not intended as a ground path, the statement "The conductive layer of this device shall not be utilized as a grounding conductor, but must be bonded to ground" applies instead.

g) For pipe or vessel applications, the statement "The presence of the heating devices shall be made evident by the posting of caution signs or markings at appropriate locations and/or at frequent intervals along the circuit." For outdoor deicing and snow-melting applications, the statement "The presence of the heating devices shall be made evident by the posting of caution signs or markings where clearly visible."

6. Design, installation, and maintenance

6.1 Introduction

This clause covers specific applications of electrical resistance heat tracing in commercial areas. Each subclause (6.2 through 6.7) provides individual guidelines for the design, installation, and maintenance of the heat tracing.

6.2 Temperature maintenance of piping systems

6.2.1 Application description

Heating devices are typically applied to a piping system to maintain the fluid in the pipe at a specified temperature above ambient. The most common application is freeze protection for potable water and fire sprinkler lines. Other common applications include temperature maintenance of hot water piping, fuel oil lines, and grease lines. In all cases addressed, the piping system is assumed to be thermally insulated.

Heating device circuits intended for these applications shall meet the requirements for installation type A tracing as defined in Table 1.

6.2.2 Design information

The following general design conditions and application inputs are needed before commencing with the system design. Additional specific information that may be required is detailed in 6.2.5.

a) Parameters
   1) Pipe maintain temperature
   2) Minimum ambient temperature
   3) Insulation thickness and type
   4) Pipe diameter, length, and routing (vertical, horizontal, oblique)
   5) Pipe type
      i) Nonmetallic
      ii) Metal
   6) Piping components such as pumps, strainers, flanges, valves, and pipe supports
   7) Flow system
      i) Pressurized
      ii) Gravity
   8) Wind effects

b) Electrical considerations
   1) Voltage supply
   2) Circuit locations
   3) Area classification

6.2.2.1 Performance level classification system

Performance classification is of interest when considering control and periodic maintenance of the heating devices.

a) Category I (minimal): Residential potable water
b) Category II (moderate): Commercial potable water, hot water, drain and grease lines, and fuel oil
c) Category III (critical): Fire sprinklers and safety showers

Note that Category I is for reference only; it is not included in the scope of this standard.

6.2.2.2 General design considerations

Items of a general nature to be considered for system designs include the following:

a) The maximum circuit length and sizing of overcurrent protection as specified by the manufacturer.
b) For nonmetallic pipes, the heating system shall be evaluated to ensure that the maximum heating device temperature does not exceed the temperature rating of the pipe. The manufacturer shall also supply recommendations for these applications, including product performance and installation guidelines.

6.2.3 Heat loss determination

For outdoor freeze protection applications with glass fiber thermal insulation, heat loss rates in watts per meter are shown in Table 5. The table is based on the condition of a 9 m/s wind, a 4 °C maintain temperature, and a 10% safety factor, which is considered a minimum level. If a greater safety factor is recommended, the values in Table 5 should be divided by 1.1 and then multiplied by the new factor (such as 1.25 or 1.5). The heat loss rates are based on the formulas provided in IEEE Std. 515, Appendix A, and on the thermal conductivity of glass fiber.

Table 5—Outdoor freeze protection heat loss rates in watts/meter based on use of glass fiber insulation

Insulation thickness (mm)	Pipe size (in.)	Minimum ambient temperature –40 °C	–29 °C	–17.7 °C	–6.7 °C
20.5	1.0	10.8	8.2	5.6	3.0
	1.5	13.8	10.5	7.2	3.6
	2.0	16.4	12.5	8.5	4.3
	2.5	19.0	14.4	9.8	4.9
	3.0	22.0	16.7	11.5	5.9
	3.5	24.6	18.7	12.8	6.6
	4.0	27.2	20.7	14.1	7.2
40.0	3.0	16.1	12.5	8.5	4.3
	4.0	19.7	15.1	10.2	5.3
	6.0	26.9	20.3	13.8	6.9
	8.0	33.5	25.6	17.4	8.9
	10.0	40.7	30.8	21.0	10.5
50.0	6.0	21.3	16.4	11.2	5.6
	8.0	26.3	20.0	13.8	6.9
	10.0	31.8	24.3	16.4	8.2
	12.0	36.8	28.2	19.0	9.5

For other types of thermal insulation, the heat loss rate given in Table 5 is multiplied by the correction factor given in Table 6. The correction factors in Table 6 are based on insulation thermal conductivities at 10 °C. The heat loss rate should be adjusted for cases involving oversized insulation, as specified in item h) of 6.2.4.1.

Table 6—Insulation correction factors

Insulation type	Correction factor	Thermal conductivity at 10 °C W/(m·°C)	Btu·in/(h·ft²·°F)
Rigid cellular urethane (ASTM C591[B8])	0.66	0.024	0.165
Polyisocyanurate foam (ASTM C591[B8])[a]	0.75	0.027	0.180
Glass fiber (ASTM C547 [B4])	1.00	0.036	0.250
Foamed elastomer (ASTM C534 [B3]])	1.16	0.042	0.290
Mineral fiber blanket (ASTM C553 [B6])	1.20	0.043	0.300
Calcium silicate (ASTM C533 [B2]])	1.50	0.054	0.375
Cellular glass (ASTM C552 [B5]])	1.60	0.058	0.400

[a]Recommended for outdoor use only.

For conditions other than those presented here, the heat loss rates should be calculated from the formulas presented in Appendix A of IEEE Std 515. Additional information regarding the selection and design of the thermal insulation system can be found in the Federal Energy Administration document “Economic Thickness for Industrial Insulation” [B9] and the *Handbook of Thermal Insulation Design Economics for Pipes and Equipment* [B17].

6.2.4 Heater and component mounting

The proper design for temperature maintenance of any piping systems should include the positioning of the heaters and system components, These recommendations can vary depending on the end-use application, which includes outdoor use, installation on nonmetallic piping, and internal heat-tracing.

6.2.4.1 Metal pipes (external heat tracing)

The following recommendations apply to externally heat traced metal pipes:

a) The pipe should be spaced at least 50 mm from adjacent walls or ceilings to facilitate installation of thermal insulation.

b) Heating cable should typically be fastened to the pipe between 310 mm and 610 mm intervals with temperature rated plastic cable ties or fiberglass tape, aluminum tape, pipe straps, or tie wire. Caution shall be taken to avoid deforming polymeric jacketed cables by the use of cable ties or metal fastening devices. Compatibility of adhesives should be verified for use with stainless steel piping.

c) The heating cable should be attached to the lower portion of the pipe, at the four or eight o'clock positions, to minimize potential for mechanical abuse. Refer to Figure 10.

d) Valves, flanges, pipe supports, and other components typically require additional heat; extra heating cable shall be provided, as specified by the manufacturer.

e) Thermal insulation shall be suitable for the particular installation, such as outdoor or below grade use.

f) A moisture-proof weather barrier surrounding the thermal insulation shall be provided for outdoor applications.

g) Staples or sheet metal screws, as a means of fastening the insulation or weather barrier, are not recommended due to the potential for damage to the heating cable.

h) For rigid insulation types, the insulation internal diameter should be one size larger than the pipe (over-sized insulation) to accommodate the heating cable. Except for prefabricated piping, grooving or routing of rigid insulation is not recommended.

i) When a line sensing controller is specified, the sensing element should be placed on the pipe at least 90° around the circumference from the heating cable, or at least 50 mm from the cable, Refer to Figure 10. The sensing line should be routed to exit at the lower portion of the thermal insulation.

j) When using an ambient sensing temperature controller, the location of mounting should be representative of the coldest region, and the sensing element should not be exposed to direct sunlight or any additional heat source.

k) The power connection should be positioned at the four to eight o'clock positions to minimize potential for water ingress. Refer to Figure 11.

l) A low point drain in the conduit leading to the power connection box is recommended, as shown in Figure 11.

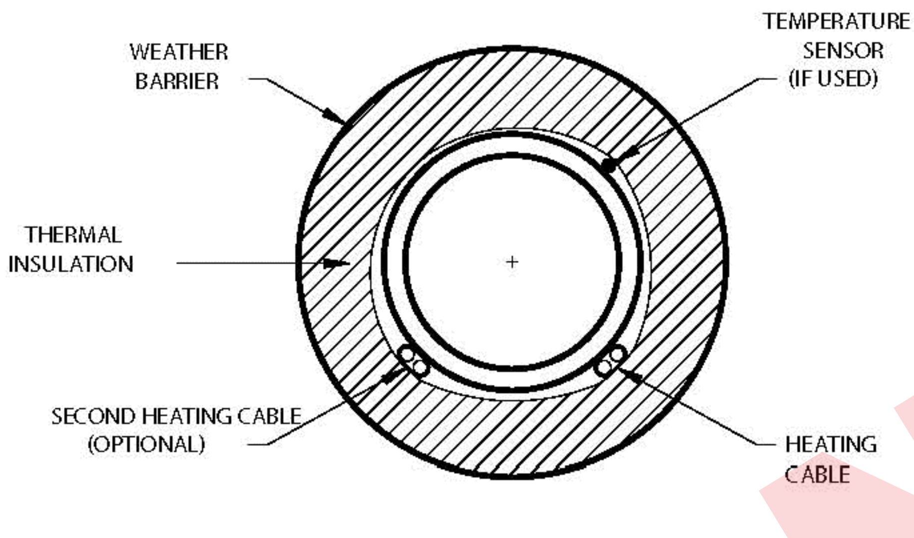


Figure 10—Recommended heating cable and sensor location

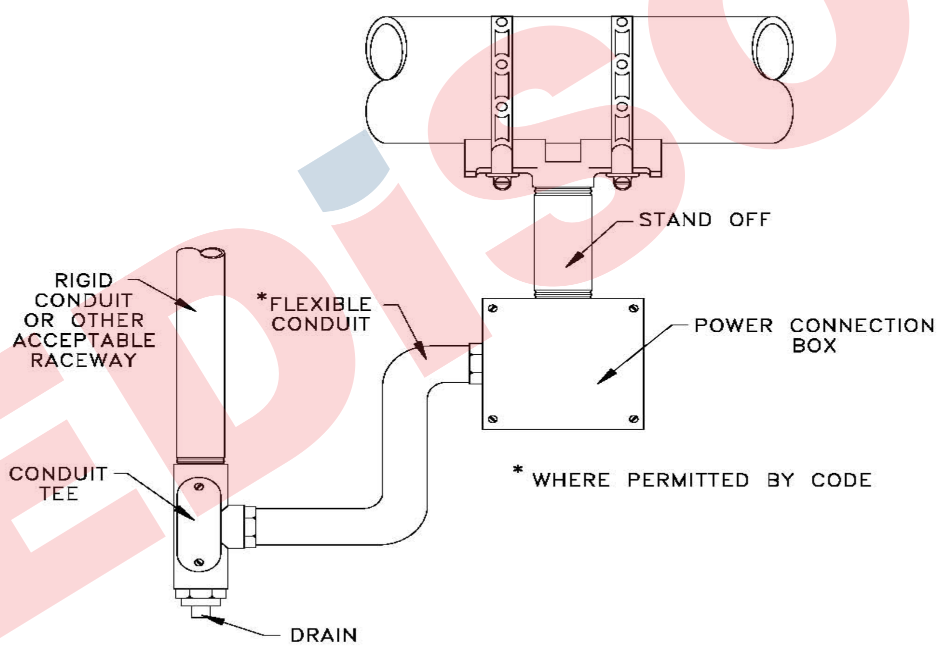


Figure 11—Conduit drain detail to prevent moisture accumulation

6.2.4.2 Nonmetallic pipes (external heat tracing)

Generally, all preceding recommendations for metal pipes also apply to nonmetallic pipes, with the following additional recommendations:

a) In addition to a normal attachment method, the cable should be covered continuously with aluminum tape along the entire cable length to enhance thermal coupling to the pipe.

b) If a line sensing temperature controller is used, the sensor should be placed 20.5–50 mm away from cable and fastened to the pipe with aluminum tape. The aluminum tape should not create a thermal path from the cable to the sensor.

6.2.4.3 Internal heat tracing

Internal heat tracing is used when external heat tracing is not practical. Internal heat tracing shall be properly fitted to make a watertight connection where the heating cable emerges from the pipe. Internal tracing of potable water lines shall also meet NSF Std 14 [B12], NSF Std 24 [B13], and NSF Std 61 [B14] guidelines. Cable circuits intended for this application shall also meet the requirements for Installation type D tracing as defined in Table 1. The manufacturer shall specify detailed application and installation procedures.

6.2.5 Special design considerations

Temperature maintenance of piping systems includes several specific applications that have different design considerations. Freeze protection, domestic hot water, fuel oil lines, and grease lines have separate requirements.

6.2.5.1 Freeze protection

When a freeze protection system is designed for commercial piping, the following special considerations may apply:

a) In the case of pre-insulated piping where the heating cable is located in a channel, the maximum sheath temperature and thermal output shall be specified by the manufacturer.

b) For energy conservation, line sensing temperature controllers are recommended for pipe sizes of 6 in. or larger, and for areas where the ambient temperature remains below 4 °C for several weeks at a time.

c) For emergency eyewash units, safety showers, and associated supply piping, the tracing is sized to prevent freezing, and the water temperature shall not exceed 35 °C by product or system design, or controllers.

6.2.5.2 Fire suppression sprinkler systems

Fire sprinkler systems have two basic systems: wet systems, where all the piping is constantly filled with water, and dry systems, where a control valve would flood the piping when a sensor or sprinkler head is activated.

Wet systems have been recognized as the simplest and most reliable systems. However, they have not been judged as practical for use in areas subject to freezing. Several approaches have been tried, including glycol-based antifreeze-filled systems. Environmental concerns with these systems have all but eliminated them as an approach. Dry systems, which are the recognized approach for most installations subject to freezing, have their own reliability issues, including:

— Dry systems rely on routine maintenance to prevent control valve leaks, which have been known to cause wet and frozen systems.

— In “pre-action” dry systems, failure of the control (flooding) valve to activate when required has been a noted problem.

— When these systems are activated, they have to be completely drained and dried out, which can be an expensive process.

— Pipe scale and rust are a concern and must be controlled to prevent sprinkler heads from plugging.

Wet systems are generally required in areas that do not freeze, because they are recognized as the most reliable systems. Using new heat tracing technologies and associated controls, it is now possible to protect wet systems in areas that are subject to infrequent freezing as well as areas traditionally protected by dry systems. These technologies include (1) monitoring the proper functioning of the heating device, (2) using a failsafe temperature control system, and (3) eliminating any possible overheating of the heating device.

Heat loss formulas have been developed and proven through 20 years of use to successfully predict pipe heat losses for minimum design conditions. Certification testing and design standards have been developed and proven since 1983. Heating cables have been reliably used for safety systems in nuclear power plants, off-shore fire suppression systems, personnel safety showers, and many other critical use systems.

a) System will normally be nonflowing; therefore, multiple pipe segments may be controlled by a single controller.

b) System installation details shall specify heat trace installation on sprinkler heads and location of thermal insulation adjacent to the sprinkler heads.

c) Products shall be certified for fire suppression system supply piping only or branch and supply lines.

d) The product ratings shall include the minimum sprinkler head activation temperature for which the system is approved. Minimum and maximum ambient temperature ratings shall be included.

e) For fire sprinkler lines, the tee section of the sprinkler head is often not thermally insulated. The additional heat required is typically provided by double tracing the tee section. Maximum uncontrolled temperature of the sprinkler head shall be verified to ensure that it is at least 3 °C below the activation temperature of the head in an ambient of 40 °C.

f) A low-temperature alarm, with remote alarm contact, shall be provided for each fire sprinkler line heating circuit. The recommended set-point is 2 °C.

6.2.5.3 Domestic hot water/tempered water

The following list contains mandatory requirements or recommendations for domestic hot water and tempered water systems:

a) Typical system design temperatures for domestic hot water and tempered water systems are listed in Table 7.

b) The local plumbing code and/or model plumbing code shall be consulted for heating of nonmetallic pipes.

c) The operating temperature and the maximum system temperature shall be verified for compatibility with the manufacturer's heating cable rating, If the piping system operates at temperatures in excess of 65 °C or experiences temperatures in excess of 85 °C at startup, the manufacturer should specify the proper heating cable selection.

d) Line sensing temperature control should be used for the following conditions:

   1) Piping that extends through areas where the ambient temperature differences is greater than 3 °C.

   2) Extended vertical risers are greater than 9 m.

   3) Systems requiring a maintenance temperature of 82 °C or higher.

e) If a hot water system is operated under low flow conditions, stratification in the tank may occur. Mixing valves or a tank circulator should be considered to avoid excessively high water temperatures.

f) Where tempered water systems are provided to supply a minimum 15 min of temperature controlled water to emergency eyewash and safety shower systems, line sensing high-limit temperature control and a high-limit alarm shall be provided.

g) Specific maintenance temperatures may be required for emergency eyewashes and safety showers in some applications, such as chemical exposures where water temperature may accelerate the reaction. Consult the appropriate sections of ANSI Z358.1-1990 and CFR Publication 29, Part 1910 (OSHA)§ 1910.151(c).

h) Feeder piping leading to emergency eyewash and safety showers shall also be maintained at required system temperatures.

i) In selecting a control system, consideration should be given to reliability, ease of calibration, narrow differential temperature band, and alarm indication.

Table 7—Domestic hot water and tempered water temperatures[a]

Application	Temperature (°C)
Safety showers and eyewashes	16–35
Hot water service without mixing valves	40
Nursing homes and hospitals	40 and 46
General purpose	49–60
Laundry service	71
Kitchen sanitization	82

[a] Consult local codes for specific application temperature requirements.

6.2.5.4 Fuel oil lines

The following list contains mandatory requirements or recommendations for fuel oil lines:

a) The heating cable outer jacket shall be resistant to hydrocarbon exposure.

b) For piping in hazardous (classified) locations, only approved heating cable, components, and wiring methods shall be used. Refer to IEEE Std 515.

c) When double containment piping is used for fuel lines, the heating cable should be applied to the outer surface of the containment pipe under the thermal insulation.

d) When double containment piping is prefabricated/pre-insulated, a channel should be provided on the outer surface of the containment pipe. Refer to Figure 12. The manufacturer shall specify thermal output and maximum sheath temperature. Splicing should be avoided, unless required to prevent exceeding the maximum pulling force of the cable. If required, splices shall be made in a suitable enclosure and sealed.

e) Line sensing temperature control with the sensor 90° from the heater is recommended.

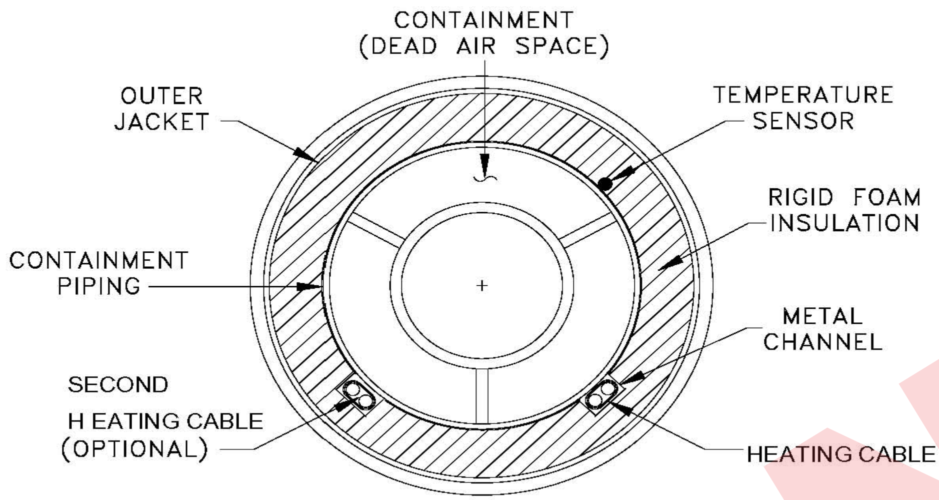


Figure 12—Double containment

6.2.5.5 Grease lines

The following list contains mandatory requirements or recommendations for grease lines:

a) The design maintenance temperature is typically between 43 °C and 49 °C.

b) As the piping is usually underground and pre-insulated, the heat loss is based on the temperature difference between the minimum soil temperature and the maintain temperature.

c) As the piping usually has gravity flow with grease only partially filling the bottom half of the pipe, the heating cable should be located at the six o'clock position. Refer to Figure 13a). Line sensing temperature control with the sensor located 50 mm from the heater is recommended.

d) If plastic pipe is used, the heating cable watt density shall be considered. Two lower wattage cables are often used at four o'clock and eight o'clock instead of one heating cable at six o'clock. Refer to Figure 13b). The temperature sensor should be located at the six o'clock position between the heat tracers.

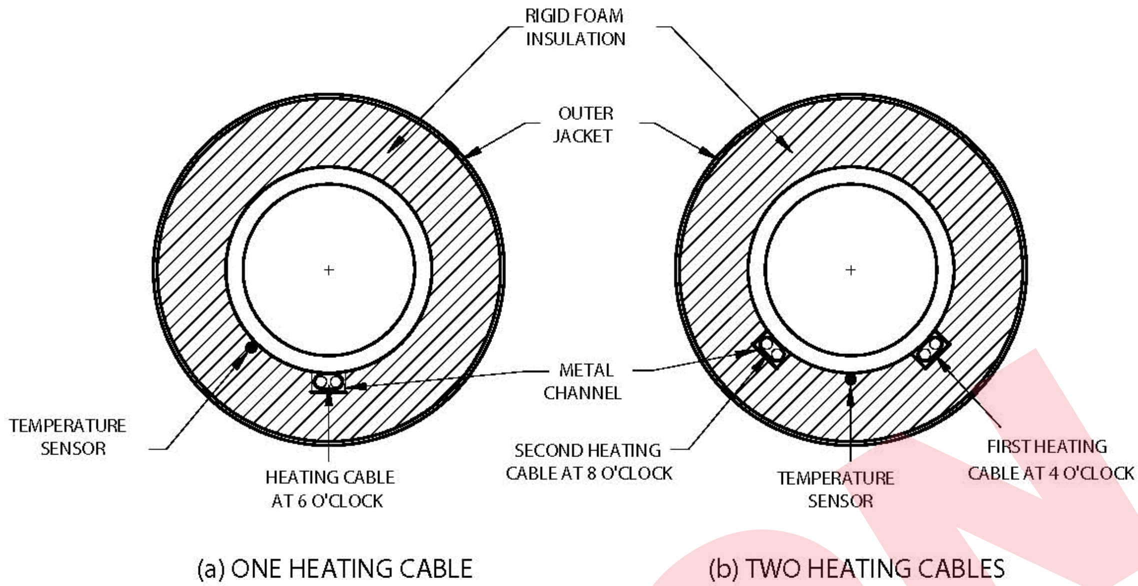


Figure 13 —Grease lines

6.2.6 Electrical design

6.2.6.1 Equipment ground-fault protection

Each heating device branch circuit or each heating device shall have ground fault equipment protection capable of interrupting high-impedance ground faults. This protection shall be accomplished by a ground-fault equipment protective device with a nominal 30 mA trip rating or a controller with ground-fault interruption capability for use in conjunction with suitable circuit protection. For higher leakage current circuits, the trip level for adjustable devices is typically set at 30 mA above any inherent capacitive leakage characteristic of the heater as specified by the manufacturer. Where conditions of maintenance and supervision ensure that only qualified persons will service the installed systems and continued circuit operation is necessary for the safe operation of the equipment or processes, ground-fault detection without interruption is acceptable if alarmed in a manner to assure an acknowledged response.

6.2.6.2 Control options

Methods for controlling a freeze protection system range widely in degree of cost and capability. The more sophisticated control approaches are recommended for fire sprinkler systems and safety showers (which are defined as Category III—Critical).

From basic to sophisticated, the control options are as follows:

a) ON/OFF switch with pilot
b) Ambient sensing (mechanical thermostat controlling several heating cable circuits by means of a contactor in the panel hoard)
c) Individual circuits with mechanical line sensing thermostats
d) Electronic temperature control with circuit monitoring

6.2.6.3 Monitoring

For safety showers and fire sprinkler lines (Category III), alarms are required to provide indication when ground fault circuit protection interrupts the circuit. Low-temperature alarms are also required for fire sprinkler lines.

6.2.6.4 Recommended level of control and monitoring

The degree or level of control and monitoring depends on the specific application and its respective category. Refer to Table 8.

Table 8—Level of monitoring and control[a]

Control					**Monitoring**				
	Manual ON/OFF	**Ambient**	**Line sensing**		**Low temperature**	**High temperature**	**Ground voltage**	**Heater supply voltage**	**High/low current**
			Mechanical	**Electronic**					
Category II									
Pot. water ≤6 in[d]	M[b]	R[c]	—	—	—	—		—	—
Pot. water >6 in[d]	M	—	R	—	—	—		—	—
Drains	M	R	—	—	—	—		—	—
Hot water	M	—	—	—	—	—		R	—
Grease	—	—	M	—	—	—		—	—
Fuel oil	—	—	M	—	—	—		—	—
Category III									
Safety showers	—	—	M	R	R	M		R	—
Fire sprinklers	—	—	—	M (NOTE 1)	M	—	M (NOTE 2)	M	M

NOTE 1—Controller shall be of a type that monitors its operation and alarms upon failure of system functions. Alarm output shall be a type that changes state upon alarm or loss of controller supply voltage. Alarm output shall be connected to fire detection alarm system.

NOTE 2—Ground fault monitor shall alarm.

[a]Ground monitoring is recommended for all underground piping.
[b]M = minimum required.
[c]R = recommended.
[d]Nominal pipe diameter.

6.2.7 Installation

Installation recommendations are divided into the various stages of the process from receiving to the final inspection.

6.2.7.1 Receiving and storage

Factory-assembled heat tracing cables should be checked for correct circuit number, catalog type, power rating, voltage rating, and length. Bulk materials should also be checked to verify catalog type, power rating, voltage rating, and quantity. Materials should be stored in clean, dry areas.

6.2.7.2 Before installation of heat tracing

The following list contains mandatory requirements or recommendations that apply before the installation of heat tracing:

a) The heating cable should be verified that it is the correct factory fabricated unit or bulk cable type before installation (wattage output and voltage rating).

b) For field-assembled systems, the components should be verified that they are designed, or recommended, for the specific heating cable used.

c) All welding, hydrostatic testing, and painting of pipe should be completed before heating cable installation.

d) The piping system shall be inspected to ensure that it is clean and has no sharp or jagged edges that might damage the heating cable.

e) Installation of the heat tracing before completion of the piping system is not recommended.

6.2.7.3 During installation

The following list contains mandatory requirements or recommendations that apply during the installation of heat tracing:

a) Valves, pipe supports, and flanges require additional heat tracing cable and shall be installed in accordance with the manufacturer's drawings or recommendations.

b) The heating cable should not be embedded in the thermal insulation.

c) The cable should not be twisted during installation.

d) Heat tracing installation materials other than those supplied or specified by the manufacturer shall not be substituted.

6.2.7.4 After heat tracing installation

After the heating cables have been installed, an insulation resistance test should be conducted with a test voltage of at least 500 V dc. However, for mineral insulated cables, a test voltage of 1000 V dc is recommended, and for polymer insulated heating cables, a test voltage of 2500 V dc is recommended. The measured value should not be less than 20 MΩ. The value should be recorded on a log sheet.

6.2.7.5 After thermal insulation installation

The following list contains mandatory requirements or recommendations that apply after the installation of thermal insulation:

a) The thermal insulation systems should be inspected for sources of water entry and proper sealing.

b) The weather barrier should be inspected to make sure no sharp edges are contacting the heating cable.

c) The insulation resistance test described in 6.2.7.4 should be conducted, and the readings should be recorded on a log sheet.

d) External pipeline decal to indicate presence of electric tracing shall be applied to the exterior of the thermal insulation cladding at intervals not to exceed 6 m and shall also be placed on the cladding over each valve or other equipment that may require periodic maintenance.

e) On fire suppression sprinkler systems, verify that thermal insulation around the sprinkler heads is per the manufacturer's instructions and does not impede the water pattern emitted by the sprinkler head.

6.2.8 Maintenance

A system inspection for freeze protection systems is recommended before the winter season. Category II systems should be inspected annually, and Category III systems semiannually or more frequently, as required. All observations and measured values (as appropriate) should be recorded on a log sheet. The checklist consists of the following:

a) Junction boxes should be checked to verify that they are free of moisture and water. The thermal insulation and weather barrier should be inspected and repaired as needed.

b) Controller set points and proper operation of the controller should be checked per the manufacturer's specifications.

c) The electrical insulation resistance of each circuit should be measured and recorded.

d) For Category III applications, the heater performance should be verified by measuring the current draw for each circuit 2 min to 5 min after energization. This value should be recorded along with the local ambient temperature. If possible, the pipe temperature should be measured directly and compared with the manufacturer's output rating at the measured pipe temperature.

e) Major changes in insulation resistance or heater current should be resolved.

6.3 Roof and gutter deicing

6.3.1 Application description

Roof and gutter deicing systems are heating systems that provide heat to prevent ice dam formation and maintain flow paths in gutters and downspouts. Maintaining low paths prevents standing water on the roof and icicle formations (see Figure 14).

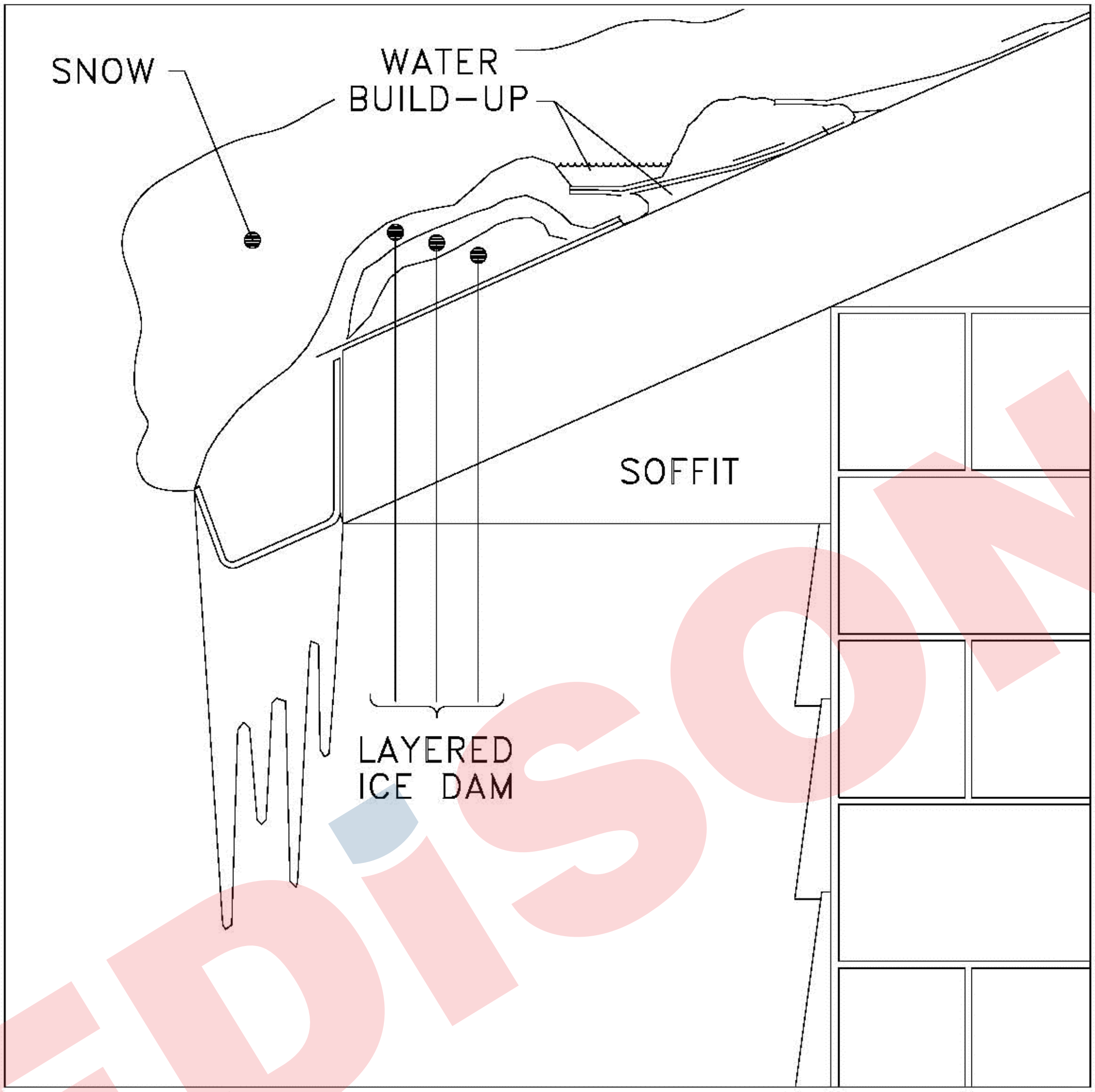


Figure 14—Ice dam formation

Cable circuits intended for these applications shall meet the requirements for type B tracing as defined in Table 1.

6.3.2 Design information

The following information should be considered before commencing with the system design:

a) Heating cables used are typically rated between 16 W/m and 66 W/m. For nonmetallic gutters and downspouts, see the special design considerations in 6.3.5.

b) Heaters shall be constructed of a material that will not be adversely affected by long-term exposure to ultraviolet rays.

c) In-line splices and tee splices should be avoided where possible.

d) A typical design will have 300 mm of heater cable per 300 mm of gutter. If a gutter is wider than 150 mm, multiple runs of heating cable are recommended.

e) Heating cable in downspouts should be looped [610 mm of heater per 300 mm of downspout] and should extend below the frost line if tied into a drainage system (see Figure 15).

f) Field-assembled end terminations should not be located in an area where moisture is present. End terminations should not be located at the lowest point of downspouts.

g) The circuit length for a given overcurrent protection device shall not exceed the maximum length specified by the manufacturer.

h) Supporting devices and attachment devices, as specified by the manufacturer, should be provided. See Figure 16 through Figure 18.

i) The manufacturer should specify the amount of cable to be provided for different distances of eaves, valleys, and overhangs.

j) Design drawings and/or data sheets detailing each circuit for each roof and gutter system are recommended.

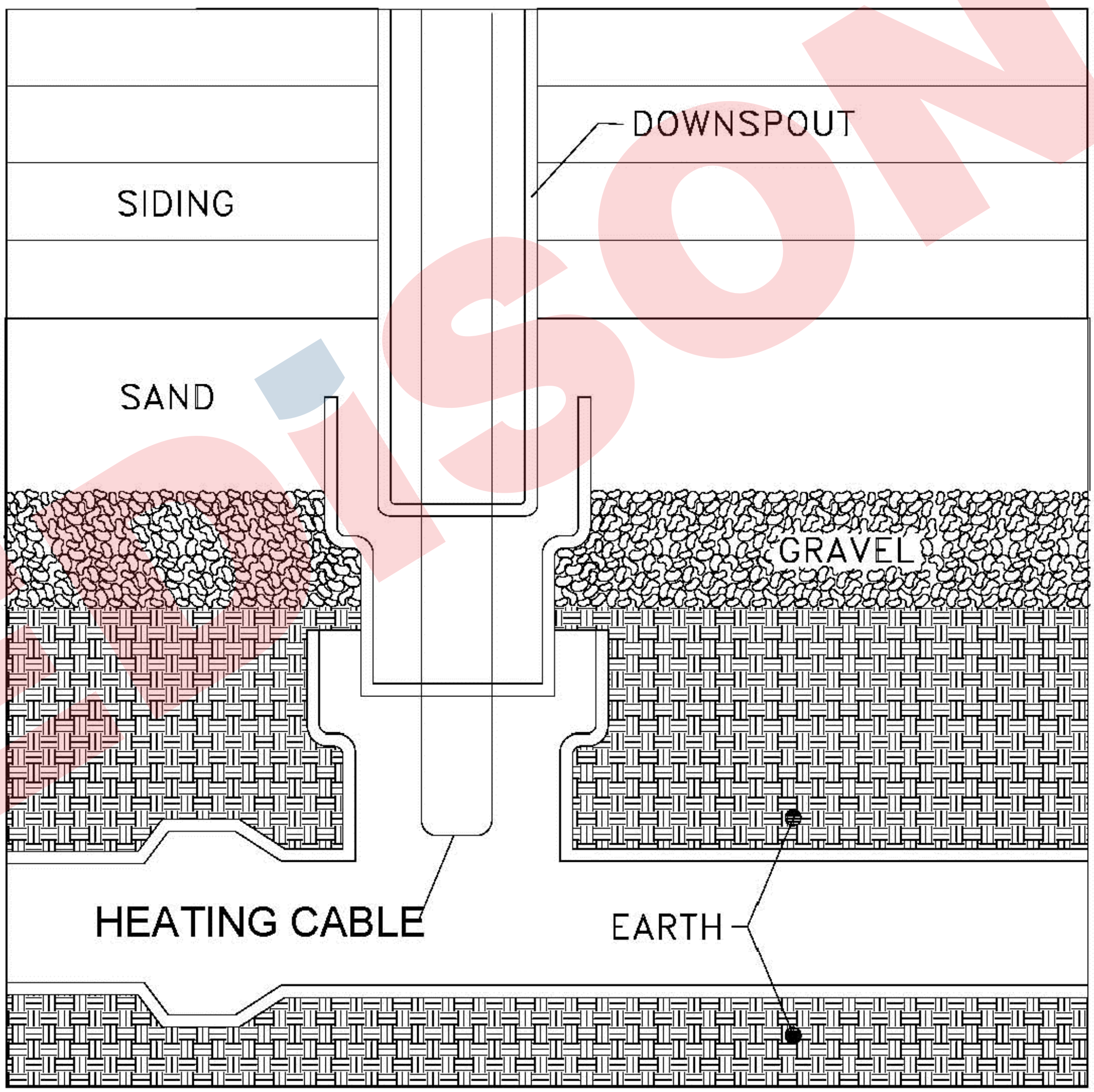


Figure 15—Downspout to underground drain

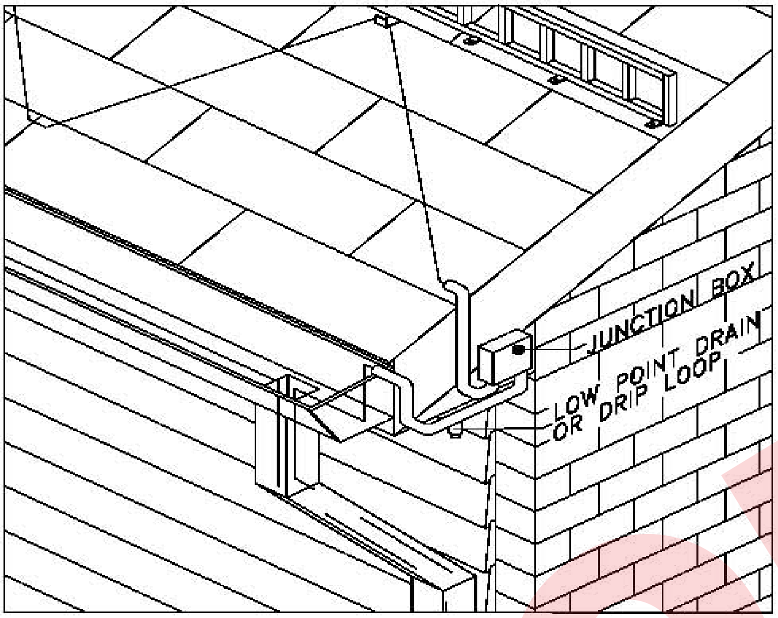


Figure 16—Roof and gutter cable arrangement

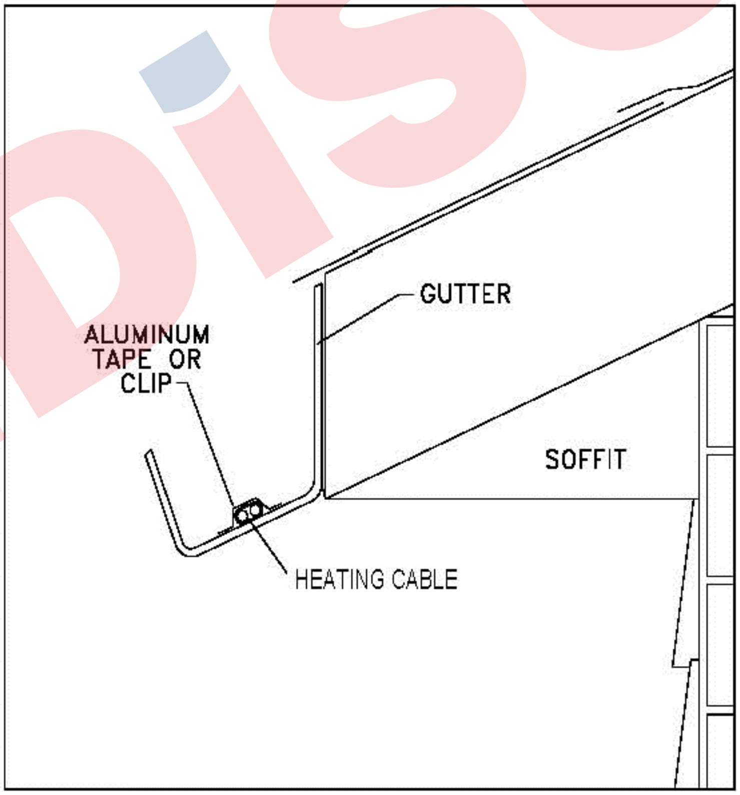
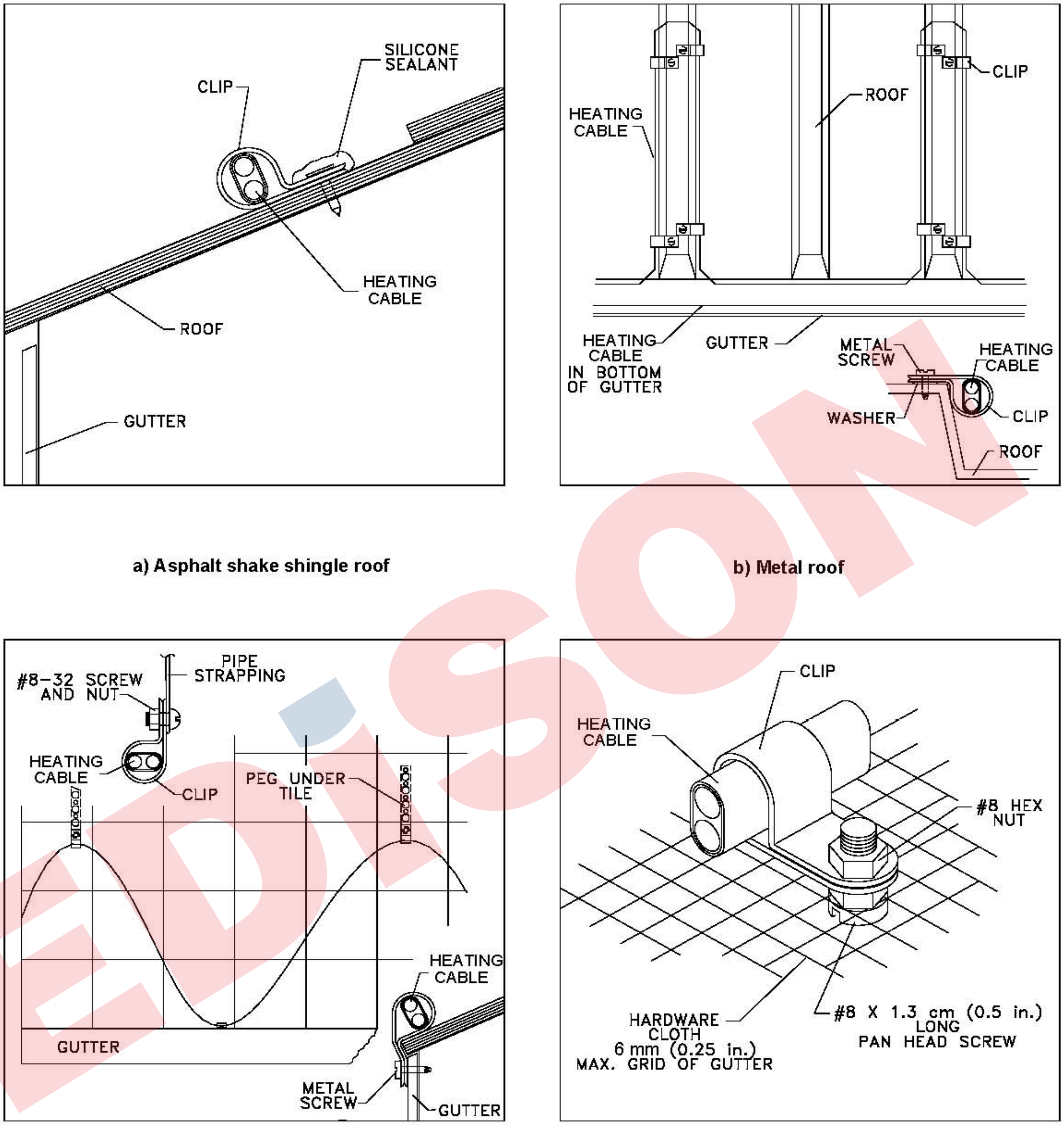


Figure 17—Gutter detail



a) Asphalt shake shingle roof

b) Metal roof

c) Tile roof

d) Flat roof

Figure 18—Typical roof mounting methods

6.3.3 Heat load determination

The heat required has been determined empirically and is based on geometric and dimensional characteristics of the roof and gutter from the manufacturer's recommendations rather than on specific weather conditions.

6.3.4 Heaters and component mounting

The details shown in Figure 18 are examples of mounting methods on typical roof materials. The manufacturer should specify materials and procedures for specific cable applications, as follows:

a) Terminate and install all cables according to the manufacturer's instructions.

b) When possible, all power connection boxes should be located in a protected area (such as under eaves) and entry should be at the bottom of the box. In all cases, a drip loop should be provided (refer to Figure 16).

c) Construction of an ice/snow fence above the tracing system is desirable to prevent damage from ice or snow slides.

d) All actual lengths installed should be recorded. The manufacturer or installer should provide as-built drawings and data.

e) All penetrations made on the surface of any style of roof should be moisture proofed by using a suitable sealant or sealing type fasteners. The installation of any heating system should not affect the overall integrity of the roof or gutter.

f) The mounting hardware should be made of corrosion resistant material and should not have sharp edges or burrs that could damage the heater cable.

6.3.5 Special design considerations

The following special design consideration may apply when designing a roof and gutter deicing system:

a) The maximum exposure temperature of all roof, gutter, and downspout materials shall be verified, and a heater shall be selected that will not exceed their temperature ratings.

b) The manufacturer should specify installation information for applying heat to a soffit to accomplish overhang deicing.

c) For roof drains leading into a heated area, a loop of heating cable is installed to a typical depth of 1 m. Refer to Figure 19.

d) Any roof or gutter application that is not specifically mentioned in this standard should be referred to the heat trace manufacturer for recommendations.

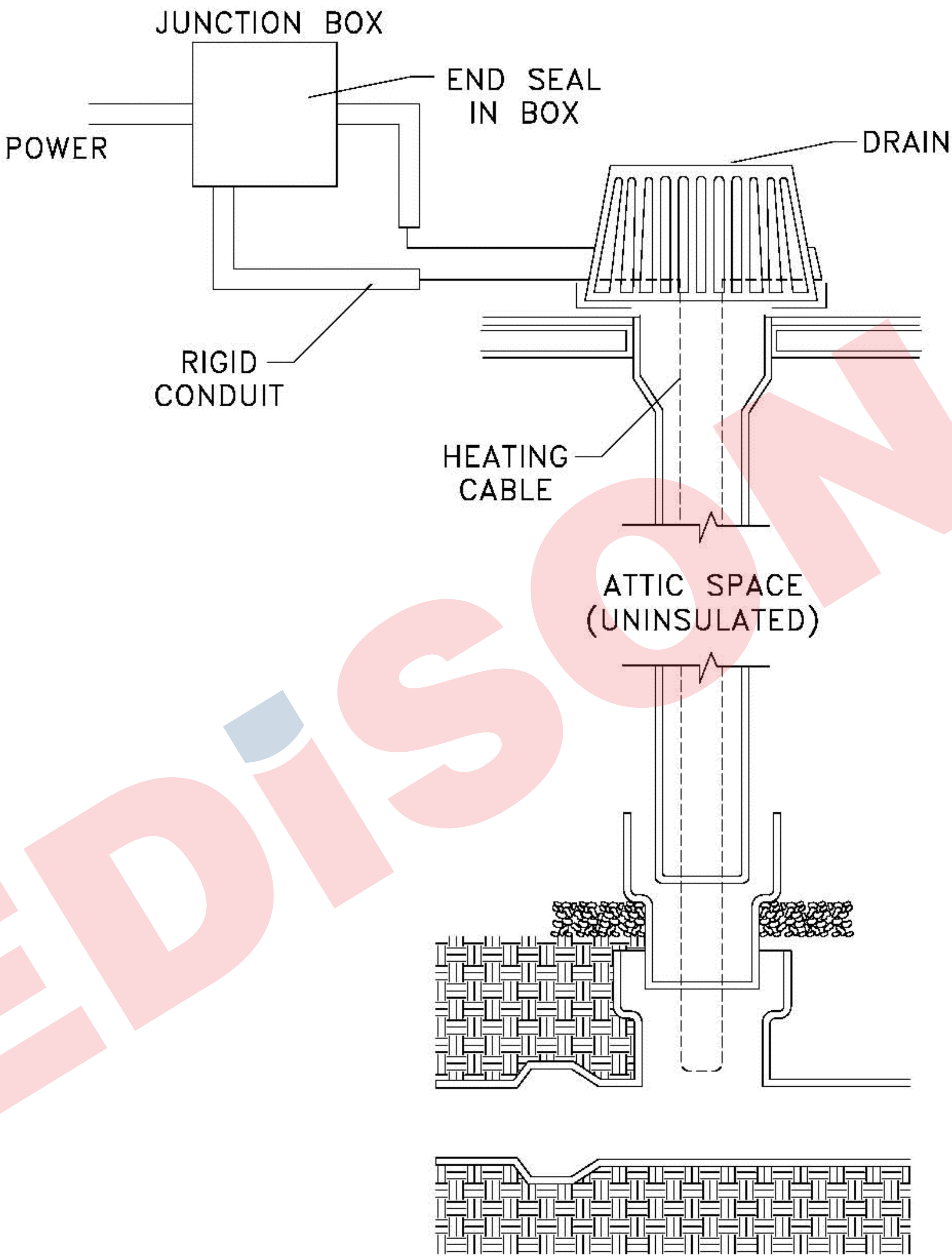


Figure 19—Drain detail for flat roof

6.3.6 Electrical design

6.3.6.1 Equipment ground-fault protection

Each heating device branch circuit or each heating device shall have ground fault equipment protection capable of interrupting high-impedance ground faults. This protection shall be accomplished by a ground-fault equipment protective device with a nominal 30 mA trip rating or a controller with ground-fault interruption capability for use in conjunction with suitable circuit protection. For higher leakage current circuits, the trip level for adjustable devices is typically set at 30 mA above any inherent capacitive leakage characteristic of the heater as specified by the manufacturer. Where conditions of maintenance and supervision ensure that only qualified persons will service the installed systems and continued circuit operation is necessary for the safe operation of the equipment or processes, ground-fault detection without interruption is acceptable if alarmed in a manner to assure an acknowledged response.

6.3.6.2 Control options

Methods for controlling a roof and gutter deicing systems are as follows:

a) ON/OFF switch with indicating light

b) Ambient sensing

c) Moisture sensing

d) Ambient and moisture sensing

The more sophisticated control approaches are recommended for the larger, more complex applications, and for systems in which energy conservation is a factor. It is recommended that the minimum level of control for a deicing system should include an ambient or moisture sensing switch. For energy conservation, both ambient and moisture sensing systems are recommended.

6.3.6.3 Monitoring

Where system integrity is important, a loss of voltage alarm is recommended.

6.3.7 Installation

Before installation, the heating cable should be verified that it is the correct factory fabricated unit or bulk cable. The layout of the heating cables on roofs and in gutters and drains is similar regardless of the roof type (such as tile, asphalt, shake, or metal). The heater manufacturer should specify the clip or bracket mounting techniques appropriate for a particular type of roof. The following general procedures are recommended:

a) Gutters and downspouts shall be cleared of debris.

b) The mounting surface shall be inspected for sharp edges where the heating cable will be located (and removed as necessary).

c) A weatherproof power connection should be located and mounted in a sheltered area.

d) The cable installation should begin at the power connection and be routed as indicated on the manufacturer’s drawings.

e) When heating cable installation is complete, an insulation resistance test should be conducted with a test voltage of at least 500 V dc. However, for mineral insulated cables, a test voltage of 1000 V dc is recommended, and for polymer insulated heating cables, 2500 V dc is recommended. The measured value should not be less than 20 MΩ.

6.3.8 Maintenance

A system inspection is recommended before each winter season. All observations and measured values as appropriate should be recorded on a log sheet. The checklist consists of the following:

a) Junction boxes should be inspected for water or evidence of previous water ingress. If moisture is present, the box should be restored to dry condition and the cause of ingress should be eliminated.

b) Gutters and/or downspouts shall be cleared of any debris.

c) Control and monitoring devices should be checked for functionality as per the manufacturer's specifications.

d) Functionality of overcurrent protection devices should be checked.

e) The insulation resistance of each heater circuit should be measured and recorded. Major charges in insulation resistance should be resolved.

6.4 Snowmelting

6.4.1 Application description

Snowmelting systems provide heat to maintain surfaces free of snow and ice. Typical applications addressed in this standard are driveways, sidewalks, entrances to commercial buildings, and parking garage ramps.

Cable circuits intended for these applications shall meet the requirements for type C tracing, as defined in Table 1, for cables directly buried in the substrate material. Cable circuits that are pulled into conduit or piping before burial shall meet the requirements for type D tracing.

6.4.2 Design information

The design conditions and application inputs in 6.4.2.1 through 6.4.2.4 are needed before commencing with the system design.

6.4.2.1 Weather data

a) Rate of snowfall

b) Ambient temperature

c) Wind velocity

d) Humidity

6.4.2.2 Surface description

a) Concrete, asphalt, pavers

b) Pouring technique (single or dual)

c) Substructure

d) Drawings

    1) Overall layout

    2) Drains, obstructions, manholes, penetrations, and expansion joints

6.4.2.3 Electrical considerations

a) Voltage supply

b) Desired control technique

6.4.2.4 Performance level classification system

Performance classification is of interest when considering control and periodic maintenance of the heating cables. For reference purposes, The *ASHRAE Application Handbook* [B15] uses three levels:

— Class I (minimum)	Residential walks and driveways
— Class II (moderate)	Commercial walks and driveways
— Class III (maximum)	Toll plazas and hospital emergency entrances

This standard uses two categories, as follows:

— Non-critical applications	Where snow removal is a convenience but not essential
— Critical applications	Where safe access is essential

Snow heat load should be determined from local worst-case winter storm conditions. However, the system design should not be based on the extreme weather conditions, such as minimum ambient and maximum wind velocity, when snowfall is not likely to occur. For example, typical snowfall occurs between –7 °C and 1 °C with 8– 24 km/h winds.

6.4.3 Heat load determination

The heat needed to perform the snowmelting function is based on several terms, which are shown in Equation (1):

$$Q_T = A_r\,(Q_e + Q_c + Q_r) + Q_s + Q_m + Q_g \tag{1}$$

where

A_r is the A_{free}/A_{total}

Q_e is the evaporation from top surface

Q_c is the convection from top surface

Q_r is the radiation from top surface

Q_s is the sensible heat

Q_m is the latent heat

Q_g is the heat loss from sides and underside by conduction

The term A_r, free area ratio, is usually 0, 0.5, or 1.0. The condition where $A_r = 1$, meaning that the surface is free of snow, is used for critical applications. The specific parameters for the heat loss or heat load terms can be found in *The ASHRAE Application Handbook* [B15]. As an alternative to calculating the snowmelting heat load with Equation (1), Table 9 provides typical snowmelting heat load values.

It is important to realize that the values in Table 9 provide overall power densities for various conditions; however, they do not address temperature distribution across the slab surface, which is primarily a function of the thermal conductivity of the slab, the heater lineal power output, and its spacing in the slab. Recommendations are presented in 6.4.4.

Table 9—Snowmelting heat loads

Snowfall	Severity	Classification	
	Rate of snow fall	Noncritical	Critical
	(mm/h)	(W/m^2)	(W/m^2)
Light	10.3	320	540
Moderate	20.5	430	650
Heavy	50	540	750

6.4.4 Heating cable and component mounting

To provide uniform heat in a slab, embedded heat tracing is typically serpentined in the slab (as shown in Figure 20), or if the heat tracing is in a conduit, it is installed as shown in Figure 21.

a) To obtain a relatively uniform temperature distribution across the surface, spacing(s) between embedded heaters or conduits usually range from 80 mm to 300 mm. The spacing for a given snowmelting application is a function of the required heat load, W/m^2, and the lineal power output of the heater selected. For example, if the snowmelt application was classified critical and required 650 W/m^2 and the heater selected had a rating of 98 W/m in concrete, the resulting spacing would be 0.15 m. Although it would seem cost effective to use a higher output heater, such as 195 W/m, and increase the spacing, a poor temperature distribution might result with some areas well in excess of 0 °C and others below freezing.

b) The recommended cable depth is 50 mm to 100 mm for concrete. For new construction with a single pour method, the heater is usually fastened to the re-bar, or a 150 × 150 mm wire mesh. For heaters with a continuous metal sheath, tie wire is used. For polymeric heater constructions, nylon cable ties are typically used. For a two-stage concrete pour, mats are an additional option. These need to be attached to the clean surface of the initial pour. Pre-punched strapping can sometimes be a convenient attachment method in two-pour applications. For asphalt, the typical cable depth is 40 mm to 50 mm.

c) Heater cables should be located a minimum of 150 mm from the edge of the slab. To minimize the number of bends, the embedded heat tracing should be oriented longitudinally in the slab section. Crossing of expansion joints should be avoided. In cases where an expansion joint transition is required, additional protection is necessary. Refer to Figure 22.

d) Heater power connections should be in an above grade junction box located, if possible, inside a building or on a structure wall. At or below grade locations should be avoided. For field-assembled heating cable systems, it is desirable to locate the heater end termination inside the junction box to facilitate troubleshooting and enhance reliability. Recommended methods are shown in Figure 23.

e) Drawings and appropriate documentation are recommended for each snowmelting application. These should include:

   1) Heater type

   2) Spacing

   3) Depth

   4) Orientation

   5) Location of power connection and expansion joints (if used)

6) Identification of circuit

7) Obstruction and penetrations

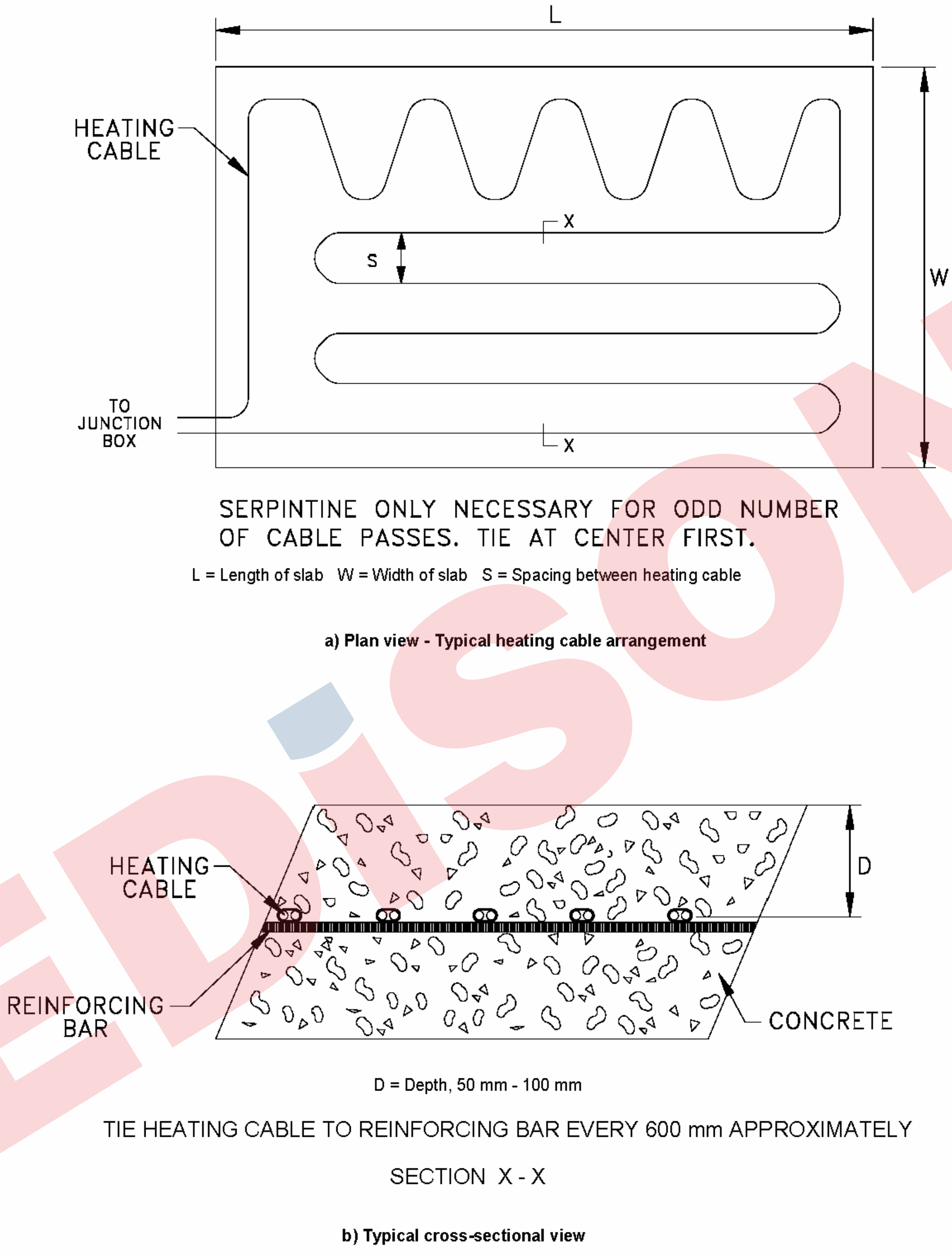
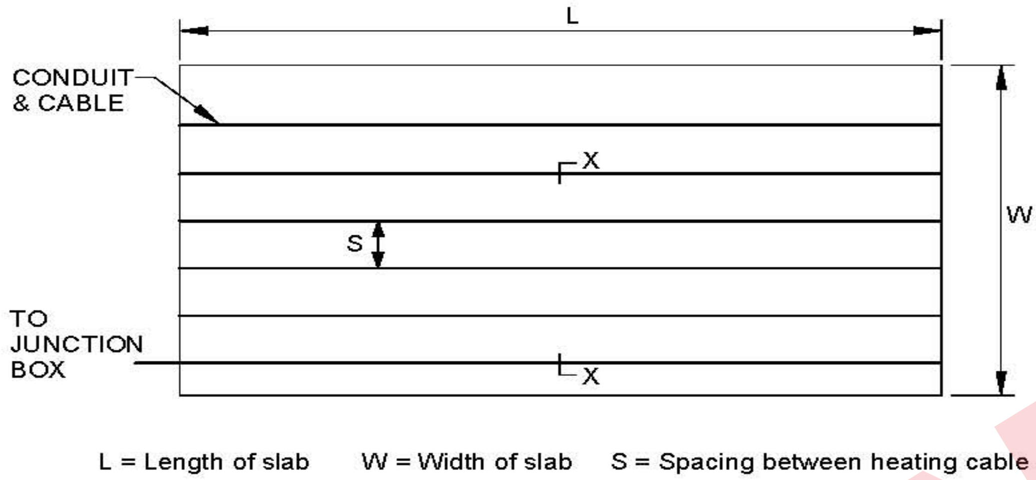
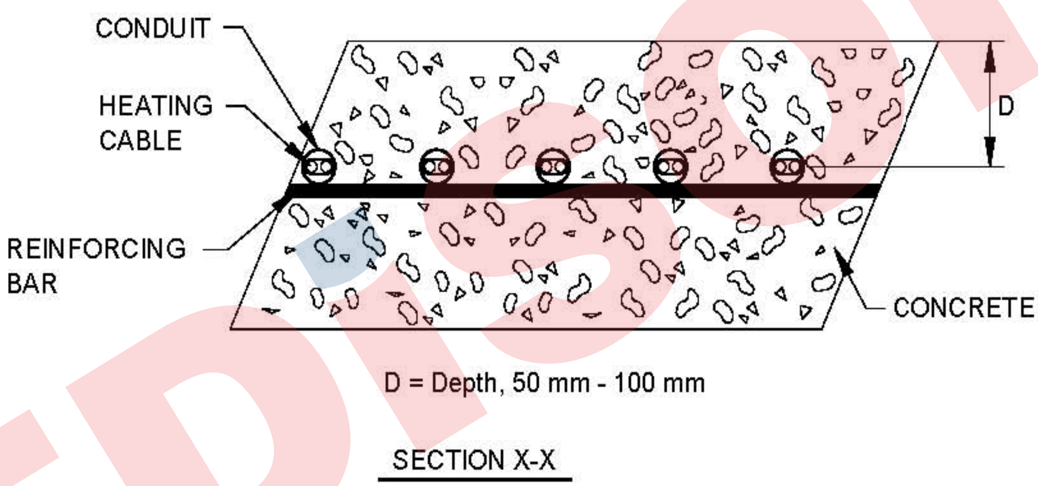


Figure 20—Snowmelting cable embedded in concrete



a) Plan view - Typical conduit arrangement



b) Typical cross-sectional view

Figure 21 —Snowmelting cable located in conduit

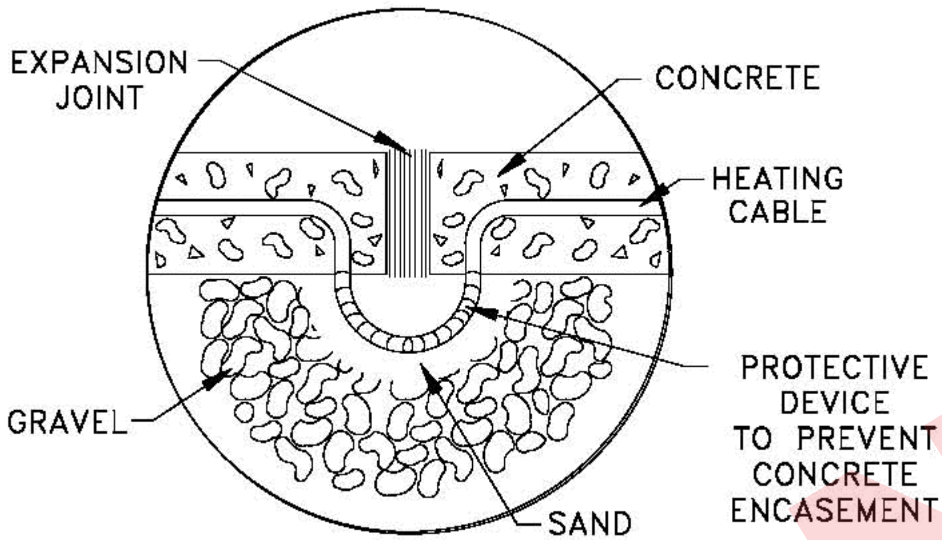


Figure 22—Expansion joint detail

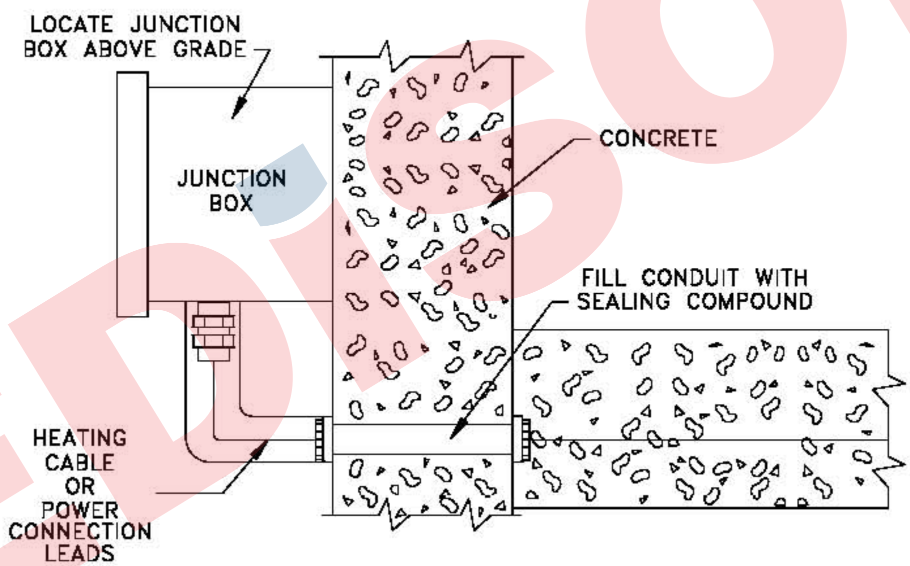


Figure 23—Snowmelting junction box location

6.4.5 Special design considerations

When designing a snowmelting system, some of the following special design considerations may apply:

a) For structural considerations on ground support slabs, the maximum distance between control joints should be less than 4.5 m and the length should be no greater than twice the width (according to *The ASHRAE Application Handbook* [B15]).

b) For systems where the heating cable is located in conduit or steel pipe, the manufacturer shall specify the maximum sheath temperature and thermal output.

c) Snowmelting applications around aircraft hanger doors or fuel storage areas may be classified. If so, the heating system shall meet the hazardous (classified) location requirements outlined in IEEE Std 515.

d) When heating cables are embedded in asphalt, the temperature exposure rating of the cable shall be capable of withstanding the hot asphalt pour.

e) Brick or paving stone constructions require special design input beyond the scope of this standard.

f) For metallic sheathed heating cables embedded in concrete, the metal sheath material should be verified as not being affected by concrete or similar chemical exposure.

6.4.6 Electrical design

6.4.6.1 Equipment ground-fault protection

Each heating device branch circuit or each heating device shall have ground fault equipment protection capable of interrupting high-impedance ground faults. This protection shall be accomplished by a ground-fault equipment protective device with a nominal 30 mA trip rating or a controller with ground-fault interruption capability for use in conjunction with suitable circuit protection. For higher leakage current circuits, the trip level for adjustable devices is typically set at 30 mA above any inherent capacitive leakage characteristic of the heater as specified by the manufacturer. Where conditions of maintenance and supervision ensure that only qualified persons will service the installed systems and continued circuit operation is necessary for the safe operation of the equipment or processes, ground-fault detection without interruption is acceptable if alarmed in a manner to assure an acknowledged response.

6.4.6.2 Control options

Methods for controlling a snowmelting system range widely in degree of cost and capability. The more sophisticated control approaches are recommended for applications classified as critical or for larger systems, in which energy conservation is a factor. From basic to sophisticated, the control options are as follows:

a) ON/OFF switch with pilot light

b) Ambient sensing

c) Slab temperature sensing

d) Remote ambient and moisture detection

e) Slab moisture and temperature sensing

6.4.7 Installation

Installation of the heating cable is dependent on the substrate material. Requirements or recommendations for concrete and asphalt installations are made in 6.4.7.1 through 6.4.7.4.

6.4.7.1 For concrete and asphalt

a) Before installation in the slab section, the heating cable should be verified to ensure that it is the correct factory fabricated unit or bulk cable type.

b) An insulation resistance test should be conducted with a test voltage of at least 500 V dc. However, for mineral insulated cables, a test voltage of 1000 V dc is recommended, and for polymer insulated heating cables, 2500 V dc is recommended. The measured value should not be less than 20 MΩ.

c) The site shall be inspected for sharp objects and burrs on the wire mesh or rebar.

d) The cable should be attached to the substructure in accordance with the spacing, bend radii, and expansion joint transition methods shown on the drawings. Strict adherence to the manufacturer's specifications for installation is required.

e) Upon completion of heating cable installation and before concrete pour or asphalt application, the drawings should be modified to reflect the as-built conditions.

f) The insulation resistance test should be conducted continuously during the pour.

6.4.7.2 For concrete only

a) The chute clearance and concrete delivery speed should be verified to ensure that the cables are not dislodged.

b) The use of metal rakes and shovels and excessive foot traffic should be avoided.

c) During the concrete pouring, the insulation resistance of the cable should be monitored continuously. Any fault should be located and repaired immediately.

d) In the case of a two-pour approach, care should be taken to ensure that the upper lift bonds to the existing concrete.

6.4.7.3 For asphalt only

a) It should be verified that the asphalt application temperature is consistent with the heater temperature rating.

b) The asphalt should be spread manually ("hand bomb") at the heater level.

c) Grades of asphalt with aggregate larger than HL4A or HLSA (as described in *The Asphalt Handbook* [B15]) are not recommended.

6.4.7.4 After installation

a) The insulation resistance reading at the end of the concrete pour or asphalt application should be recorded.

b) The cables should not be energized until either the concrete has cured or the asphalt has cooled to ambient temperature.

6.4.8 Maintenance

A system inspection is recommended before the winter season. For applications classified as critical, inspection is recommended in both the autumn and the spring. All observations and measured values, as appropriate, should be recorded on a log sheet. The checklist consists of the following:

a) Junction boxes should be inspected for water or evidence of previous water ingress. If moisture is present, the enclosure should be dried and the cause of ingress identified and repaired.

b) Control equipment set points and functionality should be checked per the manufacturer's specifications.

c) The insulation resistance of each circuit should be measured and recorded.

d) The heating performance should be verified by measuring and recording the current draw for each circuit 2 min to 5 min after energization. Slab temperature should also be recorded. As an alternative approach to verifying the heating performances, a slab section can be wetted and then monitored for uniform drying after the heater is energized.

e) Major changes in insulation resistance or heater current should be resolved.

6.5 Floor warming

6.5.1 Application description

Floor warming systems are intended to provide comfort by removing chill from a floor and are not intended to supplement or replace other forms of room heating. In this standard, floor applications for areas such as bathroom floors, day-care centers, service buildings, and garages are considered.

These applications require the use of cable circuits that meet the requirements for type C tracing (see Table 1) if the tracing is located directly in the substrate layer. If the cable is pulled into conduit or piping, then it shall meet the requirements for type D tracing.

6.5.2 Design information

The following design conditions and application inputs are needed before commencing with the system design:

a) Size and layout of area involved

b) Ambient temperature

c) Sub-floor

d) Materials of construction

e) Thermal insulation

f) Method of installation

g) In concrete

h) Under overhangs

i) Under ceramic tile

j) Electrical inputs

k) Voltage supply

l) Desired control technique

6.5.3 Heat load determination

For temperature-maintained areas such as office buildings and day-care centers, the heat load is typically between 54 W/m^2 and 108 W/m^2. Garages and warehouse areas may require 162–270 W/m^2. Assuming relatively still air and low heat loss off the floor underside, Figure 24 shows heat load requirements for a range of conditions.

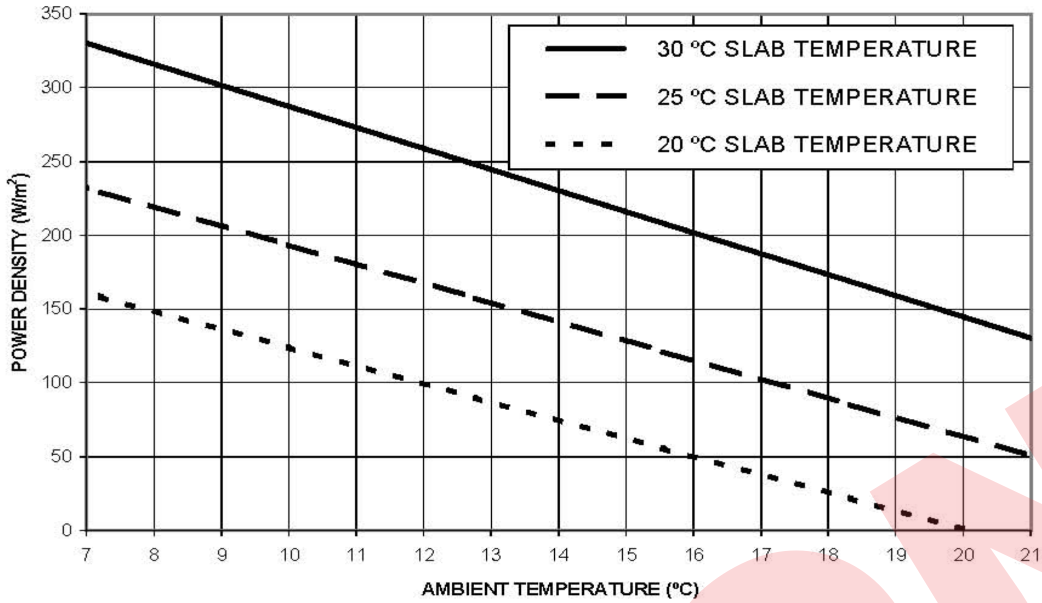


Figure 24—Typical floor heating power requirements

6.5.4 Heater and component mounting

Heater and component mounting recommendations for floor warming are described in 6.5.4.1 through 6.5.4.5.

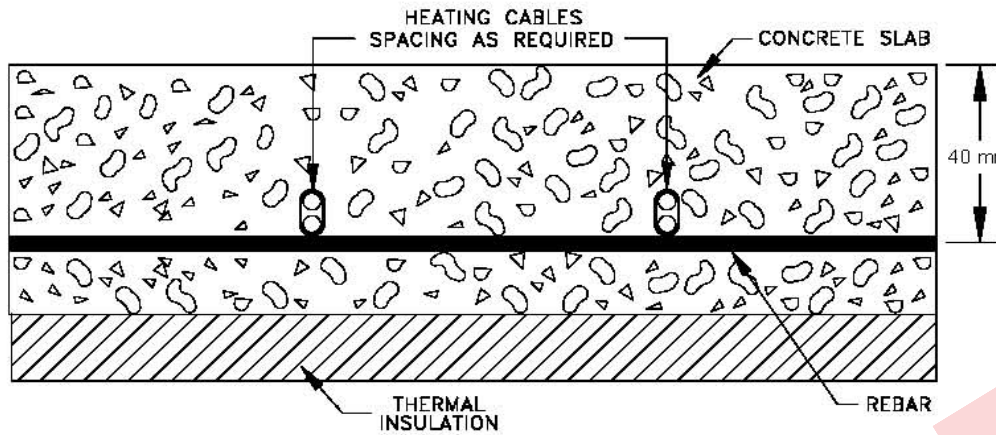
6.5.4.1 Cable mounting

Methods of laying the cables can vary. Basic approaches (illustrated in Figure 25) are as follows:

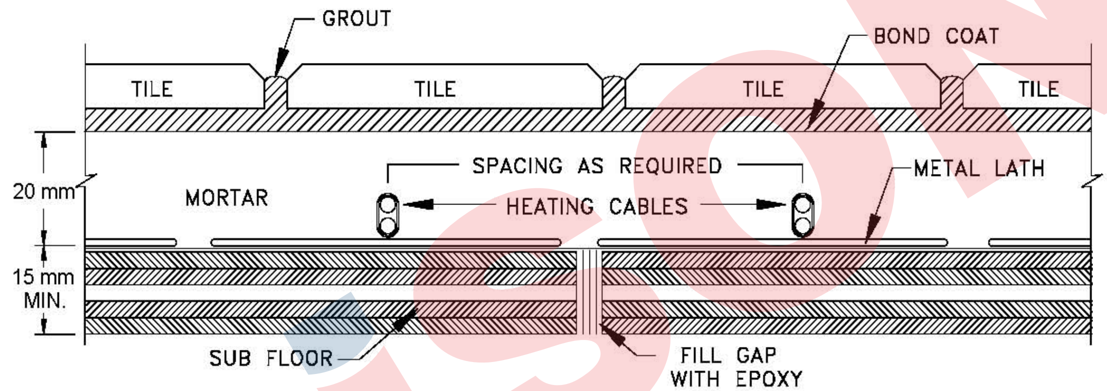
a) The cable can be directly buried in concrete by installation on rebar or wire mesh at a minimum depth of 40 mm.

b) Under ceramic tile, embedded in mortar, the cable can be tied to an expanded metal lath, wire mesh, or pre-punched strapping at a typical depth of 20 mm. A layer of mortar is typically added to a wood floor.

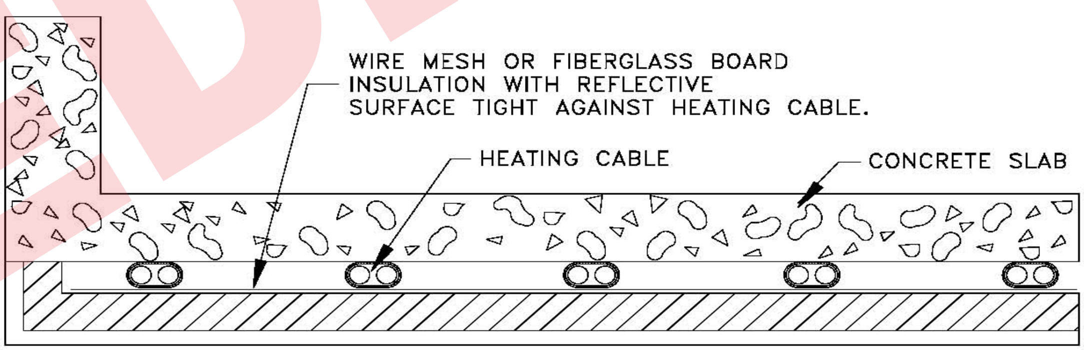
c) Installation can be made to an existing concrete slab where cable is directly applied to the slab bottom surface and held in place with rigid thermal insulation.



a) In concrete



b) Under ceramic tile embedded in mortar



c) Under elevated concrete slab

Figure 25—Typical floor heating cable mounting

6.5.4.2 Spacing

Heater cable spacing results from the watt density needed from Figure 24 and the lineal power output of the heating cable used.

$$S = P/Q \quad (2)$$

where

S is spacing of cable in meters

Q is heat load in watts/square meter

P is lineal power output of cable in watts/meter

For example, if the heat load is 108 W/m^2 and the heating cable is 16 W/m, the spacing is 0.15 m or 150 mm. The number of cable passes per unit area is then seven passes/meter.

6.5.4.3 Components

For all methods, the power connection should be in a junction box located inside the building on a wall. The heater end termination should also be located inside the junction box to facilitate troubleshooting and to enhance reliability.

6.5.4.4 Sensor location

When a temperature controller is used to control floor temperature, the sensor should be located in conduit midway between cable runs. This location will facilitate ease of replacement and provide a good representation of floor temperature.

6.5.4.5 Documentation

Drawings and appropriate documentation are recommended for each floor warming application. These should include the following:

a) Heater type
b) Spacing
c) Depth
d) Orientation
e) Identification of circuit

6.5.5 Special design consideration

When designing a floor warming system, some of the following special design considerations may apply:

a) For restrictions on maximum watt densities, consult local regulations and NFPA 70, section 424-98.
b) Watts per unit of length for a cable are limited to 54 W/m as per NFPA 70, section 424-44(a).
c) Floor warming applications in garages or fuel storage areas may be classified. If so, the heating system shall meet the hazardous (classified) location requirements outlined in IEEE Std 515.

6.5.6 Electrical design

6.5.6.1 Equipment ground-fault protection

Each heating device branch circuit or each heating device shall have ground fault equipment protection capable of interrupting high-impedance ground faults. This protection shall be accomplished by a ground-fault equipment protective device with a nominal 30 mA trip rating or a controller with ground-fault interruption capability for use in conjunction with suitable circuit protection. For higher leakage current circuits, the trip level for adjustable devices is typically set at 30 mA above any inherent capacitive leakage characteristic of the heater as specified by the manufacturer. Where conditions of maintenance and supervision ensure that only qualified persons will service the installed systems and continued circuit operation is necessary for the safe operation of the equipment or processes, ground-fault detection without interruption is acceptable if alarmed in a manner to assure an acknowledged response.

Special consideration is given for areas around pools and spas. Reference shall be made to NFPA 70 and the local electrical code.

6.5.6.2 Control options

From an energy conservation standpoint, either a timer-based ON/OFF control or a floor sensing temperature control system should be provided.

6.5.7 Installation

For floor warming installations, the following sequence is recommended:

a) Before installation, it should be verified that the heating cable is the correct factory fabricated unit or bulk cable type.

b) An insulation resistance test should be conducted with a test voltage of at least 500 V dc. However, for mineral insulated cables, a test voltage of 1000 V dc is recommended, and for polymer insulated heating cables, 2500 V dc is recommended. The measured value should not be less than 20 MΩ.

c) The floor area shall be clean and free of debris.

d) The cable should be attached to the substructure in accordance with the spacing, bending radii, and expansion joint transition methods specified on the installation drawings.

e) The insulation resistance test should be repeated after installation.

f) Upon completion of the heating cable installation and before surface floor placement, the drawings should be modified to reflect the as-built conditions.

g) The insulation resistance test should be repeated during the surface installation.

h) The heating cable should not be energized until the applied surfaces have cured.

6.5.8 Maintenance

A system inspection is recommended before the winter season. All observations and measured values, as appropriate, should be recorded on a log sheet. The checklist consists of the following:

a) Junction boxes should be inspected for water or evidence of previous water ingress. If moisture is present, the enclosure should be dried and the cause of ingress should be identified and repaired.

b) The temperature controller set points and functionality should be checked to the manufacturer's specifications.

c) The insulation resistance should be measured and recorded for each circuit. Major changes in insulation resistance should be resolved.

6.6 Frost heave prevention

6.6.1 Application description

As ice rinks, freezers, and refrigerated storage areas are typically maintained at temperatures below freezing, the resulting floor or substrate temperatures will also be at temperatures below freezing. Ice lens formation in an unheated substrate can occur and eventually result in frost heave. This application describes a design approach for frost heave prevention using electric heating cable.

Cable circuits intended to be directly embedded in the substrate shall meet the requirements for type C tracing. If the cable is installed in conduit or piping, it is required to be qualified to the type D requirements instead.

6.6.2 Design Information

Refer to Figure 26 for a typical substrate configuration. Design information needed for frost heave prevention is as follows:

a) Concrete thickness
b) Total insulation types and thicknesses
c) Vapor barrier (type)
d) Substructure material thickness and *K*-factor
e) Floor dimensions
f) Minimum freezer temperature
g) Conduit material and size
h) Electrical Inputs
i) Voltage supply
j) Circuit locations

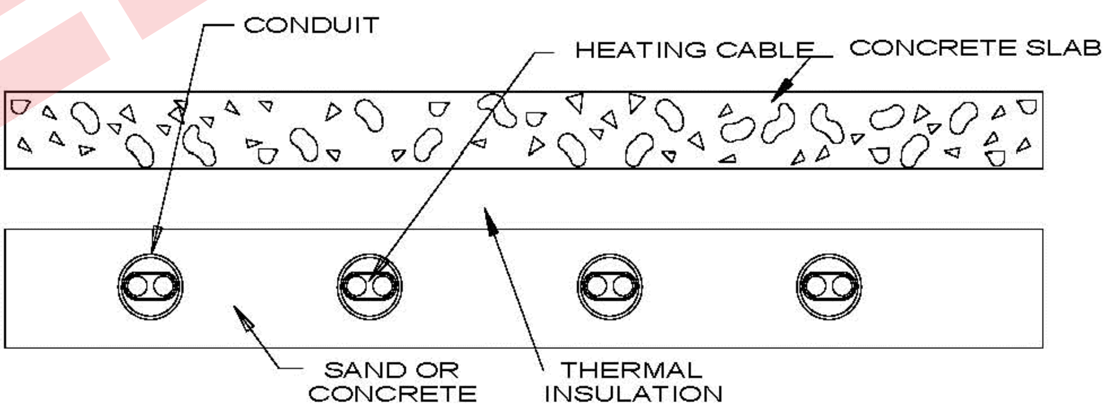
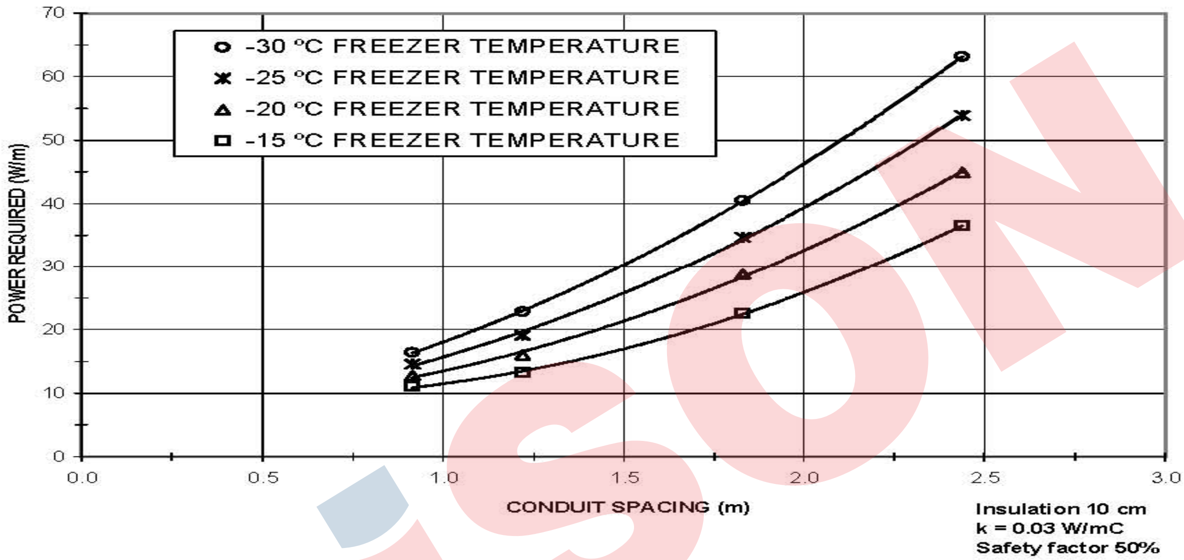


Figure 26—Typical frost heave prevention sub-structure

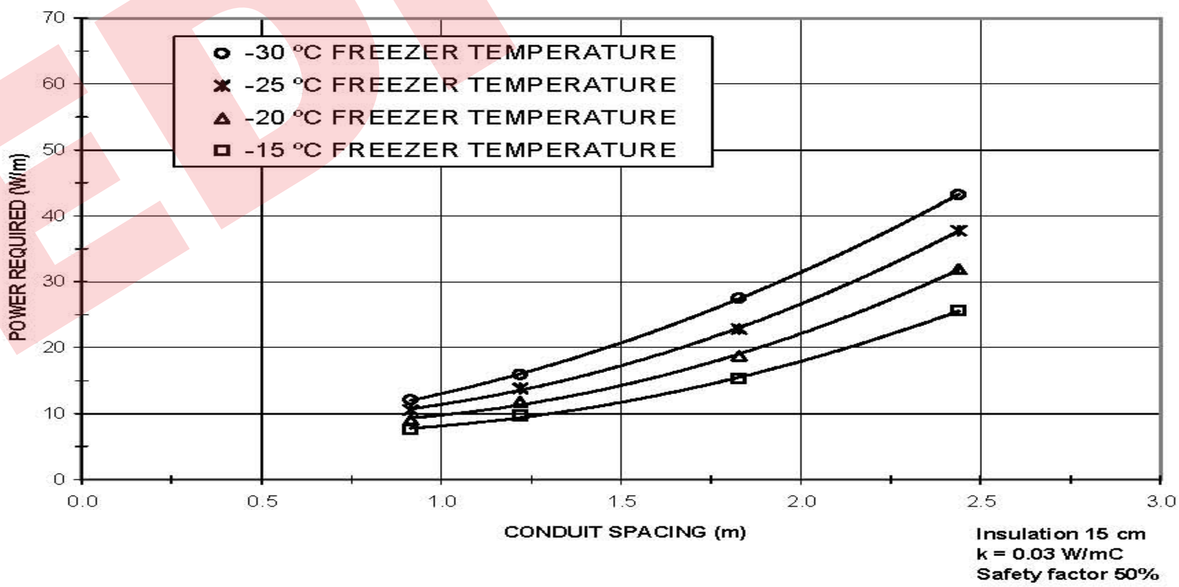
6.6.3 Heat load determination

The heat load for a frost heave prevention application is primarily dependent on the thermal insulation barrier between the floor and the heating zone or plane. For below grade applications, edge effects around the facility and heat input from the ground have little effect on total heat load. For elevated applications, thermal insulation around the perimeter should be considered.

The typical heat density W/m^2 required is shown in Figure 27 as a function of minimum freezer ambient temperature and insulation barrier thickness. This is based on an effective earth temperature of 10 °C.



a) - Insulation thickness of 10 cm



b) - Insulation thickness of 15 cm

Figure 27 —Frost heave prevention in foundations

6.6.4 Heater and component mounting

To facilitate repair or retrofit of the heating cables in the floor, the heater is typically installed in conduit, which is located in the substrate below the thermal insulation barrier. Other component mounting recommendations are listed as follows:

a) Heater power connection and end terminations should be in an accessible junction box.

b) Consideration should be given to controlling no more than 90 m^2 of floor area per heating circuit and control sensor.

c) The temperature sensor should be located in separate conduit, equally spaced between two heating conduits in the center of the area being heated.

Based on rigid foam thermal insulation with a nominal thickness of 150 mm, a typical heat load is between 6 W/m^2 and 13 W/m^2. Due to the large number of variables in assessing the heat load, a specific design is recommended for each application.

6.6.5 Special design considerations

When designing a frost heave prevention system, some of the following special design conditions may apply:

a) For all below grade applications, heater constructions with both a conductive layer and a polymer over jacket are recommended.

b) Typical spacing for the conduits is from 0.6 m to 1.2 m. For wider spacing, the resulting temperature distribution should be verified.

c) As the heating cable is freely supported in the conduit, the manufacturer should verify the thermal output and that the resulting sheath temperature is compatible with the piping material.

6.6.6 Electrical design

6.6.6.1 Equipment ground-fault protection

Each heating device branch circuit or each heating device shall have ground-fault equipment protection capable of interrupting high-impedance ground faults. This protection shall be accomplished by a ground-fault equipment protective device with a nominal 30 mA trip or a controller with ground-fault interruption capability for use in conjunction with suitable circuit protection. For higher leakage current circuits, the trip level for adjustable devices is typically set at 30 mA above any inherent capacitive leakage characteristic of the heater as specified by the manufacturer. Where conditions of maintenance and supervision ensure that only qualified persons will service the installed systems and continued circuit operation is necessary for the safe operation of the equipment or processes, ground-fault detection without interruption is acceptable if alarmed in a manner to assure an acknowledged response.

6.6.6.2 Control options

An electronic control system is recommended for this application. Features should include digital readout and an adjustable temperature differential.

6.6.6.3 Monitoring

Steady state current level monitoring is recommended to indicate any significant change in heater power output. Also recommended is ground leakage monitoring at a 30 mA level to detect degradation of the dielectric integrity of the heating circuit.

Temperature indication at other locations in the substrate may be desirable for large areas or if soil conditions vary.

6.6.7 Installation

Frost heave preventing systems involve installing heating cable in conduit. The following list contains general and specific installation recommendations for these systems:

a) It should be verified that the heating cable is the correct factory fabricated unit or bulk cable type.

b) Before pulling cable, any obstacles in the conduit shall be removed and rough edges shall be smoothed.

c) The static pulling force shall not exceed the manufacturer's recommendation, typically 650 N. The pulling force is dependent on the number of bends, lubricant type, and length of the run.

d) Only pulling lubricants specified as compatible by the cable manufacturer should be used.

e) The pulling force exerted on the cable should be by connection of a pulling eye to the conductive layer (braid or shield).

f) After heating cables have been installed, an insulation resistance test should be conducted with a test voltage of at least 500 V dc. However, for mineral insulated cables, a test voltage of 1000 V dc is recommended, and for polymer insulated heating cables, 2500 V dc is recommended. The measured value should not be less than 20 MΩ. The value should be recorded on a log sheet.

6.6.8 Maintenance

A system inspection is recommended on an annual basis. All observations and measured values (as appropriate) should be recorded on a log sheet. The checklist consists of the following:

a) Junction boxes should be inspected for water or evidence of previous water ingress. If moisture is present, the enclosure should be dried and the cause of ingress should be identified and repaired.

b) The thermal insulation and weather barrier should be inspected and repaired as necessary.

c) Temperature controller set points and functionality should be checked to the manufacturer's specifications.

d) The electrical insulation resistance of each circuit should be measured and recorded.

e) The heater current should be measured and recorded.

f) Major changes in insulation resistance or heater current should be resolved.

6.7 Earth thermal storage systems

6.7.1 Application description

Earth thermal storage heating systems provide a means of converting electrical energy to a reservoir of radiant warmth. Typical applications are warehouses and other structures with concrete floors. Thermal storage systems are particularly applicable where electrical utilities offer off-peak rates.

Cable circuits to be directly buried in the substrate shall meet the requirements for type C tracing. Cables to be installed in conduit or piping shall meet the requirements of type D tracing.

6.7.2 Design information

The following design conditions and application inputs are needed to determine system design:

a) Intended uses of the building
b) Building heat loss
c) Height of the building
d) *R*-value of wall insulation
e) *R*-value of roof insulation
f) Number and sizes of windows
g) *R*-value of windows
h) Number and sizes of doors
i) *R*-value of doors
j) Lowest expected ambient temperature
k) Building maintenance temperature
l) Proposed number of zones
m) Heat loss for each zone
n) Hours of off-peak power available per day
o) Voltage supply

6.7.3 Heat loss determination

The heat load needed for a specific application can be determined by calculating the building heat loss. A less precise method is to assume the practical maximum loss to be 110 W/m^2. This amount is the natural building heat loss only and does not include ventilation makeup or recovery for opening doors. Losses greater than this amount will require supplemental heat or additional thermal insulation.

6.7.4 Heater and component mounting

For this application, the heating cable or mat is located at a depth of 100 mm to 460 mm in a sand substrate. Refer to Figure 28 for a typical under-the-floor heating installation. The power connection or junction box is mounted above grade. The temperature control sensing element is located in a conduit that is embedded in the slab. A high-temperature sensor, if used, is routed up through the sand substrate and through the slab in a conduit. The sensing element is attached to the heating cable or center of the mat.

1 External grades should be up to slab level. Where this is not done (such as a loading dock), perimeter insulation thickness should be doubled from 50 mm to 100 mm.
2a Temperature controller sensing bulb in conduit for controlling slab temperature.
2b High temperature safety cutout sensing bulb in conduit. Taped to center of mat.
3 Perimeter insulation of 50 mm rigid Styrofoam, type SM or equivalent, should extend from floor surface down to 1.3 m depth.
4 Slab.
5 Sand depth of 300 mm should be free of stones and organic matter, and well compacted to provide a stable base for the slab.
6 Plastic sheeting vapor barrier (optional).
7 Heating cable - spaced as specified on individual job drawing.

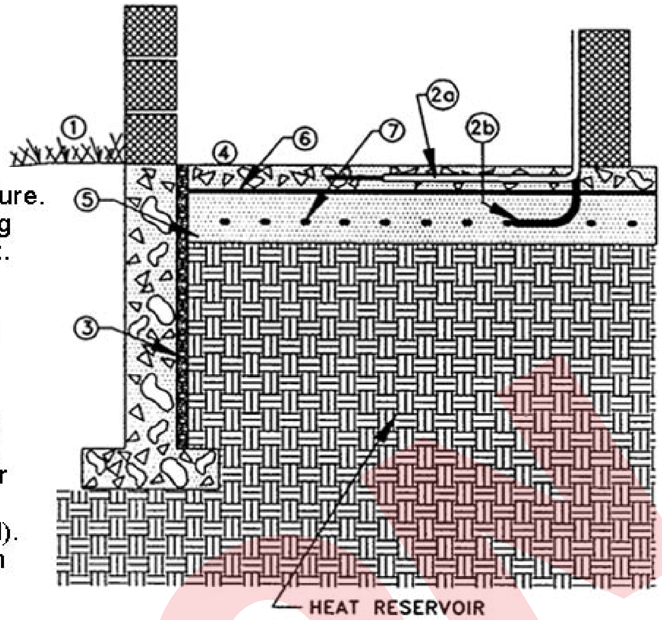


Figure 28—Typical earth thermal storage installation

When using electrical heating cables, the length and output shall be specified by the manufacturer's literature. After the cable is selected, the steps below should be followed to determine spacing:

a) The total heat loss of each zone is divided by the wattage output per unit length of the selected cable to determine the total length of cable required.

b) The total usable area for heating should be determined, with consideration to offsetting cables by 150 mm from walls, drains, footings, and other obstructions.

c) For field-assembled heating cable systems, the heater end termination should be located inside the junction box to facilitate troubleshooting and to enhance reliability.

d) The cable spacing is then calculated by dividing the total usable area by the total cable length.

6.7.5 Special design considerations

Additional considerations for earth thermal storage systems include the following:

a) Heating mats should be selected that are closest to the length or width of the building (depending on which direction the mats will be placed).

b) A vapor barrier, as shown in Figure 28, is recommended for moisture retention in sand.

c) External grade will usually be at slab level. Perimeter thermal insulation, typically 50 mm of foam extending down 1.2 m, is recommended to minimize heat loss from sides of the foundation. Refer to Figure 28. When the slab is above grade (such as a loading dock), the perimeter insulation should be increased.

d) In the case of exclusive off-peak operation, and when the system is the sole source of heat, the heating capacity should be adjusted to compensate for the system duty cycle.

6.7.6 Electrical design

6.7.6.1 Equipment ground-fault protection

Each heating device branch circuit or each heating device shall have ground-fault equipment protection capable of interrupting high-impedance ground faults. This protection shall be accomplished by a ground-fault equipment protective device with a nominal 30 mA trip rating or a controller with ground-fault interruption capability for use in conjunction with suitable circuit protection. For higher leakage current circuits, the trip level for adjustable devices is typically set at 30 mA above any inherent capacitive leakage characteristic of the heater as specified by the manufacturer. Where conditions of maintenance and supervision ensure that only qualified persons will service the installed systems and continued circuit operation is necessary for the safe operation of the equipment or processes, ground-fault detection without interruption is acceptable if alarmed in a manner to assure an acknowledged response.

6.7.6.2 Control options

a) Control circuits for thermal storage systems should be designed to accommodate multiple sensing points for the heating zones. Typical set-points for the temperature controller range from 18 °C to 24 °C.

b) A high limit temperature controller should be used to protect the integrity of the system. A maximum temperature of 54 °C should not be exceeded, as higher temperatures can reduce the moisture content and thermal conductivity of the substrate.

6.7.7 Installation

Radiant heating cables and mats are designed for installation in a carefully prepared sand base free of stones, debris, and organic matter. In some geographic areas, cables can be placed directly in the earth by means of a trenching plow. Typical installation in sand is as follows:

a) The sand base should be installed and compacted to the desired cable burial depth.

b) Before installation, it should be verified that the heating cable is the correct factory fabricated unit or bulk cable type.

c) An insulation resistance test should be conducted with a test voltage of at least 500 V dc. However, for mineral insulated cables, a test voltage of 1000 V dc is recommended, and for polymer insulated heating cables, 2500 V dc is recommended. The measured value should not be less than 20 MΩ.

d) The cable is to be laced in a predetermined pattern, adhering to spacing and bending radii specified by the cable manufacturer. Temporary frames (2 × 4 s with nails or equivalent) should be used to position and support cable loops. The insulation resistance test described in item c) should be repeated.

e) Sand should be filled to the slab installation level (except for frame areas).

f) The lacing frames (or positioning devices) should be removed, with care taken so that cable patterns are not distorted.

g) The exposed cable loops should be covered with sand, and the entire area should be compacted.

6.7.8 Maintenance

A system inspection is recommended before the heating season and again in the spring at the end of the season. All observations and measured values (as appropriate) should be recorded on a log sheet. The inspection should include the following:

a) Junction boxes should be inspected for water or evidence of previous water ingress. If moisture is present, the enclosure should be dried and the cause of ingress should be identified and repaired.

b) Control equipment set-points and functionality should be checked to the manufacturer's specifications.

c) The insulation resistance of each cable circuit or mat should be measured and recorded.

d) The current draw for each circuit should be measured, between 2 min and 5 min after energization, and recorded. Reservoir temperatures should also be recorded.

e) Major changes in insulation resistance or heater current should be resolved.

Annex A

(informative)

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Annex B

(informative)

Glossary

For the purposes of this document, the following terms and definitions apply. These and other terms within IEEE standards are found in T*he Authoritative Dictionary of IEEE Standards Terms*.[19]

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

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

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

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

end termination: The termination applied to the end of the heating 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 heating cable or surface heating device.

maintain temperature: 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: 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.

[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/).

parallel heating cable: 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 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.

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 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.

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.

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.