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

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Abstract: Specific test requirements for qualifying electrical resistance heating cables for commercial service and a basis for electrical and thermal design are provided. Heater characteristics are addressed and installation and maintenance requirements are detailed. Recommendations and requirements for unclassified heating cable applications are provided.
Keywords: design, electrical resistance, heater, heating cable, heat tracing, installation, maintenance, testing

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Introduction

(This introduction is not a part of IEEE Std 515.1-1995, IEEE Recommended Practice 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 recommended practice.

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

This recommended practice 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.

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CLAUSE PAGE

1. Overview 1

1.1 Scope 1
1.2 Purpose 1

2. References 2

3. Definitions 2

4. General product testing 4

4.1 Type test—general requirements 4
4.2 Type test—insulated surfaces 4
4.3 Type test—outdoor exposed surfaces 13
4.4 Type test—installations with embedded tracing 15
4.5 Type test—tracing Inside of piping or conduit 15
4.6 Routine testing 16

5. Markings 16

5.1 Bulk cable markings 16
5.2 Cable reel or carton markings 17
5.3 Markings for factory fabricated sets 17
5.4 Package markings for field fabrication kits 17

6. Design, installation, and maintenance 18

6.1 Temperature maintenance of piping systems 18
6.2 Roof and gutter deicing 28
6.3 Snowmelting 34
6.4 Floor warming 41
6.5 Frost heave prevention 46
6.6 Earth thermal storage systems 50

7. Bibliography 52

8. Annex Sample log sheet (Informative) 55

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

1. Overview

1.1 Scope

This recommended practice provides detailed recommendations for the testing, design, installation, and maintenance of electrical resistance heat tracing in commercial applications. Commercial applications include installations inside and outside of commercial business buildings, such as office buildings, hospitals, and airports. Typical applications include freeze 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. The recommendation also include test criteria to determine the suitability of heating cables and fittings that are utilized for these applications.

Commercial applications involving hazardous (classified) locations *should meet* the requirements in IEEE Std 515-1989[1] in addition to the requirements in this document.

1.2 Purpose

The provisions of this recommended practice 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 recommended practice is a supplement to those provisions outlined in ANSI/NFPA 70-1993, Articles 426 and 427.

[1]Information on reference can be found in clause 2.

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2. References

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

ANSI/NEMA 250-1991, Enclosures for Electrical Equipment (1000 Volts Maximum).[2]

ANSI/NFPA 70-1993, National Electrical Code (NEC).[3]

ANSI/UL 50-1987, Cabinets and Boxes.[4]

ASTM D5025-91, Specification for a Laboratory Burner Used for Small-Scale Burning Tests in Plastic Materials.[5]

ASTM D5207-91, Practice for Calibration for 20 mm and 125 mm Test Flames for Small-Scale Burning Tests on Plastic Materials.

ASTM G26-93, Practice for Operating Light-Exposure Apparatus (Xenon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials.

IEEE Std 100-1992, The New IEEE Standard Dictionary of Electrical and Electronics Terms (ANSI).[6]

IEEE Std 515-1989, IEEE Recommended Practice for the Testing, design, Installation, and Maintenance of Electrical Resistance Heat Tracing for Industrial Applications (ANSI).

3. Definitions

The following definitions apply to the subject matter presented in this recommended practice. Electrical and electronic terms used in this recommended practice are defined in IEEE Std 100-1992 .

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

3.2 connections: In-line and tee splices that are designed to join heating cables or heating cables and power leads.

3.3 dry location: A location not normally subject to dampness or wetness. A location classified as dry may be temporarily subject to dampness or wetness, as in the case of a building under construction.

3.4 electrical resistance heat tracing: The utilization of electric heating cables, other electric heating devices, and support components that are externally 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.

3.5 end termination: The termination applied to the end of the heating cable, opposite the power supply end.

3.6 factory fabricated: A heating cable assembled by the manufacturer, including terminations and connections.

3.7 field assembled: Heating cable supplied in bulk form with terminating components and connections to be assembled by field personnel.

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[2]ANSI/NEMA publications are available from the National Electrical manufacture Association, 2101 L Street NW, Suite 300, washington, DC 20037, USA.
[3]ANSI/NFPA publications are available from Publication Sales, National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101, USA.
[4]ANSI/UL publications are available from Underwriters Laboratories, Inc., 333 Pfingsten Road, Northbrock, IL 60062-2096, USA
[5]ASTM publications are available from the Customer Service Department, American society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103, USA.
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3.8 heat loss: A quantitative value of the rate of thermal energy flow from a pipe, vessel, or equipment to the surrounding ambient.

3.9 high profile: Terminations or connections designed for use outside of thermal insulation, or away from the surface being heated.

3.10 high-resistance sheath: A metallic covering with a characteristic resistance at a level high enough to prevent usage as an effective ground path. More specifically, it is a metallic covering that either does not have a conductance greater than or equal to that of the largest conductor under evaluation, based on the resistance of an equivalent sized copper conductor, or is incapable of passing an overcurrent test at levels of 1.10, 1.35, and 2.00 times the maximum branch circuit overcurrent protection for 7 h, 1 h, and 2 min, respectively.

3.11 jacket: A polymeric sheath, sometimes fabric reinforced, applied over the insulation or core of a cable.

3.12 low profile: Terminations or connections designed to be an integral part of the heating cable.

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

3.14 maximum maintain temperature: Specified maximum temperature of a surface or process which the heat tracing is capable of maintaining continuously.

3.15 metallic covering: A metal sheath or braid used to provide physical protection for heating cable and, usually, to provide an electrical ground path.

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

3.17 overjacket: A polymeric sheath, sometimes fabric reinforced, applied over the metallic covering.

3.18 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.

3.19 power connection: The connection between the heating cable and incoming power.

3.20 rated output: Total power or power/unit length of heating cable, at rated voltage or current, maintain temperature, and length, normally expressed as W/m or W/ft.

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

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

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

3.24 sheath: A continuous covering for a cable.

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

3.26 start-up current: The transient current of a heating cable immediately following energization.

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

3.28 thermal insulation: Material having air- or gag-filled pockets, void spaces, or heat-reflective surfaces that, when properly applied, will retard the transfer of heat with reasonable effectiveness under ordinary conditions.

3.29 type test: A test or series of tests carded out on heating cables and accessories, representative of a type, to determine compliance of the design, construction, and manufacturing methods within the requirements of the specified standard (in this case, IEEE Std 515.1-1995).

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3.30 weather barrier: Material that, when installed on the outer surface of thermal insulation, protects the insulation from water or other liquids; physical damage caused by sleet, wind, or mechanical abuse: and deterioration caused by solar radiation or atmospheric contamination.

4. General product testing

4.1 Type test—general requirements

Products intended for use in commercial applications should meet the requirements of the type tests given in 4.2. Products intended for type B, C, and D applications (as defined in table 1) should also meet the requirements of 4.3, 4.4, and 4.5, respectively.

Terminations and connections to be installed as an integral part of the heating cable, whether intended to be factory fabricated or field assembled, should be subjected to the same type tests as the heating cable, except where otherwise noted. These should include low-profile power connections, splices. and end terminations, as well as gland fittings or seals where a cable enters a termination enclosure.

Tests should be conducted at room temperature between 10 °C and 40 °C (50–104 °F) unless otherwise noted.

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) should meet the requirements of 4.2.1–4.2.15.

4.2.1 Dielectric test

The dielectric test should be performed on a minimum 15 m (50 ft) sample length of bulk heating cable in accordance with the following:

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

The test voltage, where E = rated voltage, should 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 Vac rms test voltage waveform should be essentially sinusoidal, with a frequency of 45–65 Hz.

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Table 1—Commercial cable 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
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

The test voltage should be applied between the conductors and the metallic covering, or a specially applied conductive metal tape or braid. Alternatively, for heating cables without a metallic covering, the dielectric test may be conducted by submerging the cable in tap water at room temperature (resistivity of tap water typically 50 000 Ωcm). The test voltage should be applied between the conductors and the water.

4.2.2 Insulation resistance test

The insulation resistance should be measured on the above sample after the dielectric test specified in 4.2.1 is completed. The resistance of the insulation should be measured between conductors and the metallic covering, or a specially applied conductive metal tape or braid, by means of dc voltage of 500 V. For heating cables without a metallic covering, the dielectric test may be conducted by submerging the cable in tap water at room temperature (resistivity of tap water typically 50 000 Ωcm). The test voltage should be applied between the conductors and the water. The measured value should not be less than 50 MΩ for all cases.

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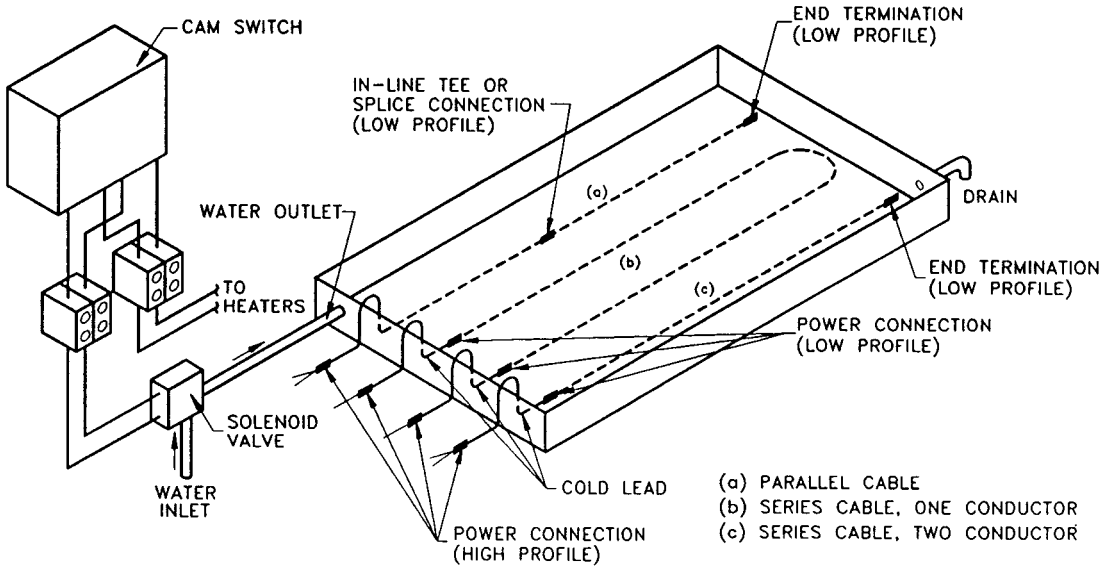


Figure 1—Heating cable termination test apparatus

4.2.3 Water resistance test

A minimum 3 m (10 ft) sample, including terminations and connections, should be immersed in water at 10–25 °C (50–77 °F) for a period of 336 h (14 days).[7] After the conditioning period, the sample should be subjected to the dielectric voltage outlined in 4.2.1 for 1 min without dielectric breakdown.

4.2.4 Terminations and connections resistance to water test

A sample of heating cable at least 3 m (10 ft) in length with factory- or field-assembled terminations and connections (as specified in 4.1) should be placed in a water flow and drain apparatus as shown in figure 1.[8] Water flow should be initiated until the heating cable, terminations, and connections are completely covered. At that point, the water flow is stopped and the cable is energized. The apparatus is then drained. The total time from the initiation of water flow to the completion of draining should be no greater than 4.5 min. The cable will continue to be energized for 30 s after the water has been drained. At that point, water flow is initiated for the second cycle and the cable is de-energized. The test should be continued for 300 cycles. After completion, the dielectric voltage outlined in 4.2.1 should be applied for 1 min without dielectric breakdown.

4.2.5 Elevated temperature exposure test

A minimum 3 m (10 ft) sample, including connections and terminations, should be placed in a forced-air convection oven. The oven temperature should be set to a level 25 °C ± 5 °C (45 °F ± 9 °F) above the maximum exposure temperature declared by the manufacturer. This level of exposure should be maintained for a period of 336 h (14 d).

A straight length of the conditioned healing cable (without terminations or connections) should be wound six close turns around a mandrel having a radius equal to one of the following two criteria:

a) Six times the diameter of the primary bending plane or thickness of the heating cable
b) The manufacturer's stated minimum bend radius

[7]Terminations and connections for systems intended strictly for use in dry and accessible locations are not subject to this test.
[8]See footnote 7.

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While still on the mandrel, the sample, except at one end where the conductors are exposed, should be submerged in tap water at 10–25 °C (50–77 °F) for 5 min. While still in the tap water, the dielectric voltage outlined in 4.2.1 should be applied for 1 min without dielectric breakdown. Overjackets subjected to this procedure should have a dielectric voltage of 500 Vac applied across the overjacket, between the metallic covering and water, for 1 min without dielectric breakdown.

4.2.6 Performance after thermal aging

Three randomly selected cable samples representing the maximum rated output of all cables under evaluation should be tested. If the set of cables has different levels of rated voltages, then the cables selected should represent the lowest rated voltage level and the maximum rated output. Three randomly selected cable samples representing the maximum rated voltage and the minimum rated output should also be tested.

Samples should be terminated according to the manufacturer's specifications, such that an effective heating length of at least 0.61 m (2 ft) is provided. Before determining the initial values, the samples should be conditioned by exposure to the aging temperature of the test for 120 h ± 24 h. The aging temperature should be the maximum declared maintain temperature of the heating cable. 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 the procedure in 4.2.11, item c). For this case, the heating cable should be evaluated at rated voltage and at the manufacturer's stated reference temperature for rated output. The rated output should be equal to or greater than the manufacturer's stated rated output.

The cable samples should be maintained at the specified aging temperature to a ± 1 °C (± 2 °F) tolerance for 5000 h. The cables should be operated at rated output for series cable or rated voltage for parallel cable. The power supply should be attached to a 15 min cycle timer such that the cables are energized for 12 min and de-energized for 3 min. At the end of the 5000 h period, the output of the samples should be determined by the same procedure as utilized for the initial readings. The percent change relative to the initial output should be calculated. These values should not show a change of more than 25% or 6.5 W/m (2 W/ft), whichever is less, from the initial wading. For a parallel cable with zones, all zones should remain functional.

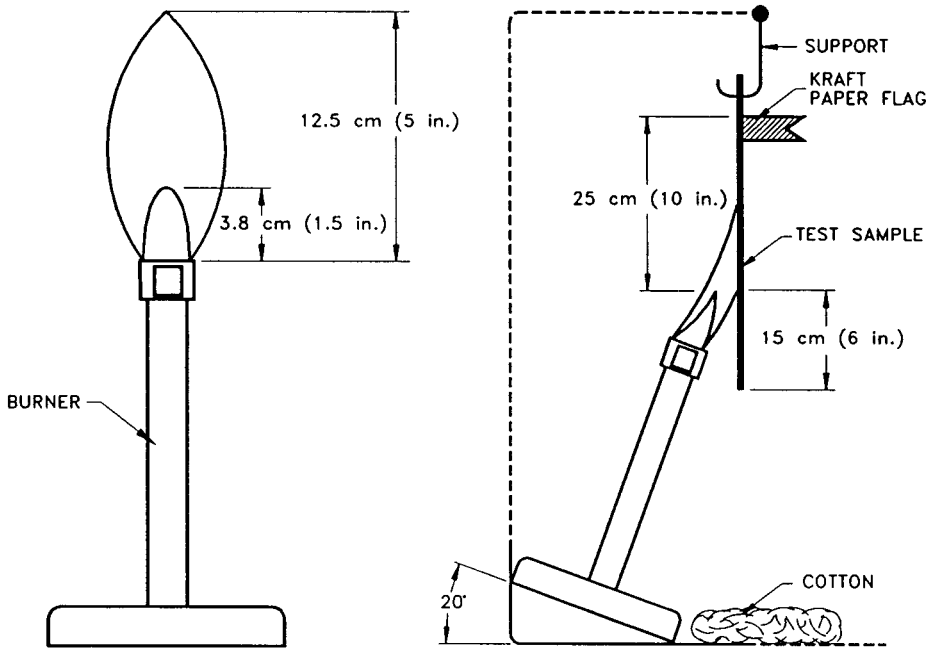
4.2.7 Flammability test

A flammability test should be performed on samples of heating cables, terminations, and connections. The full range of sizes should be capable of complying with the test. The test should be conducted in a three-sided metal cabinet having dimensions of 30 cm (12 in) wide, 35 cm (14 in) deep, and 65 cm (25 in) high. The cabinet in which the test is conducted should be in a draft-free room or chamber. A specimen of heating cable at least 46 cm (18 in) in length should be supported in a vertical position. A gummed kraft paper indicator should be wrapped once around the specimen such that it projects 2 cm (0.75 in) born the specimen.

The paper indicator should be positioned 25 cm (10 in) above the point at which the inner blue cone of the flame contacts the specimen. In addition, a layer of dry, untreated surgical cotton not more than 0.6 cm (0.25 in) in depth should be placed underneath the sample, such that the distance from the cotton to the point of the flame application is 23–24 cm (9–9.5 in).

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a) Burner and flame adjustment **b) Test position**

Figure 2—Flammability test

A standard laboratory burner, as described in ASTM D5025-91, should be used for the test. The gas flame produced by the burner is to be calibrated as described in ASTM D5207-91. The fuel should be methane, propane, or natural gas, and should be of a grade suitable for calibration to the ASTM D5207-91 procedure.

As shown in figure 2, the flame should be adjusted to a 12.5 cm (5 in) length with a 3.8 cm (1.5 in) inner blue cone. The burner should be tilted to an angle of 20° from the vertical and the flame applied to the heating cable so that the tip of the inner blue cone of the flame touches the specimen at a point 25 cm (10 in) below the kraft paper flame indicator and approximately 15 cm (6 in) from the bottom of the specimen. For termination assemblies, the flame should be set such that it will contact the material at the most vulnerable point. Clamps used to support the specimen should be above the paper indicator and at least 8 cm (3 in) below the point of flame application.

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

The test results should be considered satisfactory if the heating cable does not

— Support combustion for more than 1 min after the fifth application of the flame
— Burn more than 25% of the extended kraft paper
— Ignite the cotton from burning falling particles

4.2.8 Deformation test

A sample of heating cable at least 20 cm (8 in) in length, as well as a sample of each type of termination and connection as defined in 4.1, should be used for testing. The ends of each sample should be stripped back, and sealed if necessary, to expose the conductors. Each sample should be placed on top and at right angles to a 0.6 cm (0.25 in) diameter steel rod, resting on a rigid flat steel support. Proof loading should be gradually applied without shock at the

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point of intersection of the specimen and the steel rod by means of a rigid square pressure plate having face dimensions of 10 × 10 cm (3.94 × 3.94 in).

The proof load should be applied by means of the pressure plate and should be either a gravitational force load of 102 kg (225 lb) or an equivalent mechanical force load. After 30 s and with the proof loading continuously applied, the dielectric voltage outlined in 4.2.1 should be applied for 1 min without dielectric breakdown.

The test voltage should be applied between the heating cable conductors and the metallic covering, or where a metallic covering is not provided, between tile conductors and the steel rod.

4.2.9 Impact test

The impact test should be conducted on a sample of the heating cable and a sample of each type of termination and connection—both of 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 still at the minimum recommended installation temperature, each component of the sample should be individually positioned on the steel plate. A 5.1 cm (2 in) diameter cylindrical steel plunger with smoothly rounded edges, having a mass of 1.8 kg (4 lb), should be allowed to free fall from a height of 76 cm (30 in), resulting in an impact energy of 13.6 J (10 ft·lb). The impacted portion of each sample should be immersed in tap water at room temperature for 5 min, and the dielectric voltage outlined in 4.2.1 should be applied for 1 min without dielectric breakdown. Overjackets subjected to this procedure should have a dielectric voltage of 500 Vac applied between the metallic covering and water for 1 min without dielectric breakdown.

4.2.10 Cold bend test

The apparatus used for the bend test should 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. A sample of heating cable without terminations and connections should be fixed in the apparatus as shown. The apparatus and sample should 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 should be fixed in the apparatus as shown in figure 3. The sample should 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 the bending operations should be carried out in the same plane. This cycle of operations should be performed knee times. When this has been completed, the sample should be immersed in tap water at room temperature for 5 min, and then the dielectric voltage outlined in 4.2.1 should be applied for 1 min without dielectric breakdown.

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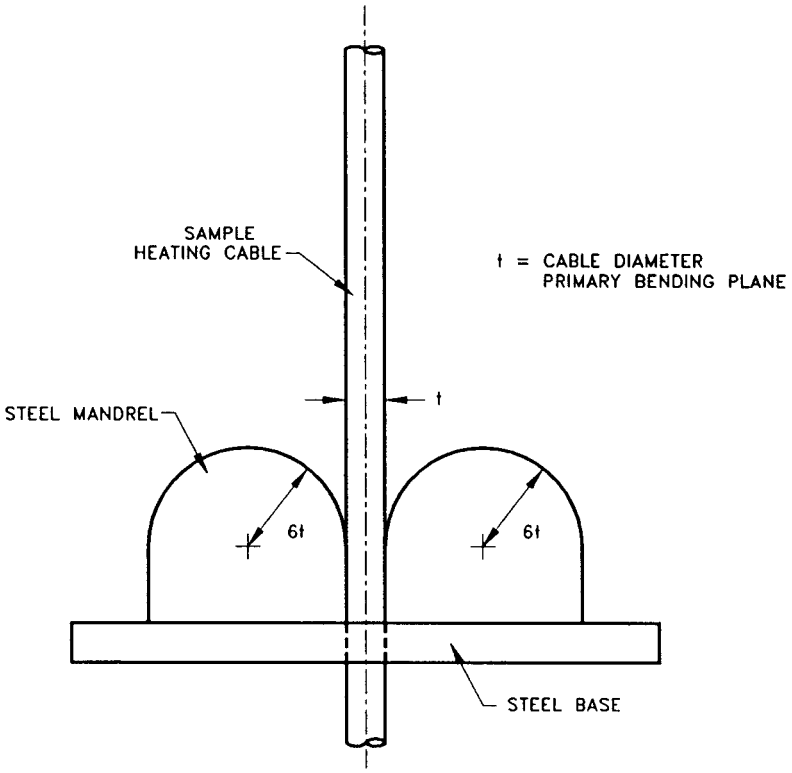


Figure 3—Cold bend test apparatus

4.2.11 Verification of rated output

The rated output of the heating cable should be verified by one of the following three methods:

a) Conductance—the measured ac conductance per unit length at a specified temperature should be within the manufacturer's declared tolerance.
b) Resistance—the measured dc resistance per unit length at a specified temperature should be within the manufacturer's declared tolerance.
c) Thermal—heating cables that change power output with temperature should be measured by the installation of a 3–6 m (10–20 ft) sample on a schedule 40 carbon steel pipe of 5.1 cm (2 in) diameter or greater, as shown in figure 4. The cable should be installed in accordance with the manufacturer's instructions. The test apparatus should be completely covered with a fiberglass thermal insulation of 2.5 cm (1 in) or equivalent.

A suitable heat transfer fluid in the liquid phase should be circulated through the pipe at a sufficient rate to establish turbulent flow corresponding to a Reynolds number greater than 2300. This will establish negligible temperature difference between the fluid and the pipe temperature. Sufficient means should be utilized to maintain constant temperature of the heat transfer fluid. These parameters should be verified by thermocouples placed at the entry and exit ends of the pipe. Flow velocity should be sufficient so that the fluid temperature will not differ by more than 2 °C (3.6 °F) from end to end.

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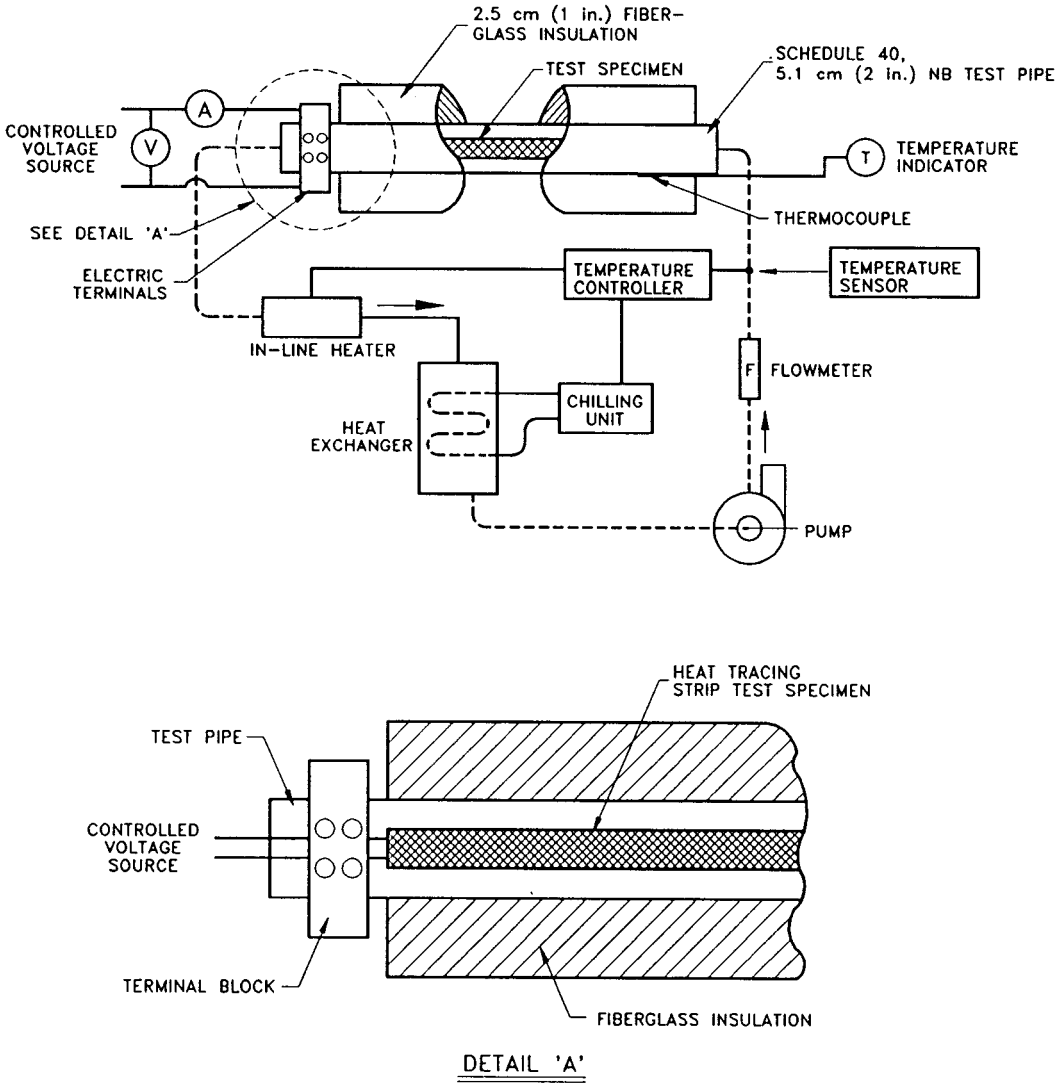


Figure 4—Verification of rated output

The thermal output of the heating cable should be measured at three pipe temperatures over the heater operating range. The heating cable should be powered at its rated voltage and allowed to attain equilibrium. The voltage, current, and fluid temperature should be recorded at each test temperature. Determinations should be made on knee separate samples. The resulting values should be within the manufacturer's declared tolerances.

4.2.12 Verification of start-up current

This test is applicable to heating cables that change output with temperature. The start-up current of the heating cable should be measured at the manufacturer's minimum designated start-up temperature. A sample of heating cable at least 1 m (3 ft) in length is installed in accordance with the manufacturer's instructions on a minimum 5.1 cm (2 in) diameter fluid-filled steel pipe or solid rod. The testing apparatus should be completely covered with thermal insulation and conditioned at the test temperature for at least 4 h. (The apparatus described in 4.2.11 can be used for this test.)

After the conditioning period, med voltage should be applied and the time/current characteristics should be recorded from time zero to at least 120 s. The start-up current reported should be the highest current response of three samples. This time-current characteristic should not be more than the value declared by the manufacturer.

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4.2.13 Verification of metallic covering conductivity

A metallic covering should meet the requirements of 4.2.13.1, 4.2.13.2, or 4.2.13.3.

4.2.13.1 Grounded metallic covering—low impedance

If a metallic covering is intended to be a ground path, then the dc conductance should not be less than the conductance of the largest conductor under evaluation, based on the resistance of an equivalent mm^2 (AWG) copper conductor, but in no case less than $0.81 mm^2$ (18 AWG). This measurement should 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 should be established by taking the reciprocal of the resistance measured and multiplying it by the specimen length.

4.2.13.2 Grounded metallic covering—other than low Impedance

Alternatively, the metallic covering may be evaluated by installing a 3 m (10 ft) long sample of heating cable on a flat horizontal surface that is both non-combustible and electrically non-conductive. The heating cable should be installed in three parallel runs and should not be kinked or crossed over itself. The distance between parallel runs should be 15 cm (6 in). A thermocouple should be affixed to the surface of the sample in the middle run to measure the sheath temperature. Four layers of cheesecloth should then be laid over the entire heating cable and thermocouple installation.

A 50 or 60 Hz variable voltage source should be connected across the ends of the metallic covering. A voltmeter and ammeter should be connected to measure the voltage and current of the test circuit. The variable voltage supply should 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 metallic covering for the times specified below:

Test current = multiplier × maximum branch circuit overcurrent protection

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

The results of the test should 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

4.2.13.3 Bonding of metallic coverings

Metallic coverings not intended as a ground path (high resistance metallic sheath) should, however, be bonded to ground. Further, the heating cable package markings and set markings should conform to 5.2 and 5.3, respectively.

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4.2.14 Strain relief test for fittings

Fittings designed to terminate exposed heating cables directly to an exposed enclosure should 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 30 cm (12 in) of heating cable attached to the subject fitting according to the manufacturer's instructions. A steady load of 9 kg (20 lb) for conductors smaller than 0.81 mm^2 (18 AWG) and 16 kg (35 lb) for all other cases is to be gradually applied between the heating cable and fitting. The load should be maintained for a period of 1 min. As a result of this test, the heating cable should not loosen or separate by more than 1 mm (0.039 in) from the fitting, and there should be no damage to the conductors, insulation, or fitting.

4.2.15 Enclosure considerations

Enclosures, mounting brackets, and associated components should be evaluated for their intended environments in accordance with ANSI/NEMA 250-1991 and ANSI/UL 50-1987, or should be approved for use with the heating cable by a nationally recognized testing authority.

4.3 Type test—outdoor exposed surfaces

Deciding 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) should also meet the requirements of 4.3.1–4.3.5.

4.3.1 Increased moisture resistance test

A minimum 3 m (10 ft) sample, including terminations and connections, should be immersed in water at 10–25 °C (50–77 °F) for a period of 2000 h (12 weeks).

After conditioning as above, the sample should be subjected to the dielectric voltage outlined in 4.2.1 for 1 ruin without dielectric breakdown.

4.3.2 UV and condensation test

A sample of heating cable, approximately 30 cm (12 in) in length, should be hung vertically in the drum of a xenon-arc light-exposure apparatus as described in ASTM G26-93.

The procedure should be as described in ASTM G26-93 for a total period of 500 h. The cycle should be set for 102 min of light and 18 min of combined fight and water spray. At the end of this time, the sample should be removed from the chamber and subjected to the cold bend test in 4.2.10. The dielectric test is to be applied only to the outermost jacket.

4.3.3 Resistance to cutting test

A sample of heating cable, at least 20 cm (8 in) in length, should be used for testing. The sample should be placed on top of a rigid flat steel support. A cutting surface with a 0.25 mm (0.010 in) radius edge should be mounted to a piston hanging above the sample such that the cutting surface is at a right angle to the sample. An ohmmeter should be attached to the cable conductors shorted together, and to the metal cutting surface.

A proof load of 445 N (100 lb) is to be gradually applied to the sample. The cutting edge should not cut through to the conductors of the cable, as indicated by the ohmmeter.

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4.3.4 Abrasion test

Six straight samples, approximately 91 cm (36 in), should be prepared. Samples containing a metallic covering should be evaluated initially for electrical resistance of the shield with an ohmmeter having an accuracy of ± 1%. The average resistance for the samples should be calculated. The samples should be attached to a horizontal reciprocating table while the table is at one end of its travel. The other end of each specimen should be attached to a weight of 340 g (0.75 lb). Each specimen should be laid over a 9 cm (3.5 in) 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 5. The longitudinal axis of the cylinder should be horizontal and perpendicular to each of the vertical planes that contain the specimens as they are rubbed against the abrasive cloth.

The table should be started in its horizontal reciprocating motion at the rate of approximately 30 cycles per minute. Each cycle should consist of one complete back and forth motion with a stroke of approximately 16 cm (6.25 in). The table should be stopped every 50 cycles and the abrasive cloth should 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 should be stopped and the samples braid resistance should be measured again. The average braid resistance should be calculated and compared to the initial value. There should be no broken strands, and the resistance value should not exceed 125% of the initial value. For overjacketed cables, the underlying braid should not be exposed.

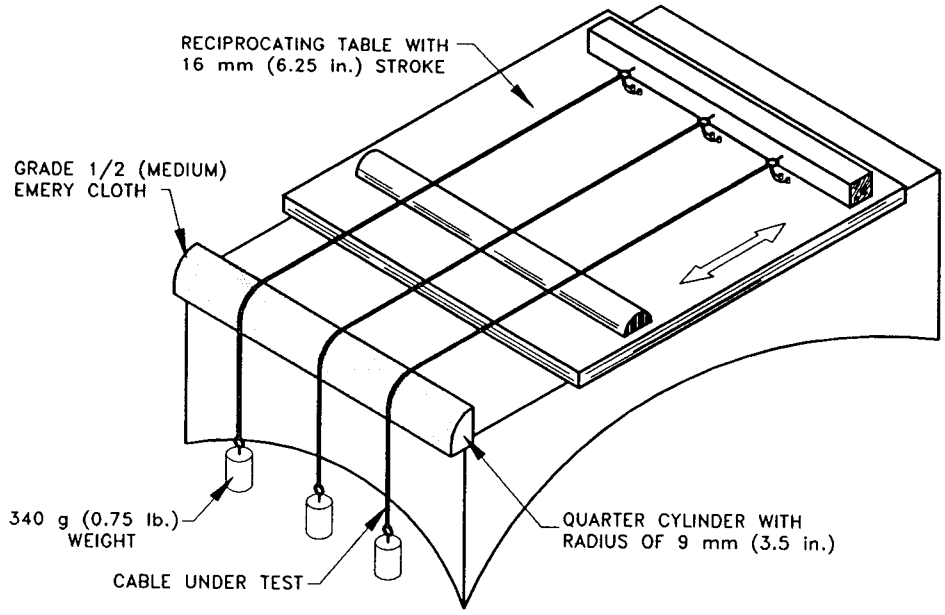


Figure 5—Abrasion test

4.3.5 Tension test

A 32 kg (70 lb) weight (intended to simulate the weight of a 5 mm × 10 mm × 6 m (2 in × 4 in × 20 ft) long section of ice) should be suspended from the free end of the heating section while the other end of a 90 cm (3 ft) portion should be secured tightly. The test duration should be 1 h. There should be no breakage of the conductors or braid and there should be no damage to the insulation.

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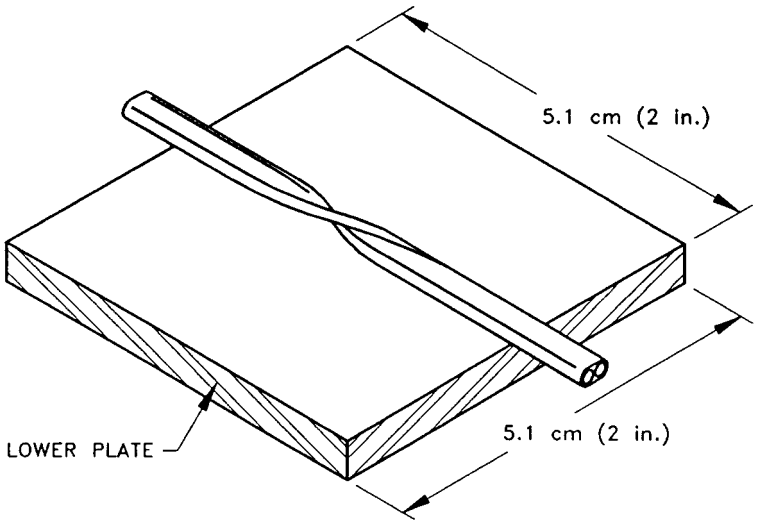


Figure 6—Resistance to crushing test

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, cable systems intended for embedding (type C applications as defined in table 1) should 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 20 cm (8 in) sample should be placed in a compression device, between the flat rigid steel plates mounted horizontally and parallel to each other. As shown in figure 6, the dimensions of each plate should be 5.1 cm (2 in) in the horizontal direction (width) parallel to the longitudinal axis of the heating cable.

If applicable, the sample should be twisted 180° between the plates, so as to cause the conductors to overlap during the compression. A force of 8900 N (2000 lb) should be applied gradually to the plates. There should be no electrical contact between the two conductors, or between the conductors and the metallic braid and plates. The measurement should 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 should 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

This test is described in 4.3.1.

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4.5.2 Pull-strength test

A 68 kg (150 lb) weight, or a weight equivalent to the manufacturer's stated maximum conduit pull strength value, whichever is greater, should be suspended from the free end of a 1 m (3 ft) length of heating cable while the other end is secured tightly. The test duration should be 1 min. The weight should 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 should be no breakage of the conductors or braid and there should be no damage to the insulation.

4.6 Routine testing

These tests should be carried out during production or prior to shipment.

4.6.1 Output rating

The output rating for each shipped length of electric heating cable, whether bulk or an individually fabricated circuit, should be verified by measurement of the dc resistance, conductance, or current at a given voltage and temperature. The value should be within the manufacturer's tolerance.

4.6.2 Dielectric test

Each shipped length, whether a bulk or individually fabricated circuit, should be subjected to the dielectric test as outlined in 4.2.1.

Heating cables without a metallic covering should have the dielectric test conducted while immersed in tap water at room temperature. Heating cables with a metallic covering should have the dielectric test conducted without being immersed in water. Heating cables with a polymeric jacket over the metallic covering for corrosion resistance should be subjected to the dielectric test while immersed in water.

As an alternate to immersing in water, heating cables may be subjected to a dry-spark test, with a minimum test voltage of 4500 Vac rms that has a substantially sinusoidal waveform at 2500–3500 Hz. The speed/frequency relationship should be set such that the cable should be subjected to at least 9 full cycles of the ac voltage waveform.

5. Markings

5.1 Bulk cable markings

Parallel or series cable intended for field fabrication should be clearly and permanently surface-marked with the following information:

a) The manufacturer's name, trademark, or other recognized symbol of identification.
b) The catalog number, reference number, or model.
c) The month and year of manufacture, date coding, applicable serial number, or equivalent.
d) The rated voltage.
e) The rated power output in watts per unit length at the rated voltage, and at a stated maintain temperature for cables that change output with temperature.
f) The statement "Refer to Form No. _____," or equivalent, to cross-reference the cable to kits specifically certified with the cable. This form should include the installation instructions for the kits, or a moss-reference to the applicable instructions.

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5.2 Cable reel or carton markings

The carton, container, spool, or reel in or on which the heating cable is delivered should be marked with the following information:

a) The manufacturer's name, trademark, or other recognized symbol of identification.
b) The catalog number, reference number, or model.
c) The rated voltage.
d) The rated power output in watts per unit length at the rated voltage, and at a stated maintain temperature for cables that change output with temperature. For series cable in bulk form, the maximum ratings should be stated instead.
e) The statement "Refer to Form No. _____," or equivalent, to cross-reference the cable to kits specifically certified with the cable. This form should include the installation instructions for the kits, or cross-reference to the applicable instructions.
f) The intended use(s) as shown in table 1, either by type definition of by examples of type.
g) Where a metallic covering is not intended as a ground path, as described in 4.2.13.3, the phrase "High resistance metallic sheath should not be utilized as a grounding conductor (except for ground fault circuit protection), but should be bonded to ground," or equivalent wording.
h) The maximum continuous exposure temperature of the cable.

5.3 Markings for factory fabricated sets

Factory-fabricated sets should be provided with a durable tag permanently attached to the sets within 7.6 cm (3 in) of the power connection or power connection string, and marked with the following information:

a) The manufacturer's name, trademark, or other recognized symbol of identification.
b) The catalog number, reference number, or model.
c) The month and year of manufacture, date coding, applicable serial number, or equivalent.
d) The rated voltage.
e) The rated steady-state current, or total wattage, at a stated maintain temperature.
f) Where a metallic covering is not intended as a ground path as described in 4.2.13.3, the phrase "high-resistance metallic sheath should not be utilized as a grounding conductor (except for ground fault circuit protection), but should he bonded to ground," or equivalent wording, Alternatively, the phrase "High Resistance Metallic Sheath" should be used if the additional information is included on the cable packaging.
g) The statement "Intended for dry locations only" or equivalent wording, for systems investigated only for dry locations.

5.4 Package markings for field fabrication kits

The kit packaging should be marked as approved, listed, or certified, and the following information should be provided:

a) The manufacturer's name, trademark, or other recognized symbol of identification.
b) The catalog number, reference number, or model.
c) The intended use(s), such as "power connection assembly."
d) The statement "Refer to Form No._____," or equivalent, to cross-reference the kit to the cable type specifically certified with the cable, This form should include the installation instructions for the kits, or a cross-reference to the applicable instructions.
e) The statement "Intended for dry locations only," or equivalent wording, for systems investigated only for dry locations.

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6. Design, installation, and maintenance

The following subclauses cover specific applications of electrical resistance heat tracing in commercial areas. Each subclause provides individual guidelines for the design, installation, and maintenance of the heat tracing.

6.1 Temperature maintenance of piping systems

6.1.1 Application description

Heating cable is 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 portable 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 should be thermally insulated.

Cable circuits intended for these applications should meet the requirements for type A tracing as defined in table 1.

6.1.2 Design information

The following general design conditions and application inputs are needed prior to commencing with the system design. Additional specific information that may be required is detailed in 6.1.5.

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

6.1.2.1 Performance level classification system

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

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 recommended practice.

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6.1.2.2 General design considerations

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

a) Maximum circuit length and sizing of overcurrent protection. These items should be specified by the manufacturer.
b) For non-metallic pipes, the heating cables should have a metallic braid or sheath.
c) For non-metallic pipes, the heating system should be evaluated to ensure that the maximum cable temperature does not exceed the temperature rating of the pipe. The manufacturer should also supply recommendations for these applications, including product performance and installation guidelines.

6.1.3 Heat loss determination

For outdoor freeze protection applications with glass fiber thermal insulation, heat loss rates in W/m (W/ft) are shown in table 2. The table is based on the condition of a 32 km/h (20 m/h) wind, a 4 °C (40 °F) maintain temperature, and a 10% safety factor. This is considered a minimum level. If a greater safety factor is recommended, the values in table 2 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 515-1989 , Appendix A, and on the thermal conductivity of glass fiber.

For other types of thermal insulation, the heat loss rate given in table 2 is multiplied by the correction factor given in table 3, The correction factors in table 3 are based on insulation thermal conductivities at 10 °C (50 °F). The heat loss rate should be adjusted for cases involving oversized insulation, as specified in 6.1.4.1 item h).

Table 2—Outdoor freeze protection heat loss rates in W/m (W/ft) based on use of glass fiber insulation

Insulation thickness		Pipe size		Minimum ambient temperature							
cm	in	cm	in	–40 °C	–40 °F	–29 °F	–20 °F	–17.7 °C	0 °F	–6.7 °C	20 °F
2.5	1.0	2.5	1.0	10.8	3.3	8.2	2.5	5.6	1.7	3.0	0.9
		4.0	1.5	13.8	4.2	10.5	3.2	7.2	2.2	3.6	1.1
		5.0	2.0	16.4	5.0	12.5	3.8	8.5	2.6	4.3	1.3
		6.0	2.5	19.0	5.8	14.4	4.4	9.8	3.0	4.9	1.5
		7.5	3.0	22.0	6.7	16.7	5.1	11.5	3.3	5.9	1.8
		9.0	3.5	24.6	7.5	18.7	5.7	12.8	3.9	6.6	2.0
		10.0	4.0	27.2	8.3	20.7	6.3	14.1	4.3	7.2	2.2
4.0	1.5	7.5	3.0	16.1	4.9	12.5	3.8	8.5	2.6	4.3	1.3
		10.0	4.0	19.7	6.0	15.1	4.6	10.2	3.1	5.3	1.6
		15.0	6.0	26.9	8.2	20.3	6.2	13.8	4.2	6.9	2.1
		20.0	8.0	33.5	10.2	25.6	7.8	17.4	5.3	8.9	2.7
		25.0	10.0	40.7	12.4	30.8	9.4	21.0	6.4	10.5	3.2
5.0	2.0	15.0	6.0	21.3	6.5	16.4	5.0	11.2	3.4	5.6	1.7
		20.0	8.0	26.3	8.0	20.0	6.1	13.8	4.2	6.9	2.1
		25.0	10.0	31.8	9.7	24.3	7.4	16.4	5.0	8.2	2.5
		30.0	12.0	36.8	11.2	28.2	8.6	19.0	5.8	9.5	2.9

For conditions other than those presented here, the heat loss rates should be calculated from the formulas presented in Appendix A of IEEE Std 515-1989 , 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" [B19] and the *Handbook of Thermal Insulation Design Economics for Pipes and Equipment* [B28][9]

[9]The numbers in brackets preceded by the letter B correspond to the bibliography entries in clause 7..

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Table 3—Insulation correction factors

Insulation type	Correction factor	Thermal conductivity at 10 °C (50 °F)	
		W/m °C	(Btu-in/h-ft^2-°F
Rigid cellular urethane (ASTM C591)	0.66	0.024	0.165
Polyisocyanurate foam (ASTM C591)*	0.75	0.027	0.180
Glass fiber (ASTM C547)	1.00	0.036	0.250
Foamed elastomer (ASTM C534)	1.16	0.042	0.290
Mineral fiber blanket (ASTM C553)	1.20	0.043	0.300
Calcium silicate (ASTM C533)	1.50	0.054	0.375
Cellular glass (ASTM C552)	1.60	0.058	0.400

*Recommended for outdoor use only.

6.1.4 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 non-metallic piping, and internal heat-tracing.

6.1.4.1 Metal pipes (external heat tracing)

a) The pipe should be spaced at least 5 cm (2 in) from adjacent walls or ceilings to facilitate installation of thermal insulation.
b) Heating cable should typically be fastened to the pipe between 31 cm (12 in) and 61 cm (24 in) intervals with temperature rated plastic cable ties or fiberglass tape, aluminum tape, pipe straps or tie wire. Caution should 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 7.
d) Valves, flanges, pipe supports, and other components typically require additional heat, Extra heating cable should be provided, as specified by the manufacturer.
e) Thermal insulation should be suitable for the particular installation, such as outdoor or below grade use.
f) A moisture-proof weather barrier surrounding the thermal insulation should 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 5 cm (2 in) from the cable, Refer to figure 7. 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 8.
l) A low point drain in the conduit leading to the power connection box is recommended, as shown in figure 8.

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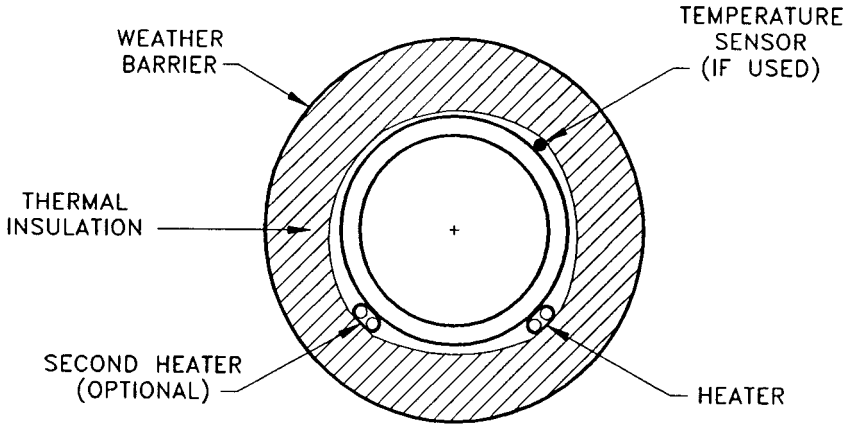


Figure 7—Tracers

6.1.4.2 Non-metallic pipes (external heat tracing)

Generally, all of the preceding recommendations for metal pipes also apply to non-metallic 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 2.5–5 cm (1–2 in) 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.

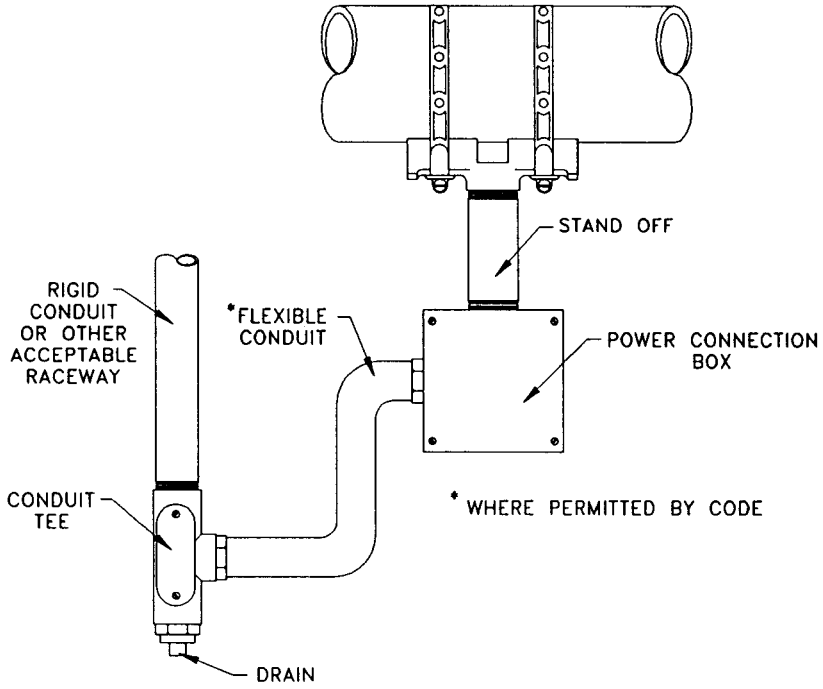


Figure 8—Conduit drain detail to prevent moisture accumulation

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6.1.4.3 Internal heat tracing

Where external heat tracing is practical, internal heat tracing typically is not recommended, Internal heat tracing is, however, occasionally used for freeze protection of nonpressurized drain lines, These units should be properly fitted to make a watertight connection where the heating cable emerges from the pipe, Internal tracing of potable water lines should also meet NSF Std 14-90 [B23], NSF Std 24-88 [B24], and NSF Std 61-92 [B25] guidelines. Cable circuits intended for this application should also meet the requirements for type D tracing as defined in table 1, The manufacturer should specify detailed application and installation procedures.

6.1.5 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,

6.1.5.1 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 should be specified by the manufacturer.
b) For energy conservation, line sensing temperature controllers are recommended for pipe sizes of 15 cm (6 in) or larger, and for areas where the ambient temperature remains below 40 °F for several weeks at a time.
c) For fire sprinkler lines, the tee section of the sprinkler head is 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 (5 °F) below the activation temperature of the head in an ambient of 40 °C (104 °Φ).
d) A low temperature alarm, with remote alarm contact, is required for each fire sprinkler line heating circuit, The recommended set-point is 2 °C (35 °F).
e) For emergency eyewash units, safety showers, and associated supply piping the tracing is sized to prevent freezing, and the water temperature is limited to no more than 35 °C (95 °F) by product or system design, or controllers.

6.1.5.2 Domestic hot water/tempered water

a) Typical system design temperatures for domestic hot water and tempered water systems are listed in table 4.
b) The local plumbing code and/or model plumbing code should be consulted for heating of non-metallic pipes.
c) The operating temperature and the maximum system temperature should be verified for compatibility with the manufacturer's heating cable rating, If the piping system operates at temperatures in excess of 65 °C (150 °F) or experiences temperatures in excess of 85 °C (185 °F) at start-up, the manufacturer should specify the proper heating cable selection.
d) Line sensing temperature control should be considered for the following conditions:
    1) Piping that extends through areas where the ambient temperature differences is greater than 3 °C (5 °F)
    2) Extended vertical risers are greater than 9.1m (30 ft)
    3) Systems requiring a maintenance temperature of 82°C (180 °F) or higher

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Table 4—Domestic hot water and tempered water temperatures*

Application	Temperature	
	°C	°F
Safety showers and eyewashes	16–35	60–95
Hot water service without mixing valves	40	105
Nursing homes and hospitals	40 and 46	105 and 115
General purpose	49–60	120–140
Laundry service	71	160
Kitchen sanitization	82	180

*Consult local codes for specific application temperature requirements.

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 should be provided.
g) Specific maintenance,temperatures may be required for emergency eye washes 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 [B6] and CFR Publication 29, Part 1910 (OSHA)§ 1910.151(c) [B16].
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.

6.1.5.3 Fuel oil lines

a) The heating cable outer jacket should be resistant to hydrocarbon exposure.
b) For piping classified as Class I, Division 2, only approved heating cable, components, and wiring methods should be used. Refer to IEEE Std 515-1989 .
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 9. Thermal output and maximum sheath temperature should be specified by the manufacturer. Splicing should be avoided, unless required to prevent exceeding the maximum pulling force of the cable. If required, splices should be made in a suitable enclosure and sealed.
e) Line sensing temperature control with the sensor 90° from the heater is recommended.

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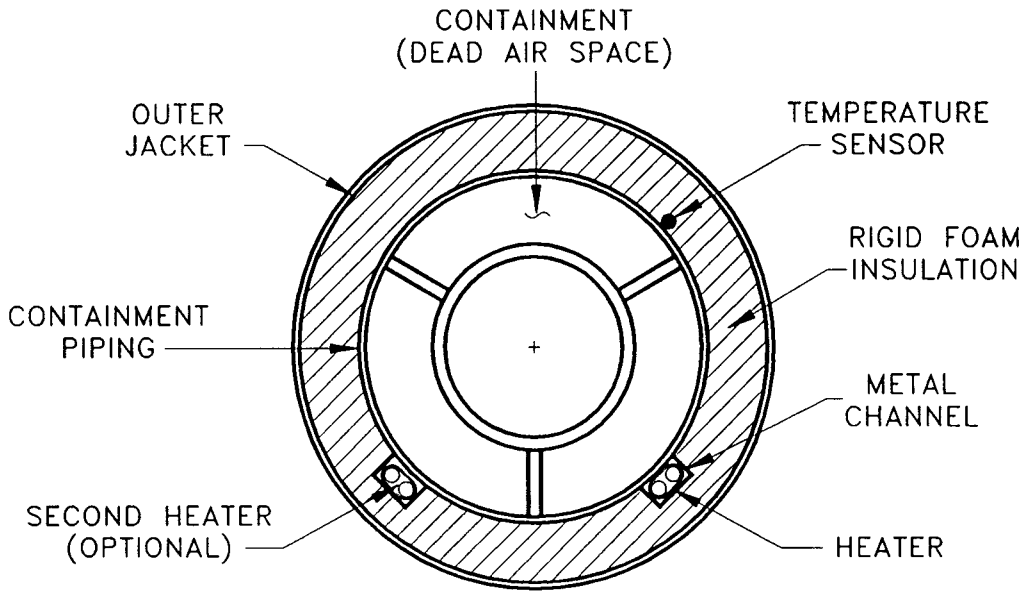


Figure 9—Double containment

6.1.5.4 Grease lines

a) The design maintenance temperature is typically between 43 °C and 49 °C (110 °F and 120 °F).
b) Since 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) Since 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 10 a). Line sensing temperature control with the sensor located 5 cm (2 in) 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 and eight o'clock instead of one heating cable at six o'clock. Refer to figure (10 b). The temperature sensor should be located at the six o'clock position between the heat tracers.

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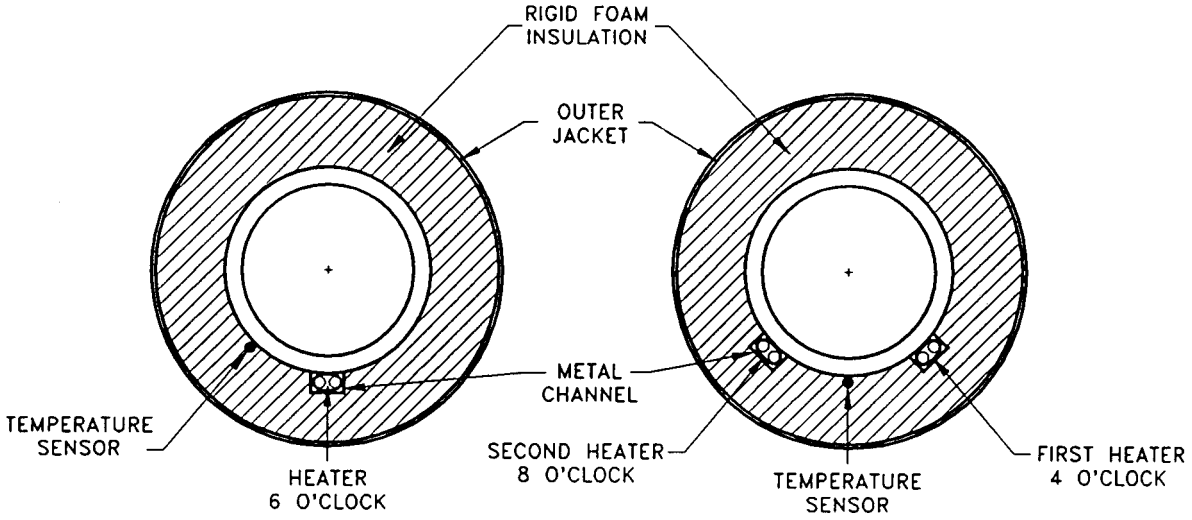


Figure 10—Grease lines

6.1.6 Electrical design

6.1.6.1 Circuit protection

The heating cable branch circuit protection equipment should be capable of interrupting high impedance faults, as well as bolted or hard faults. This should be accomplished by a ground-fault equipment protective device with a nominal 30 mA trip rating, such as a controller with ground fault interruption capability for use with a molded-case circuit breaker, or other system of devices which meet this intent.[10] The trip level for adjustable devices is to be set 30 mA above any inherent capacitive characteristic level, as specified by the manufacturer.

6.1.6.2 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

a) On/off switch with pilot
b) Ambient sensing (mechanical thermostat controlling a number of 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

6.1.6.3 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.

[10]Exception: Where continued circuit operation is essential for safe operation of equipment. However, ground fault detection and alarm should be considered.

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6.1.6.4 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 5.

6.1.7 Installation

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

6.1.7.1 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.

6.1.7.2 Prior to installation of heat tracing

a) The heating cable should be verified that it is the correct factory fabricated unit or bulk cable type prior to 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 should 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 prior to completion of the piping system is not recommended.

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Table 5—Level of monitoring and control

	Control				Monitoring*			
	Manual on/off	Ambient	Line sensing		Low temp.	High temp.	Supply voltage	Continuity
			Mechanical	Electronic				
Category II								
Pot. water < 6 in	M	R	—	—	—	—	—	—
Pot. water > 6 in	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	—	R	M	—	—	M

M = minimum required

R = recommended

*Ground monitoring is recommended for all underground piping.

6.1.7.3 During installation

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 should not be substituted.

6.1.7.4 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 Vdc. However, for mineral insulated cables, a test voltage of 1000 Vdc is recommended, and for polymer insulated heating cables, a test voltage of 2500 Vdc is recommended. The measured value should not be less than 20 MΩ. The value should be recorded on a log sheet as shown in the annex.

6.1.7.5 After thermal insulation installation

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 6.1.7.A should be conducted, and the readings should be recorded on a log sheet (refer to the annex).
d) Caution labels denoting the presence of heat tracing should be installed on the thermal insulation/weather barrier at 5–6 m (16–20 ft) intervals.

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6.1.8 Maintenance

A system inspection for freeze protection systems is recommended prior to 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 (refer to the annex). 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 2–5 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 to the manufacturer's output rating at the measured pipe temperature.
e) Major changes in insulation resistance or heater current should be resolved.

6.2 Roof and gutter deicing

6.2.1 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 11).

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

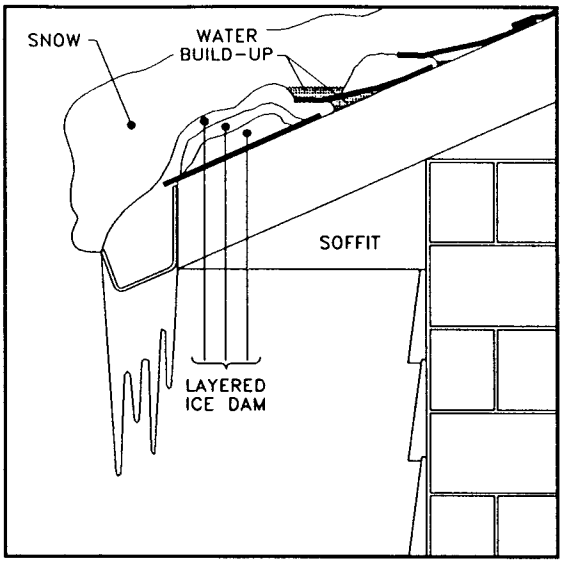


Figure 11—Ice dam formation

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6.2.2 Design information

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

a) Heating cables used are typically rated between 16 and 66 W/m (5 and 20 W/ft). For nonmetallic gutters and downspouts see the special design considerations in 6.2.5.
b) The type of heater selected shall have a metallic covering (metal sheath, braid or equivalent), which should be bonded to the equipment ground.
c) Heaters shall be constructed of a material that will not be adversely affected by long term exposure to ultraviolet rays.
d) In-line splices and tee splices should be avoided where possible.
e) A typical design will have 30 cm (12 in) of heater cable per 30 cm (12 in) of gutter. If a gutter is wider than 15 cm (6 in), multiple runs of heating cable are recommended.
f) Heating cable in downspouts should be looped [61 cm (24 in) of heater per 30 cm (12 in) of downspout] and should extend below the frost line if tied into a drainage system (see figure 12).
g) 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.
h) The circuit length for a given overcurrent protection device should not exceed the maximum length specified by the manufacturer.
i) Supporting devices and attachment devices, as specified by the manufacturer, should be provided. See figures 13, 14, and 15.
j) The amount of cable to be provided for different distances of eaves, valleys, and overhangs should be specified by the manufacturer.
k) Design drawings and/or data sheets detailing each circuit for each roof and gutter system are recommended.

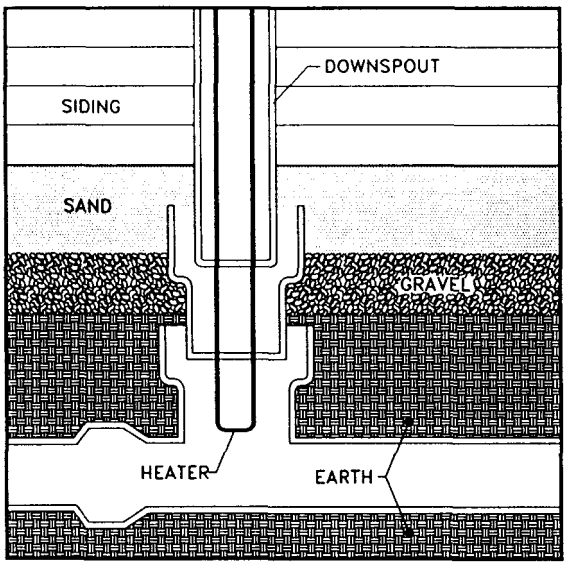


Figure 12—Downspout to underground drain

6.2.3 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.

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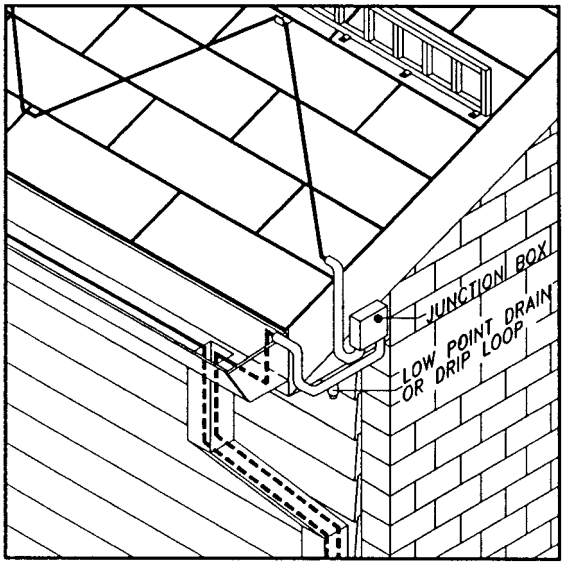


Figure 13—Roof and gutter cable arrangement

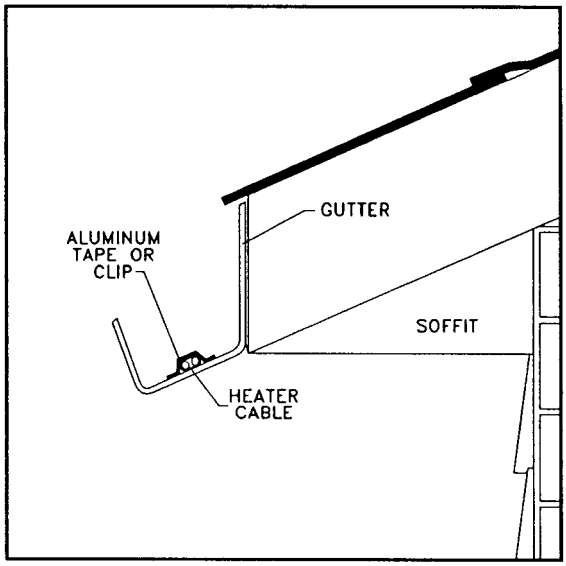


Figure 14—Gutter detail

6.2.4 Heaters and component mounting

The details shown in figure 15 are examples of mounting methods on typical roof materials. The manufacturer should specify materials and procedures for specific cable applications.

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 13).

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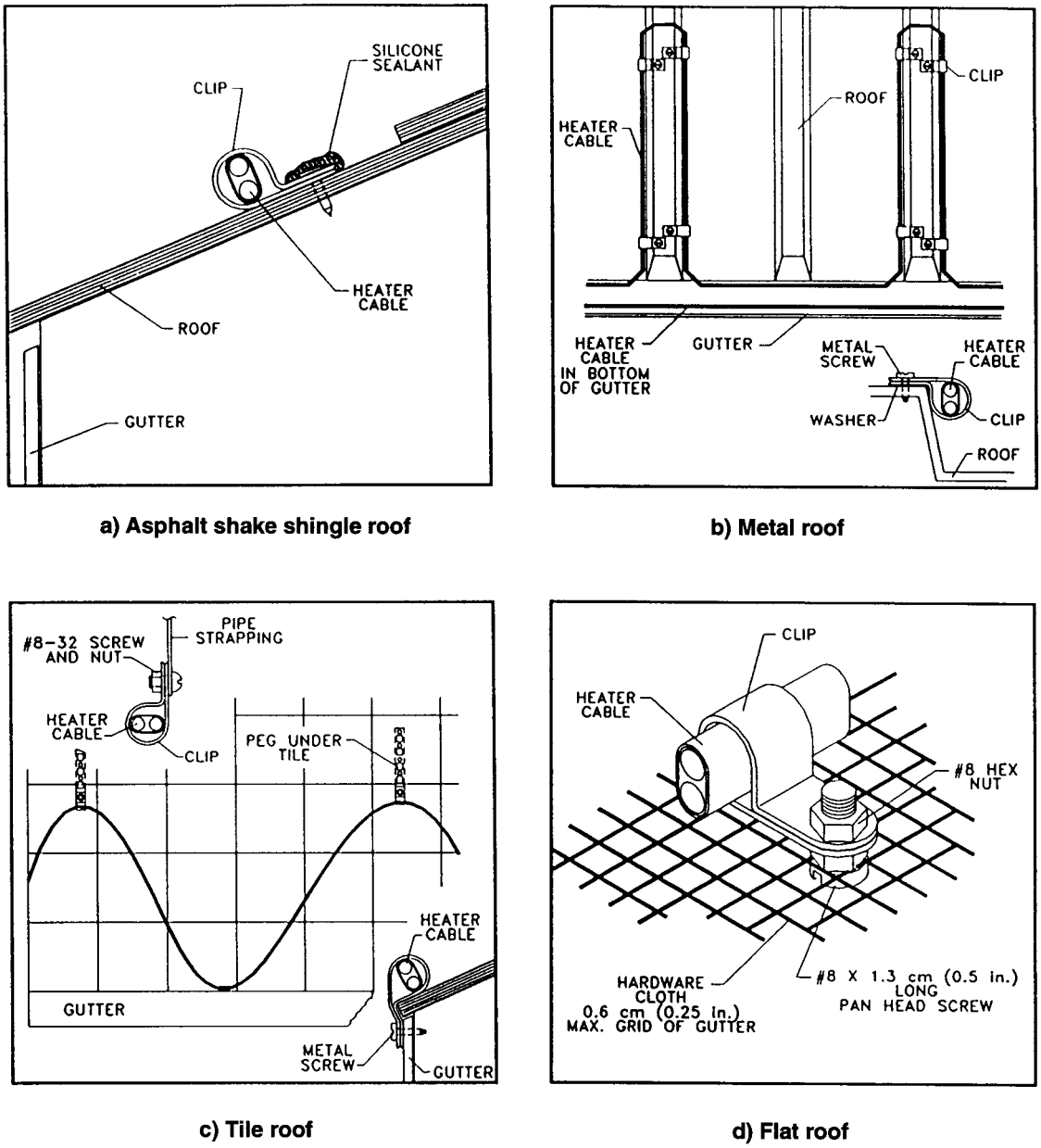


Figure 15—Typical roof mounting methods

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. As-built drawings and data should be provided by the manufacturer or installer.

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.

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6.2.5 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 should be verified, and a heater should 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 (3 ft). Refer to figure 16.
d) Any roof or gutter application that is not specifically mentioned in this recommended practice should be referred to the heat trace manufacturer for recommendations.

6.2.6 Electrical design

6.2.6.1 Circuit protection

The heating cable branch circuit protection equipment should be capable of interrupting high impedance faults, as well as bolted or hard faults. This should be accomplished by a ground-fault equipment protective device with a nominal 30 m A trip rating, such as a controller with ground fault interruption capability for use with a molded-case circuit breaker, or other system of devices that meet this intent.[11] The trip level for adjustable devices is to be set 30 mA above any inherent capacitive characteristic level, as specified by the manufacturer.

6.2.6.2 Control options

Methods for controlling a roof and gutter deicing systems are:

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.

6.2.6.3 Monitoring

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

[11]Exception: Where continued circuit operation is essential for safe operation of equipment. However, ground fault detection and alarm should be considered.

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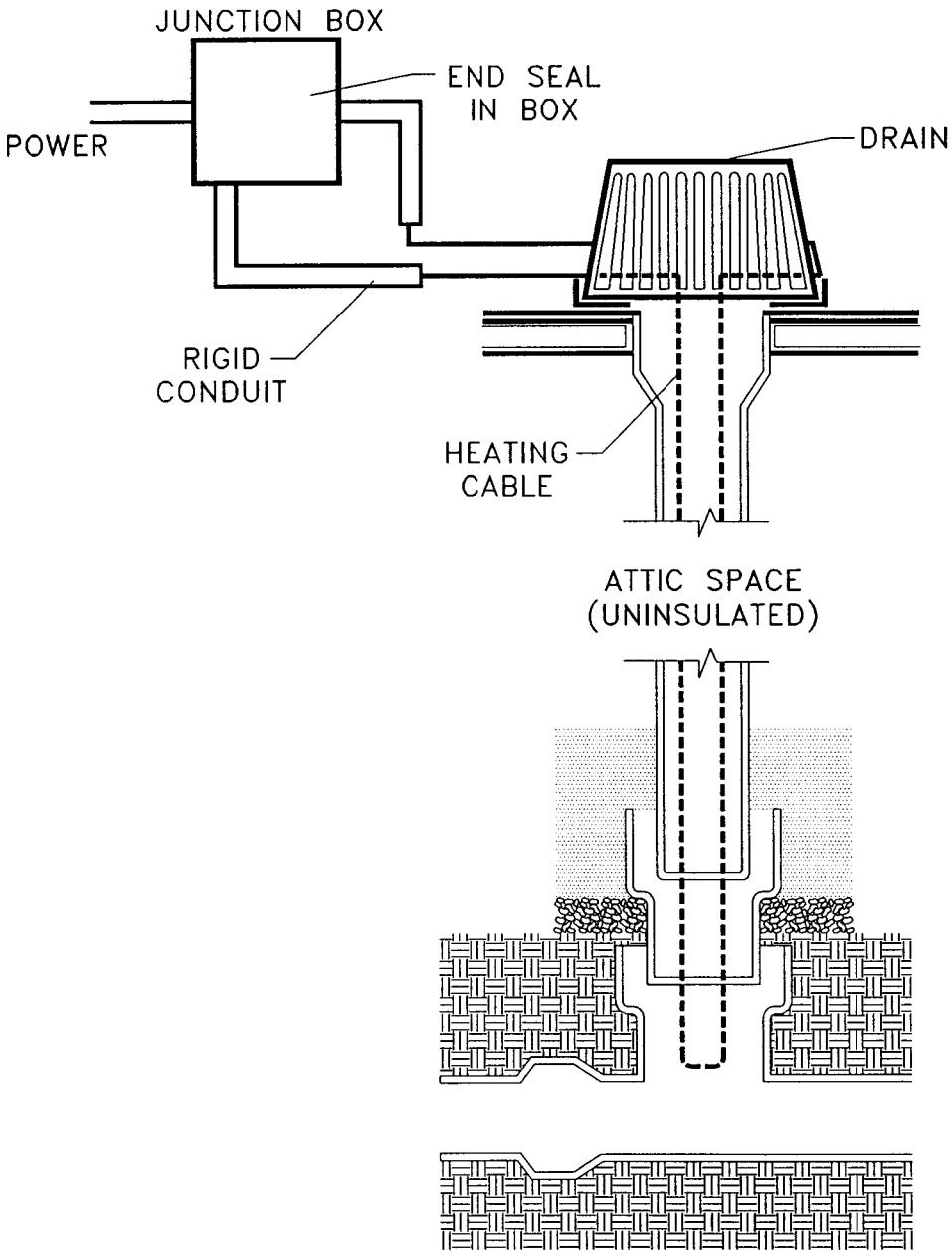


Figure 16—Drain detail for flat roof

6.2.7 Installation

Prior to 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 should be cleared of debris.
b) The mounting surface should be inspected for sharp edges where the heating cable will be located (and removed as necessary).

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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 Vdc. However, for mineral insulated cables, a test voltage of 1000 Vdc is recommended, and for polymer insulated heating cables, 2500 Vdc is recommended. The measured value should not be less than 20 MΩ.

6.2.8 Maintenance

A system inspection is recommended prior to each winter season. All observations and measured values as appropriate should be recorded on a log sheet (refer to the annex). 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 should 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.

6.3 Snowmelting

6.3.1 Application description

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

Cable circuits intended for these applications should 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 prior to burial should meet the requirements for type D tracing.

6.3.2 Design information

The design conditions and application inputs in 6.3.2.1–6.3.2.4 are needed prior to commencing with the system design.

6.3.2.1 Weather data

a) Rate of snowfall
b) Ambient temperature
c) Wind velocity
d) Humidity

6.3.2.2 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

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6.3.2.3 Electrical considerations

a) Voltage supply
b) Desired control technique

6.3.2.4 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* [B26] 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 recommended practice uses two categories, as follows:

Noncritical 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 wont 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 (20 °F and 34 °F) with 8–24 km/h (5–15 m/h) winds.

6.3.3 Heat load determination

The heat needed to perform the snowmelting function is based on a number of terms, which are shown in equation (1) below:

$$Q_T = A_r(Q_e + Q_c + Q_r) + Q_s + Q_m + Q_g \quad (1)$$

where

A_r is A_{free}/A_{total}
Q_e is evaporation from top surface
Q_c is convection from top surface
Q_r radiation from top surface
Q_s is sensible heat
Q_m is latent heat
Q_g is heatloss 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* [B26]. As an alternative to calculating the snowmelting heat load with equation (1), table 6 provides typical snowmelting heat load values.

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Table 6—Snowmelting heat loads

Snowfall	Severity		Classification			
Category	Rate of snowfall		Non-critical		Critical	
	(cm/h)	(in/h)	(W/m^2)	(W/ft^2)	(W/m^2)	(W/ft^2)
Light	1.3	0.5	320	30	540	50
Moderate	2.5	1	430	40	650	60
Heavy	5	2	540	50	750	70

It is important to realize that the values in table 6 provide overall power densities for various conditions, however, they do not address temperature distribution across the slab surface. This 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 6.3.4.

6.3.4 Heater and component mounting

To provide uniform heat in a slab, embedded heat tracing is typically serpentined in the slab (as shown in figure 17) or if the heat tracing is in a conduit, it is spliced as shown in figure 18.

a) To obtain a relatively uniform temperature distribution across the surface, spacing(s) between embedded heaters or conduits usually range between 8–30 cm (3–2 in). The spacing for a given snowmelting application is a function of the required heat load, W/ft^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 (60 W/ft^2) and the heater selected had a rating of 98 W/m (30 W/ft) in concrete, the resulting spacing would be 0.15 m (0.5 ft). While it would appear cost effective to use a higher output heater, such as 195 W/m (60 W/ft), and increase the spacing, a poor temperature distribution might result with some areas well in excess of 0 °C (32 °F) and others below freezing.

b) The recommended cable depth is 5–10 cm (2–4 in) for concrete. For new construction with a single pour method, the heater is usually fastened to the re-bar, or a 15 × 15 cm (6 × 6 in) 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 4–5 cm (1.5–2 in).

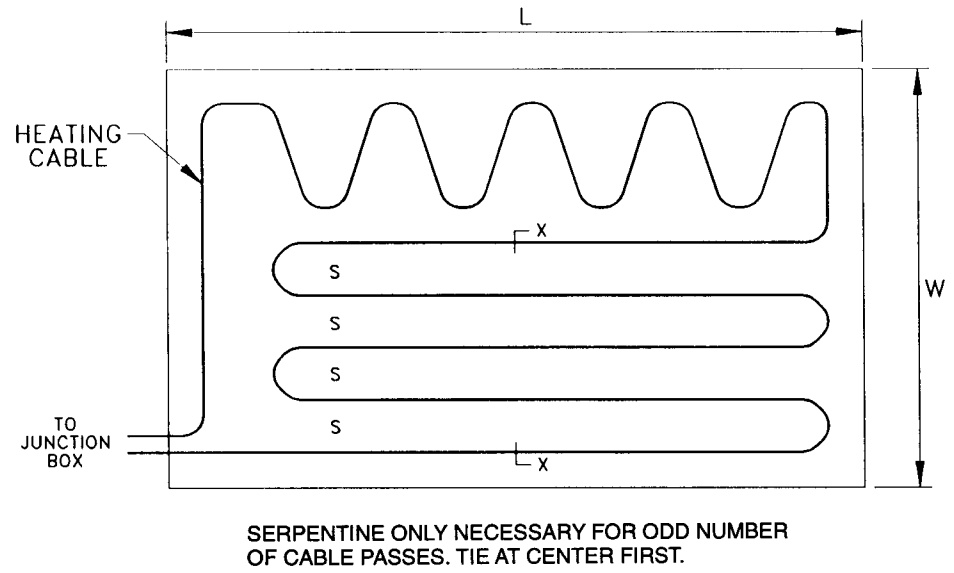
c) Heater cables should be located a minimum of 15 cm (6 in) from the edge of the slab. To minimize the number of bends, the embedded heat tracing should be oriented longitudinally in the slab section. Crossing of expansion joints should be avoided. In cases where ar expansion joint transition is required, additional protection is necessary. Refer to figure 19.

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 trouble shooting and enhance reliability. Recommended methods are shown in figure 20.

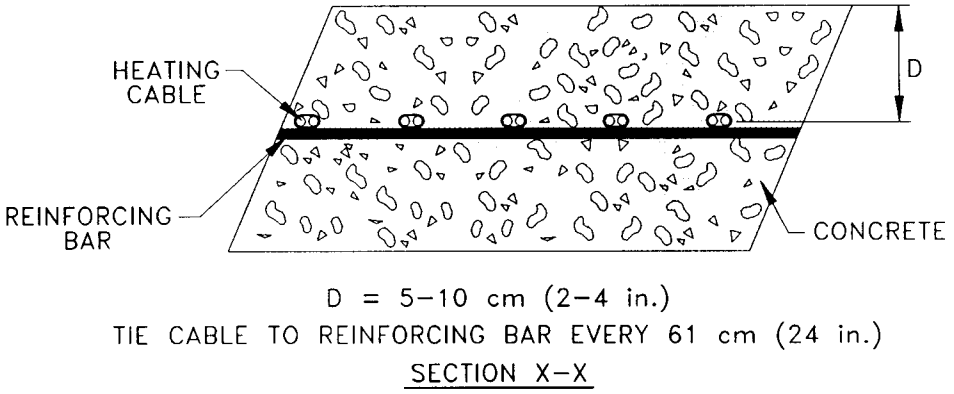
e) Drawings and appropriate documentation are recommended for each snow melting application. These should include:
   1) Heater type
   2) Spacing
   3) Depth
   4) Orientation
   5) Location of power connection and expansion joints (if used)
   6) Identification of circuit
   7) Obstruction and penetrations

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a) Plan view—Typical cable arrangement

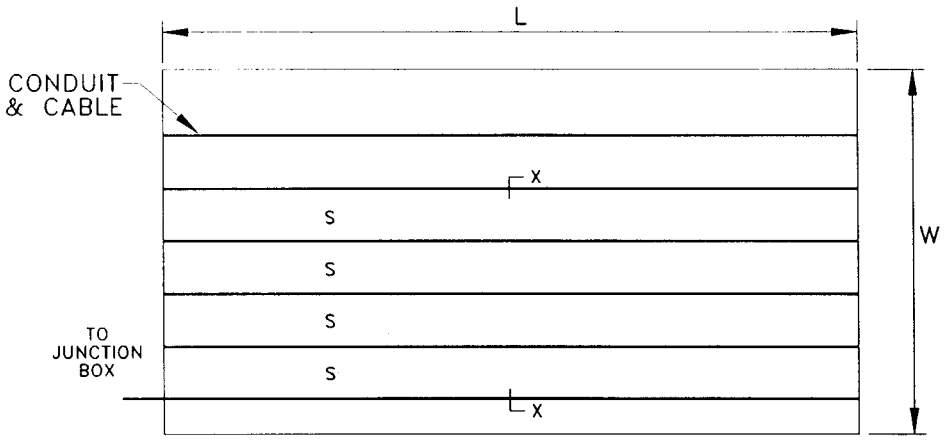


b) Typical cross-sectional view

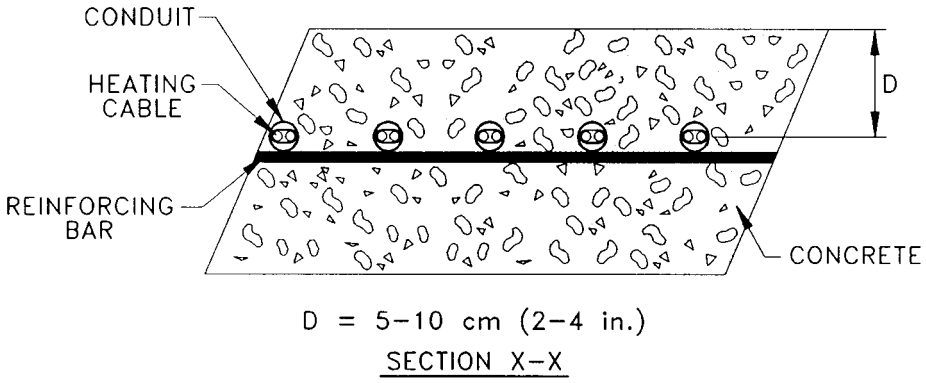
Figure 17—Snowmelting cable embedded in concrete

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a) Plan view—Typical conduit arrangement



b) Typical cross-sectional view

Figure 18—Snowmelting cable located in conduit

6.3.5 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 (15 ft) and the length should be no greater than twice the width (according to *The ASHRAE Application Handbook* [826]).
b) For systems where the heating cable is located in conduit or steel pipe, the maximum sheath temperature and thermal output should be specified by the manufacturer.
c) Snowmelting applications around aircraft hanger doors or fuel storage areas may be classified. If so, the heating system shall meet the CID1 or CID2 requirements outlined in IEEE Std 515-1989.

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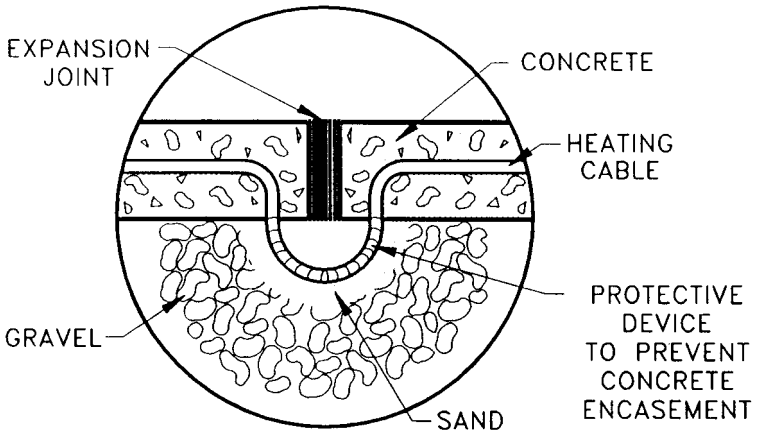


Figure 19—Expansion joint detail

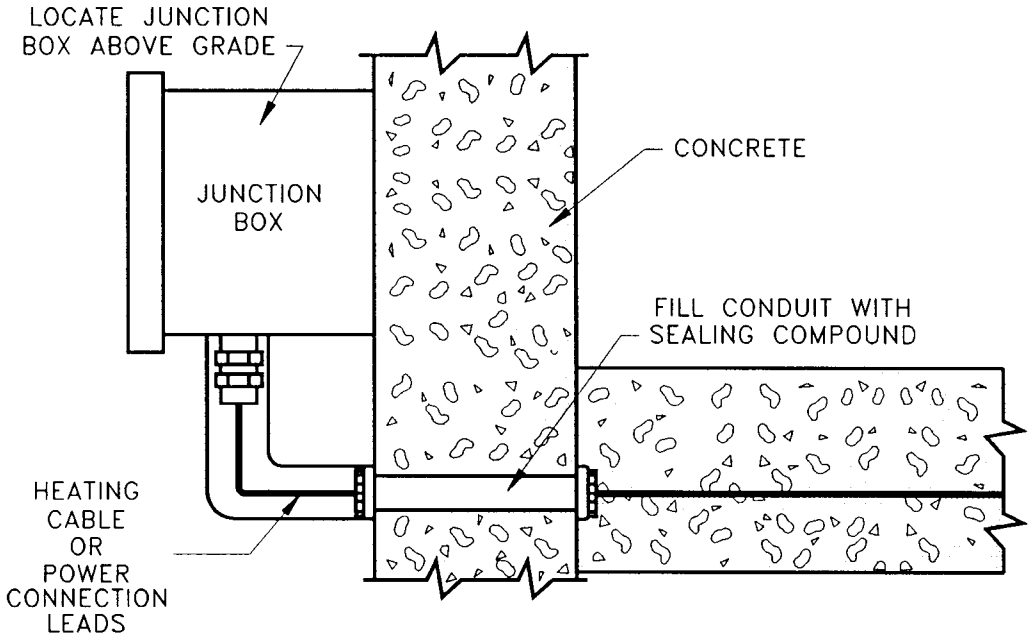


Figure 20—Snowmelting junction box location

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 recommended practice.
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.

6.3.6 Electrical design

6.3.6.1 Circuit protection

The heating cable branch circuit protection equipment should be capable of interrupting high impedance faults, as well as bolted or hard faults. This should be accomplished by a ground-fault equipment protective device with a nominal 30 mA trip rating, such as a controller with ground fault interruption capability for use with a molded-case circuit

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breaker, or other system of devices tbat meet this intent.[12] The trip level for adjustable devices is to be set 30 mA above any inherent capacitive characteristic level, as specified by the manufacturer.

6.3.6.2 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:

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

6.3.7 Installation

Installation of the heating cable is dependent on the substrate material. Recommendations for concrete and asphalt installations are made in 6.3.7.1–6.3.7.4

6.3.7.1 Concrete and asphalt

a) Prior to installation in the slab section, the heating cable should be verified ta 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 Vdc. However, for mineral insulated cables, a test voltage of 1000 Vdc is recommended, and for polymer insulated heating cables, 2500 Vdc is recommended. The measured value should not be less than 20 MΩ.
c) The site should be inspected for sharp objects and burrs on the wire mesh or re-bar.
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 prior to 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.

6.3.7.2 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 shall be taken to ensure that the upperlift bonds to the existing concrete.

6.3.7.3 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* [B27]) are not recommended.

[12]Exception—where Continued circuit operation is essential for safe operation of equipment. However, ground fault detection and alarm should be considered.

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6.3.7.4 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.

6.3.8 Maintenance

A system inspection is recommended prior to the winter season. For applications classified as critical, inspection is recommended both in the autumn and spring. All observations and measured values, as appropriate, should be recorded on a log sheet (refer to the annex). 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 ingtess identified and repaired.
b) Control equipment setpoints 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 2–5 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.

6.4 Floor warming

6.4.1 Application description

FIoor 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 recommended practice, 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 should meet the requirements for type D tracing.

6.4.2 Design Information

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

a) Size and layout of area involved
b) Ambient temperature
c) Subfloor
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

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6.4.3 Heat load determination

For temperature maintained areas such as office buildings and day-care centers, the heat load is typically between 54 and 108 W/m^2 (5 and 10 W/ft^2). Garages and warehouse areas may require 162–270 W/m^2 (15–25 W/ft^2). Assuming relatively still air and low heat loss off the floor underside, figure 21 shows heat load requirements for a range of conditions.

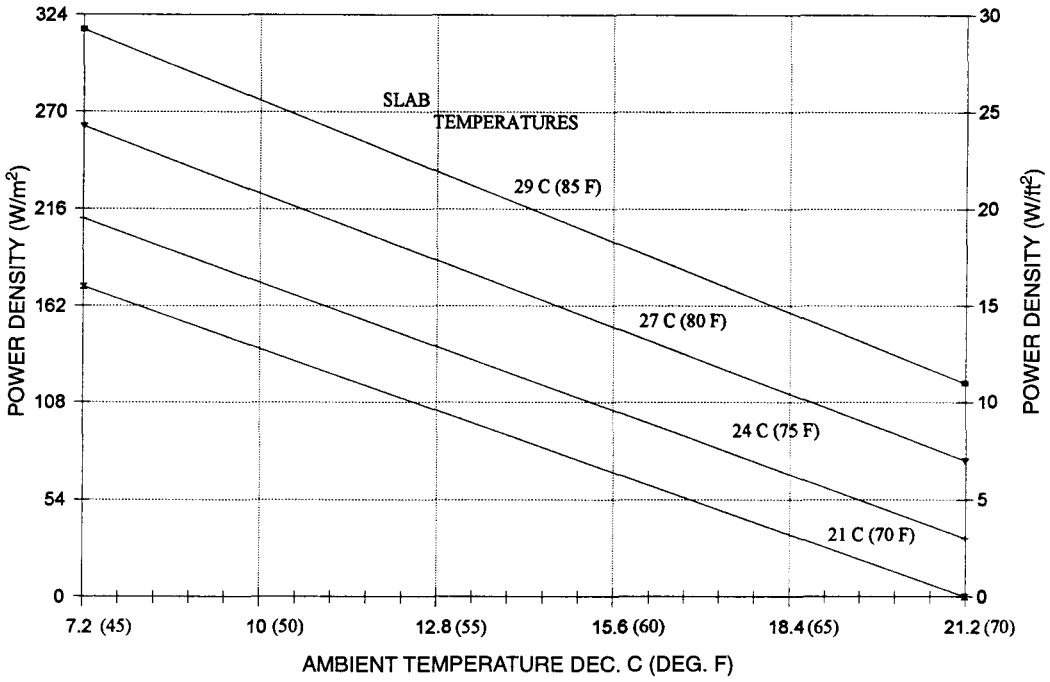


Figure 21—Typical floor heating power requirements

6.4.4 Heater and component mounting

Heater and component mounting recommendations for floor warming are described in 6.4.4.1-6.4.4.5.

6.4.4.1 Cable mounting

Methods of laying the cables can vary. Basic approaches (illustrated in figure 22) are as follows:

a) The cable can be directly buried in concrete by installation on rebar or wire mesh at a minimum depth of 4 cm (1.5 in).
b) Under ceramic tile, embedded in mortar, the cable can be tied to an expanded metal lath, wire mesh, or prepunched strapping at a typical depth of 2 cm (0.75 in). A layer of mortar is typically added to a wood floor.
c) Installation can be made ta an existing concrete slab where cable is directly applied to the slab bottom surface and held in place with rigid thermal insulation.

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6.4.4.2 Spacing

Heater cable spacing results from the watt density needed from figure 21 and the lineal power output of the heating cable used.

$$S = P/Q \qquad (2) \tag{2}$$

where

S is spacing of cable in m (ft)
Q is heat load in W/m^2 (W/ft^2)
P is lineal power output of cable in W/m W/ft)

For example, if the heat load is 108 W/m^2 (10 W/ft^2) and the heating cable is 16 W/m (5 W/ft), the spacing is 0.15 m (0.5 ft) or 15 cm (6 in). The number of cable passes per unit area is then 7 passes/m (2 passes/ft).

6.4.4.3 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 trouble shooting and to enhance reliability.

6.4.4.4 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 also provide a good representation of floor temperature.

6.4.4.5 Documentation

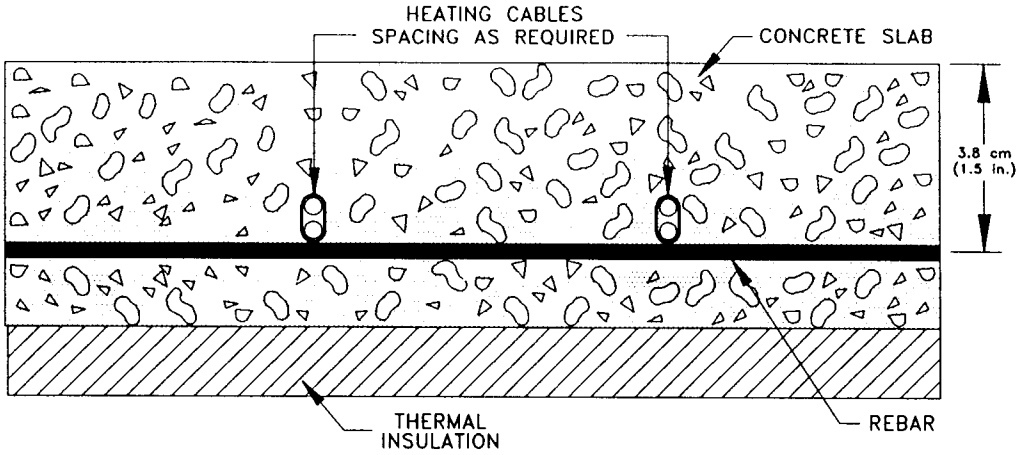
Drawings and appropriate documentation are recommended for each floor warming application. These should include the following:

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

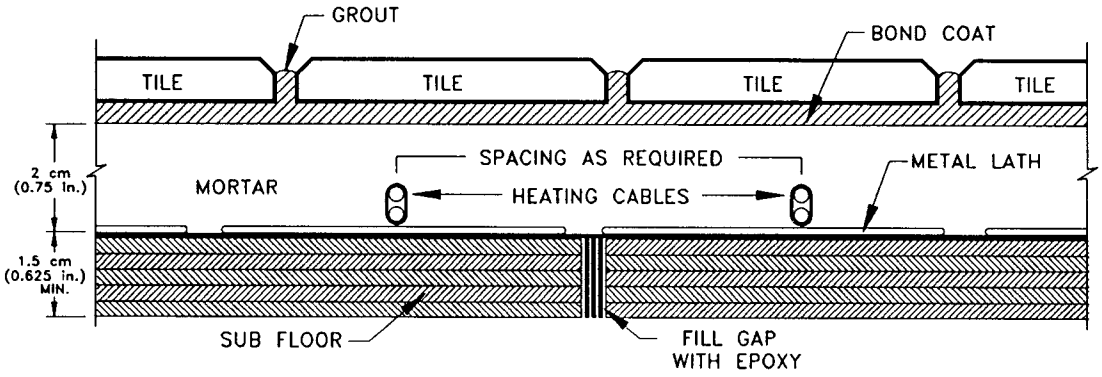
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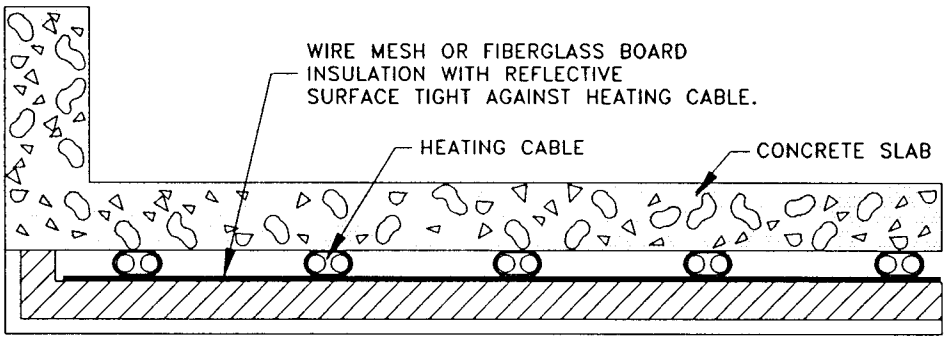
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a) In concrete



b) Under ceramic tile embedded in mortar



c) Under elevated concrete slab

Figure 22—Typical floor heating cable mounting

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6.4.5 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 ANSI/NFPA 70-1993, section 424-98.
b) Watts per linear foot for a cable are limited to 54 W/m (16.5 W/ft) as per ANSI/NFPA 70-1993, section 424-44(a).
c) FIoor warming applications in garages or fuel storage areas may be classified. If so, the heating system shall meet the C1D1 or CID2 requirements outlined in IEEE Std 515-1989 .

6.4.6 Electrical design

6.4.6.1 Circuit protection

The heating cable branch circuit protection equipment should be capable of interrupting high impedance faults, as well as bolted or hard faults. This should be accomplished by a ground-fault equipment protective device with a nominal 30 mA trip rating, such as a controller with ground fault interruption capability for use with a molded-case circuit breaker, or other system of devices which meet this intent.[13] The trip level for adjustable devices is to be set 30 mA above any inherent capacitive characteristic level, as specified by the manufacturer.

Special consideration is given for areas around pools and spas. Reference should be made to the ANSI/NFPA 70-1993 and the local electrical code.

6.4.6.2 Control options

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

6.4.7 Installation

For floor warming installations, the following sequence is recommended:

a) Prior to 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 Vdc. However, for mineral insulated cables a test voltage of 1000 Vdc is recommended, and for polymer insulated heating cables, 2500 Vdc is recommended. The measured value should not be less than 20 MΩ.
c) The floor area should 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 prior to surface floor placement, the drawings should be modified ta 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.

[13]Exception: Where continued circuit operation is essential for safe operation of equipment. However, ground fault detection and alarm should be considered.

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6.4.8 Maintenance

A system inspection is recommended prior to the winter season. All observations and measured values, as appropriate, should be recorded on a log sheet (refer to the annex). 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.

6.5 Frost heave prevention

6.5.1 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 should meet the requirements for type C tracing. If the cable is installed conduit or piping, it is required to be qualified ta the type D requirements instead.

6.5.2 Design Information

Refer to figure 23 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

6.5.3 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 (W/ft^2) required is shown in figure 24 as a function of minimum freezer ambient temperature and insulation barrier thickness. This is based on an effective earth temperature of 10 °C (50 °F).

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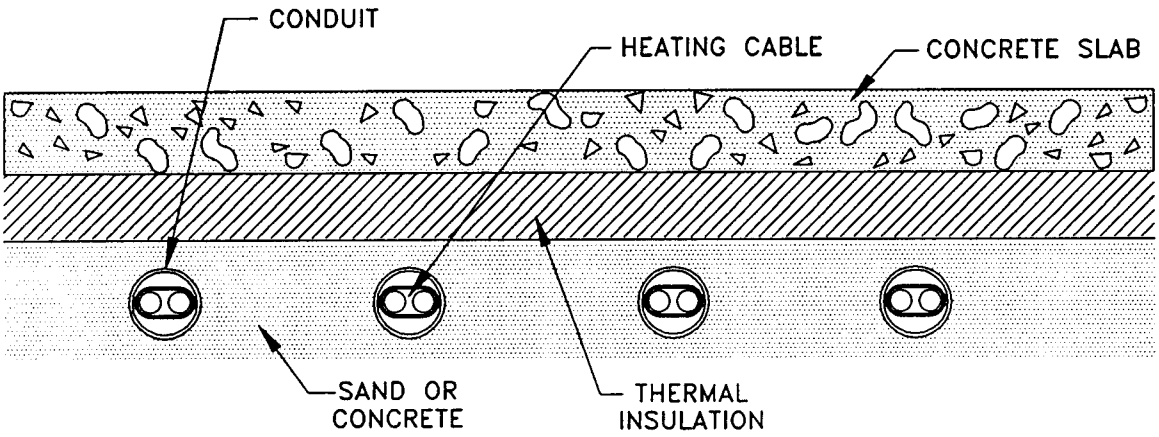


Figure 23—Typical frost heave prevention sub-structure

6.5.4 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 below.

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 (1000 ft^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 15 cm (6 in), a typical heat load is between 6 and 13 W/m^2 (0.6 and 1.2 W/ft^2). Due to the large number of variables in assessing the heat load, a specific design is recommended for each application.

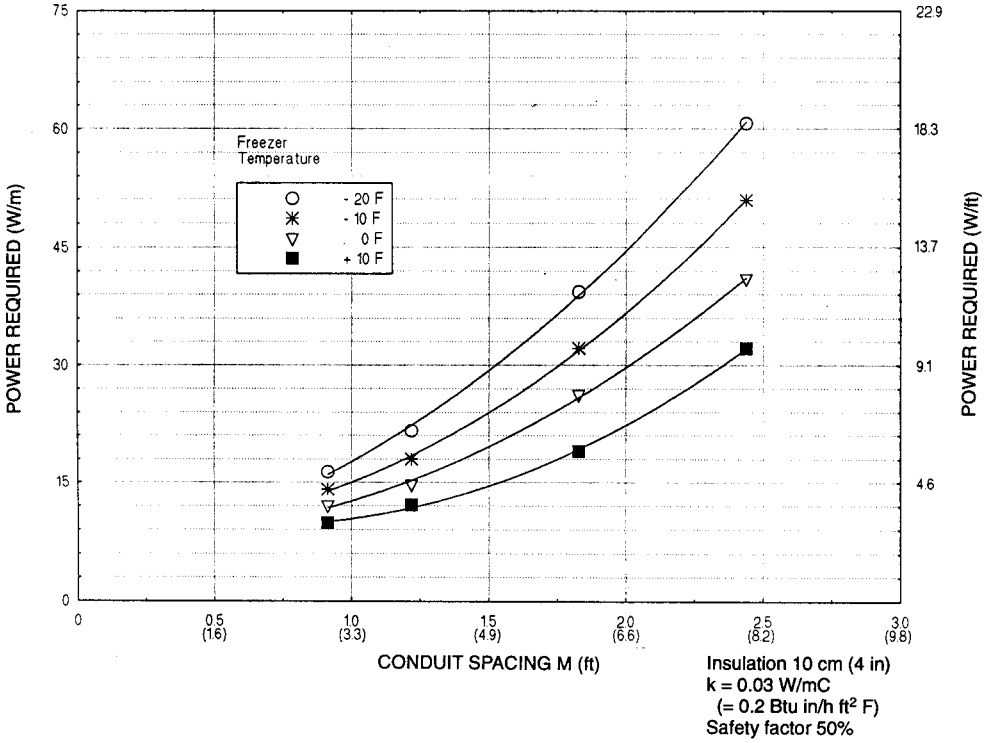
6.5.5 Special design considerations

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

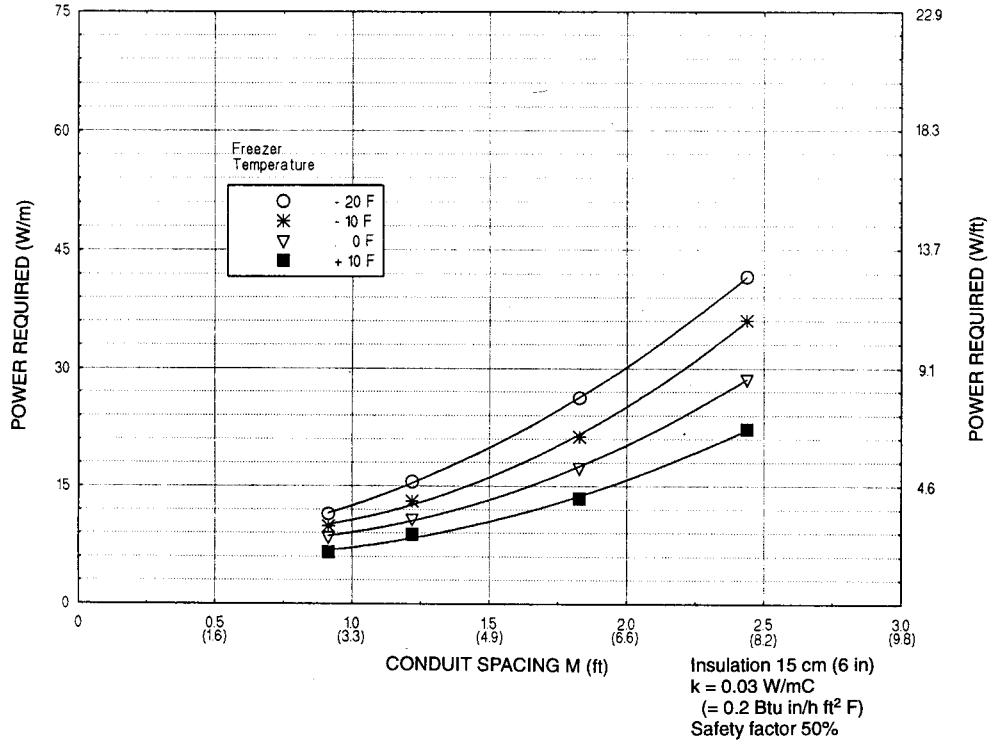
a) The heater should have a metallic braid or sheath.
b) For all below grade applications, heater constructions with both a metallic braid and polymer over jacket are recommended.
c) Typical spacing for the conduits is 0.6–1.2 in (2–4 ft). For wider spacing, the resulting temperature distribution should be verified.
d) Since 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.

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a) Insulation thickness of 10 cm (4 in)



b) Insulation thickness of 15 cm (6 in)

Figure 24—Frost heave prevention in foundations

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6.5.6 Electrical design

6.5.6.1 Circuit protection

The heating cable branch circuit protection equipment should be capable of interrupting high impedance faults as well as bolted or hard faults. This should be accomplished by a ground-fault equipment protective device with a nominal 30 mA trip rating, such as a controller with ground fault interruption capability for use with a molded-case circuit breaker, or other system of devices which meet this intent.[14] The trip level for adjustable devices is to be set 30 mA above any inherent capacitive characteristic level, as specified by the manufacturer.

6.5.6.2 Control options

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

6.5.6.3 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.

6.5.7 Installation

Frost heave preventing systems involve installing heating cable in conduit. The following are 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) Prior to pulling cable, any obstacles in the conduit should be removed and rough edges should be smoothed.
c) The static pulling force should not exceed 667 N (150 lb). 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 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 Vdc. However, for mineral insulated cables, a test voltage of 1000 Vdc is recommended, and for polymer insulated heating cables, 2500 Vdc is recommended. The measured value should not be less than 20 MΩ. The value should be recorded on a log sheet.

6.5.8 Maintenance

A system inspection is recommended on an annual basis. All observations and measured values (as appropriate) should be recorded on a log sheet (refer to the annex). 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.

[14]Exception: Where continued circuit operation is essential for Safe operation of equipment. However, ground fault detection and alarm should be considered.

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6.6 Earth thermal storage systems

6.6.1 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 utilizing concrete floors. Thermal storage systems are particularly applicable where electrical utilities offer off-peak rates.

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

6.6.2 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 zone
m) Heat loss for each zone
n) Hours of off-peak power available per day
o) Voltage supply

6.6.3 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 108 W/m^2 (10 W/ft^2). This is the natural building heat loss only and does not include ventilation makeup or recovery for opening doors, etc. Losses greater than this will require supplemental heat or additional thermal insulation.

6.6.4 Heater and component mounting

For this application, the heating cable or mat is located at a depth of 10–46 cm (4–18 in) in a sand substrate.Refer to figure 25 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.

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 15 cm (6 in) from walls, drains, footings, and other obstructions.

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c) For field assembled heating cable systems, the heater end termination should be located inside the junction box to facilitate trouble shooting and to enhance reliability.
d) The cable spacing is then calculated by dividing the total usable area by the total cable length.

1 External grade should be up to slab level. Where this is not done (such as a loading dock), perimeter insulation thickness should be doubled from 5 cm to 10 cm (2 in to 4 in).
2a Temperature controller sensing bulb in conduit for controlling slab temperature.
2b High temperature safety cutout sensing bulb in conduit. Taped to center cable of mat.
3 Perimeter insulation of 5 cm (2 in) rigid styrofoam, type SM or equivalent, shall extend from floor surface down to 1.3 m (4 ft) depth.
4 Slab
5 Sand depth of 30 cm (12 in) 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.

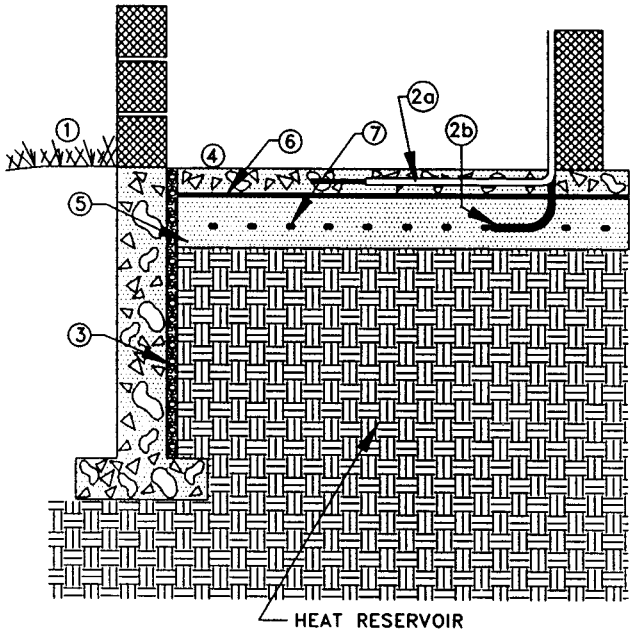


Figure 25—Typical earth thermal storage installation

6.6.5 Special design considerations

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 25, is recommended for moisture retention in sand.
c) External grade will usually be at slab level. Perimeter thermal insulation, typically 5 cm (2 in) of foam extending down 1.2 m (4 ft), is recommended to minimize heatloss from sides of the foundation. Refer to figure 25. 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.

6.6.6 Electrical design

6.6.6.1 Circuit protection

The heating cable branch circuit protection equipment should be capable of interrupting high impedance faults as well as bolted or hard faults. This should be accomplished by a ground-fault equipment protective device with a nominal 30 mA trip rating, such as a controller with ground fault interruption capability for use with a molded-case circuit breaker, or other system of devices which meet this intent.[15] The trip level for adjustable devices is to be set 30 mA above any inherent capacitive characteristic level, as specified by the manufacturer.

[15]Exception: Where continued operation is essential for safe operation of equipment. However, ground fault detection and alarm should be considered.

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6.6.6.2 Control options

a) Control circuits for thermal storage systems should be designed to accommodate multiple sensing points for the heating zones. Typical setpoints for the temperature controller range from 18–24 °C (65–75 °F).
b) A high limit temperature controller should be used to protect the integrity of the system. A maximum temperature of 54 °C (130 °F) should not be exceeded, as higher temperatures can reduce the moisture content and thermal conductivity of the substrate.

6.6.7 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) Prior to 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 Vdc. However, for mineral insulated cables a test voltage of 1000 Vdc is recommended, and for polymer insulated heating cables, 2500 Vdc 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 × 4s 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.

6.6.8 Maintenance

A system inspection is recommended prior to 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 (refer to the annex). 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 setpoints 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 two and five minutes after energization, and recorded. Reservoir temperatures should also be recorded.
e) Major changes in insulation resistance or heater current should be resolved.

7. Bibliography

[B1] ANSI/ISA S82.01-1988, Electric and Electronics Test, Measuring, Controlling, and Related Equipment: General Requirements.

[B2] ANSI/ISA S82.02-1988, Electric and Electronic Test, Measuring, Controlling, and Related Equipment: Electrical and Electronic Test and Measuring Equipment.

[B3] ANSI/ISA S82.03-1988, Electric and Electronic Test, Measuring, Controlling, and Related Equipment: Electrical and Electronic Process Measurement and Control Equipment.

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[B4] ANSI/NFPA 13-1994, Installation of Sprinkler Systems.

[B5] ANSI/UL 94-1990, Tests for Flammability of Plastic Materials for Parts in Devices and Appliances.

[B6] ANSI Z358.1-1990, Emergency Eyewash and Shower Equipment.

[B7] ASTM C450-94, Practice for Prefabrication and Field Fabrication of Thermal Insulating Fitting Covers for NPS Piping, Vessel Lagging, and Dished Head Segments.

[B8] ASTM C533-85 (Reaff 1990), Specification for Calcium Silicate Block and Pipe Thermal Insulation.

[B9] ASTM C534-94, Specification for Preformed Flexible of Elastomeric Cellular Thermal Insulation in Sheet and Tubular Form.

[B10] ASTM C547-77 (Reaff 1993), Specification for Mineral Fiber Preformed Pipe Insulation.

[B11] ASTM C552-91, Specification for Cellular Glass Block and Pipe Thermal Insulation.

[B12] ASTM C553-92, Specification for Mineral Fiber Blanket and Thermal Insulation for Commercial and Industrial Applications.

[B13] ASTM C585-90, Practice for Inner and Outer Diameters of Rigid Thermal Insulation for Nominal Sizes of Pipe and Tubing (NPS System).

[B14] ASTM C591-85, Specification for Unfaced Preformed Rigid Cellular Polyurethane Thermal Insulation.

[B15] CENELEC EN 50019, Increased Safety 'e,' Sept. 1990.

[B16] CFR (Code of Federal Regulations) Publication 29, Part 1910 (OSHA) § 1910.151 (c).

[B17] CSA Std C22.2 No. 130.1-M90, Heat Tracing Cable Systems for Use in Industrial Locations.

[B18] CSA Std C22.2 No. 130.2-93, Heat Cable Systems for Use in Other Than Industrial Establishments.

[B19] Federal Energy Administration, "Economic Thickness for Industrial Insulation," Energy Conservation Paper, no. 46, Aug, 1976.

[B20] IEC 20B/WG10, Draft Standard for Heating Cables for Industrial Applications, 11/19/90.

[B21] IEC 216 (1990), Guide for the determination of thermal endurance properties of electrical insulating materials—Part I: General guidelines for ageing procedure and evaluation of test results.

[B22] IEC 800 (1992), Heating cables with a rated voltage of 300/500 V for comfort heating and prevention of ice formation.

[B23] NSF (National Sanitation Foundation) Std 14-90, Plastic Piping Components and Related Materials.

[B24] NSF Std 24-88, Plumbing System Components for Manufactured Homes and Recreational Vehicles.

[B25] NSF Std 61-92, Drinking Water System Components—Health Effects.

[B26] *The ASHRAE Application Handbook,* Chapter 45.

[B27] *The Asphalt Handbook*. College Park, Maryland: The Asphalt Institute, 1960.

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[B28] Turner, William, C., and Malloy, John, F., *Handbook of Thermal Insulation Design Economics for Pipes and Equipment,* New York: Robert E. Kruger Publishing Company, McGraw-Hill Book Company, 1980.

[B29] UL 746C-1989, Polymeric Materials Use in Electrical Equipment Evaluations.

[B30] UL Outline 1462, Outline of Investigation for Mobile Home Pipe Heating Cable.

[B31] UL Outline 1588, Outline of Investigation for Roof and Gutter De-Icing Cable Units.

[B32] UL Outline 2049, Outline of Investigation for Residential Pipe Heating Cable.

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8. Annex Sample log sheet (Informative)

Heat-Tracing System Log Sheet Example

System Application: _____ Date: _____

Accessories: (boxes, end seals, fastening equipment) Cat. No.: _____ Cable Type (Cat. No.): _____

_____ Controller Type (Cat. No.): _____

Date:																	
Circuit No.:																	
VISUAL																	
No signs of overheating, moisture, corrosion or physical breakage, Initial:																	
Comment (Y/N):																	
All boxes, controllers, end seals, etc. intact and according to spec. Initial:																	
Comment (Y/N):																	
Controller set properly. Initial:																	
Comment (Y/N):																	
Set Point:																	
Actual pipe/surface temperature:																	
ELECTRICAL																	
Insulation resistance test (bypass controller if applicable). Initial:																	
Branch to branch voltage. At Panel:																	
Circuit current. Start-up after 2-5 min.:																	
Test ground leakage devices Initial:																	
Comments & Action Taken:																	

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