

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

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IEEE Std 515-1989



Published by the Institute of Electrical and Electronics Engineers, Inc., 345 East 47th Street, New York, NY 10017, USA.

February 9, 1990

SH13078

IEEE
Std 515-1989
(Revision of
ANSI/IEEE Std 515-1983)

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

Approved August 30, 1989
IEEE Standards Board

Abstract: IEEE Std 515-1989, *IEEE Recommended Practice for the Testing, Design, Installation, and Maintenance of Electrical Resistance Heat Tracing for Industrial Applications*, provides the specific test requirements for qualifying electrical resistance heating cables for industrial service, and provides the basis for electrical and thermal design. Heater characteristics are addressed, and installation and maintenance requirements are detailed. Recommendations and requirements are made for unclassified, Class I, Division 2, and Class I, Division 1 heating cable applications.

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Foreword

(This Foreword is not a part of IEEE Std 515-1989, IEEE Recommended Practice for the Testing, Design, Installation, and Maintenance of Electrical Resistance Heat Tracing for Industrial Applications.)

The utilization of electrical resistance heat tracing by industry has steadily increased because of the availability of more reliable products and efficient operation. The need for broad-based technical information about electrical resistance heat-tracing systems and uniformity in the approval process for these systems provides the necessity for this recommended practice.

IEEE Std 515-1989 provides the specific test requirements for qualifying electrical resistance heating cables for industrial service, and provides the basis for electrical and thermal design. Type and routine production tests are outlined in this recommended practice and address such topics as mechanical durability, resistance to moisture, and electrical and thermal ratings. This recommended practice outlines specific recommendations for the utilization of thermal insulation systems in conjunction with electrical resistance heat tracing. Installation and maintenance requirements are detailed and include electrical and mechanical requirements, along with those management functions that should be considered.

Detailed technical information and equations with examples on the thermal relationships important to electrical resistance heat tracing are presented in the Appendixes.

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

1. Scope

This recommended practice provides recommendations for the testing, design, installation, and maintenance of electrical resistance heat tracing in general industries as applied to pipelines, vessels, and mechanical equipment. The electrical resistance heat tracing is in the form of series-heating cables and parallel-heating cables. The recommendations also include test criteria to determine the suitability of heating cables that are utilized for these applications.

2. Purpose

The provisions of this recommended practice should ensure that process, fluid, or material temperatures are maintained and provide electrical, thermal, and mechanical durability to the heat-tracing system, such that in normal use its performance is reliable and poses no danger to the user or surroundings. This recommended practice is a supplement to those provisions outlined in ANSI/NFPA 70-1990 [3]¹, Article 427.

3. Definitions

The following definitions apply to the subject matter presented in this recommended practice:

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.

¹The numbers in brackets correspond to the references listed in Section 4 of this recommended practice.

cold-end terminations (CET). The termination applied to the end of a heating cable where the power is supplied.

cold lead. An electrically insulated conductor used to connect a heating conductor to the branch-circuit conductors and designed so as not to produce any appreciable heat.

conductor temperature. The temperature of the heat-producing element.

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

factory fabricated. A heating cable assembled by the manufacturer, including hot- and cold-end terminations and cold lead.

field assembled. Heating cable supplied in bulk form with terminating components to be assembled (terminated) by field personnel.

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

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

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

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

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

hot-end termination (HET). The termination applied to the end of a heating cable, opposite where the power is supplied.

jacket. A polymeric covering, sometimes fabric reinforced, applied over the insulation, core, metallic sheath, or armor of a cable.

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

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.

metallic covering. A metal sheath or braid used to provide physical protection for heating cable and, in some cases, to provide an electrical ground path.

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

over-size insulation. A term applied to thermal insulation when the inside diameter of the thermal insulation must be larger than the nominal outside diameter of a particular pipe so as to accommodate the heating cable.

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.

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

rated voltage. The voltage to which operating and performance characteristics of heating cables are referred.

routine test. A test that is carried out by the manufacturer of the heating cable during the production process.

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

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

sheath. The outermost continuous covering for a cable.

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

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

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

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

type test. A test or series of tests carried out on heating cables and accessories, representative of a type, to determine compliance of the design, construction, and manufacturing methods within the requirements of this recommended practice.

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. References

- [1] ANSI/ASTM C450-1976 (88e1), Recommended Practice for Prefabrication and Field Fabrication of Thermal Insulating Fitting Covers for NPS Piping, Vessel Lagging, and Dished Head Segments.²
- [2] ANSI/ASTM C585-1989, Recommended Practice for Inner and Outer Diameters of Rigid Thermal Insulation for Nominal Sizes of Pipe and Tubing (NPS System).

²ASTM documents are available from the Sales Department, The American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

[3] ANSI/NFPA 70-1990, National Electrical Code.³

[4] FEDERAL ENERGY ADMINISTRATION. Economic Thickness for Industrial Insulation. Energy Conservation Paper, no. 46, Aug. 1976.

[5] NFPA 325M-1984, Fire Hazard Properties of Flammable Liquids, Gases, and Volatile Solids.

[6] NFPA 497M-1986, Classification of Gases, Vapors, and Dusts for Electrical Installations in Hazardous (Classified) Locations.

[7] TURNER, WILLIAM C., and MALLOY, JOHN F. *Handbook of Thermal Insulation Design Economics for Pipes and Equipment*. Robert E. Kruger Publishing Company, McGraw-Hill Book Company: New York, 1980.

5. General Product Testing

5.1 Type Test—General Purpose/Ordinary Locations. The following tests are intended to qualify a particular heating cable construction for the applications within the scope of this recommended practice for General Purpose/Ordinary Locations. Samples of heating cable at least 3 m (10 ft) in length, unless otherwise specified, shall be selected for testing. Tests shall be conducted at room temperature between 10 °C–40 °C (50 °F–104 °F) unless otherwise noted.

5.1.1 Dielectric Test. The dielectric test shall be performed by the manufacturer on heating cables in accordance with the following table:

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

The test voltage where E = rated voltage shall be applied at a rate of rise neither less than 100 V/s nor more than 200 V/s and maintained for 1 min without dielectric breakdown. The test voltage waveform shall be essentially sinusoidal, with a frequency of 45 Hz to 65 Hz.

³NFPA publications are available from Publications Sales, National Fire Protection Association, Batterymarch Park, Quincy, MA 02269. Copies are also available from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018.

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

5.1.2 Insulation Resistance Test. The insulation resistance shall be measured on the above sample immediately after the dielectric test specified in 5.1.1. The resistance of the insulation shall be measured between conductors and the metallic outer covering, or a specially applied conductive metal tape or braid, by means of dc voltage of 500 V. The measured value shall not be less than 50 MΩ.

5.1.3 Water-Resistance Test. A sample shall be immersed (except at terminations, or ends where the conductors are exposed) in water at 10 °C–25 °C (50 °F–77 °F) for a period of 14 days.

Within 1 h after conditioning as above, the sample shall be subjected to the dielectric test outlined in 5.1.1.

5.1.4 Elevated Temperature Exposure Test. A sample of heating cable shall be placed in a forced-circulation air oven. The oven shall be heated to, and maintained at, a temperature of 25 °C ± 5 °C (77 °F ± 9 °F) above the highest exposure temperature declared by the manufacturer for a period of 14 days.

The sample, after it has been removed from the air oven and cooled to room temperature, shall have no visible cracks when examined with normal vision prior to or after being wound six close turns around a mandrel having a radius equal to six times the diameter of the primary bending plane or thickness of the heating cable. While still on the mandrel the sample, except at terminations or ends where the conductor is exposed, shall be submerged in tap water at 10 °C–25 °C (50 °F–77 °F) for 5 min. While still in the tap water, the dielectric test outlined in 5.1.1 shall be performed.

5.1.5 Deformation Test. A sample of heating cable, at least 200 mm (8 in) in length, shall be used for testing. The ends of the sample shall be stripped back to expose the conductors. The sample shall be placed on top and at right angles to a 6 mm (0.25 in) diameter steel rod, resting on a rigid flat steel support. Proof loading shall be gradually applied without shock at the point of intersection of the specimen and the steel rod by means of a rigid square pressure plate having face

dimensions of 100 mm (3.937 in) $\times$ 100 mm (3.937 in).

The proof load to be applied by means of the pressure plate shall be either a gravitational force load of 102 kg (225 lb) or an equivalent mechanical force load. After a minimum time of not less than 30 s and with the proof loading continuously applied, the dielectric test outlined in 5.1.1 shall be conducted.

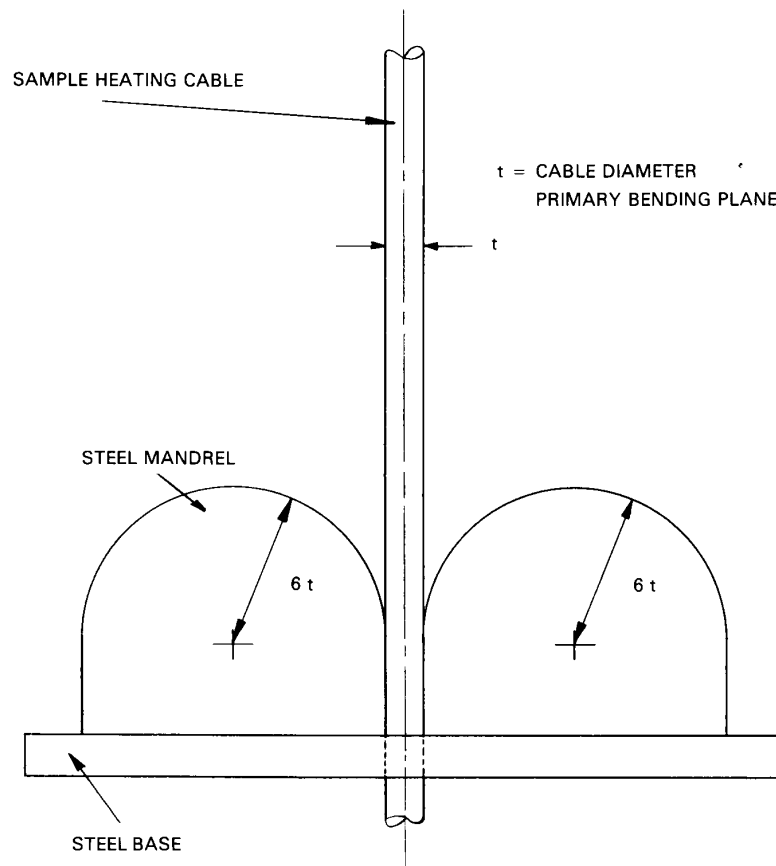
The test voltage shall be applied between the heating cable conductors and the metallic covering, or where a metallic covering is not provided, between the conductors and the steel rod.

5.1.6 Impact Test. The impact test shall be conducted on a sample that is positioned on a hardened rigid steel plate and the assembly conditioned for a minimum of 4 h at the manufacturer's minimum recommended installation temperature.

After conditioning and while still at the minimum recommended installation temperature, a sample shall be subjected to the impact forces of a 5.08 cm (2 in) diameter cylindrical steel plunger with smoothly rounded edges, having a mass of 1.8 kg (4 lb) and allowed to free fall from a height of 76.2 cm (30 in), resulting in an impact force of 13.6 J (10 ft-lbs). Then the impacted portion of the sample shall be immersed in tap water at room temperature, and the dielectric test outlined in 5.1.1 shall be conducted. After testing, the sheath shall have no visible cracks when examined with normal vision.

5.1.7 Cold Bend Test. The apparatus used for the bend test shall be as represented in Fig 1. A sample of heating cable or cold lead shall be fixed in the apparatus as shown in Fig 1. With the test sample in position, the apparatus shall be placed in a refrigerated compartment and maintained at

Fig 1
Cold Bend Test Apparatus



the minimum recommended installation temperature for a period of not less than 4 h. At the end of this period, and with the sample maintained at the minimum recommended installation temperature, the sample shall be bent through 90° around one of the bending mandrels, then bent through 180° in the opposite direction over the second bending mandrel and straightened to its original position. All the bending operations shall be carried out in the same plane. This cycle of operations shall be performed three times. When this has been completed, the sample shall be immersed in tap water at room temperature for 5 min, and then the dielectric test outlined in 5.1.1 shall be conducted.

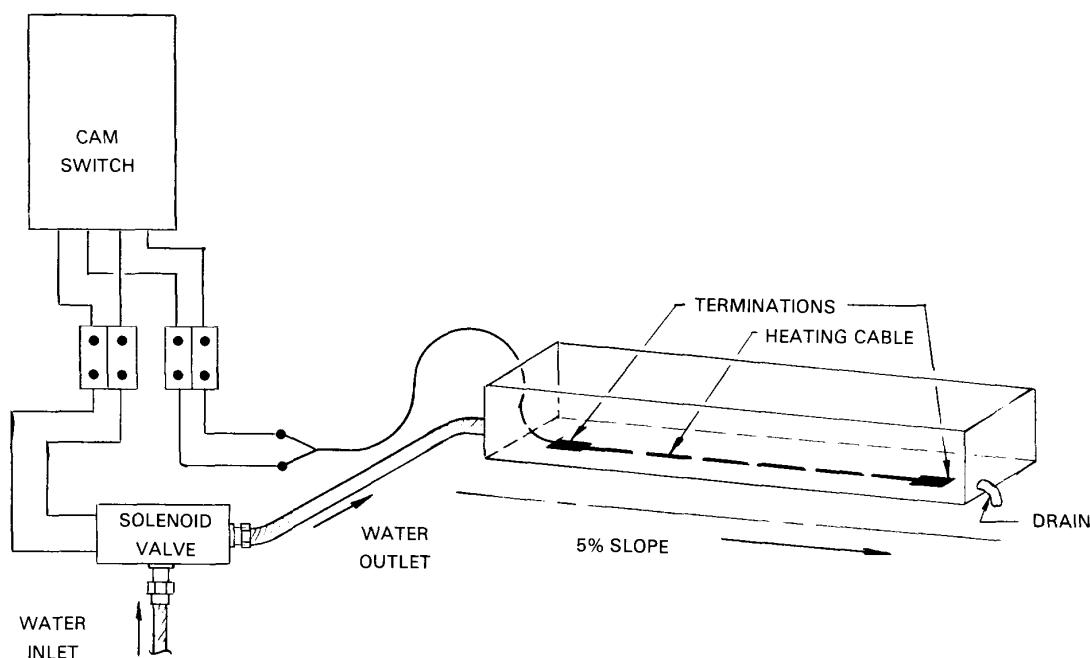
5.1.8 Cold- and Hot-End Terminations' Resistance to Water. A sample of heating cable at least 3 m (10 ft) in length with factory- or field-assembled terminations shall be placed in a water flow and drain apparatus as shown in Fig 2. The rate of the water flow shall be regulated to completely cover the heating cable and terminations, a minimum of every 5 min. The voltage to the water flow solenoid and the voltage applied to the heating cable shall be controlled by a cam switch or equivalent means. The timing sequences shall be such that the heating cable shall be energized

for 30 s after the water has been drained. The test shall be continued for a period of 24 h. After completion, the dielectric test outlined in 5.1.1 shall be performed. The end termination shall be inspected to verify no evidence of water ingress.

5.1.9 Verification of Rated Output. The rated output of the heating cable shall be verified by one of the following three methods:

- (1) Conductance—the measured ac conductance per unit length at a specified temperature shall be within the manufacturer's declared tolerance.
- (2) Resistance—the measured dc resistance per unit length at a specified temperature shall be within the manufacturer's declared tolerance.
- (3) Thermal—the thermal output shall be measured by installation of a single 3 m to 6 m (10 ft to 20 ft) sample of heating cable on a schedule 40 carbon steel pipe of 50.8 mm (2 in) diameter or greater, as shown in Fig 3. The cable shall be installed per the manufacturer's instructions. The test apparatus shall be completely covered with a fiber glass thermal insulation of 25.4 mm (1 in) or equivalent.

Fig 2
Heating Cable Termination Test Apparatus



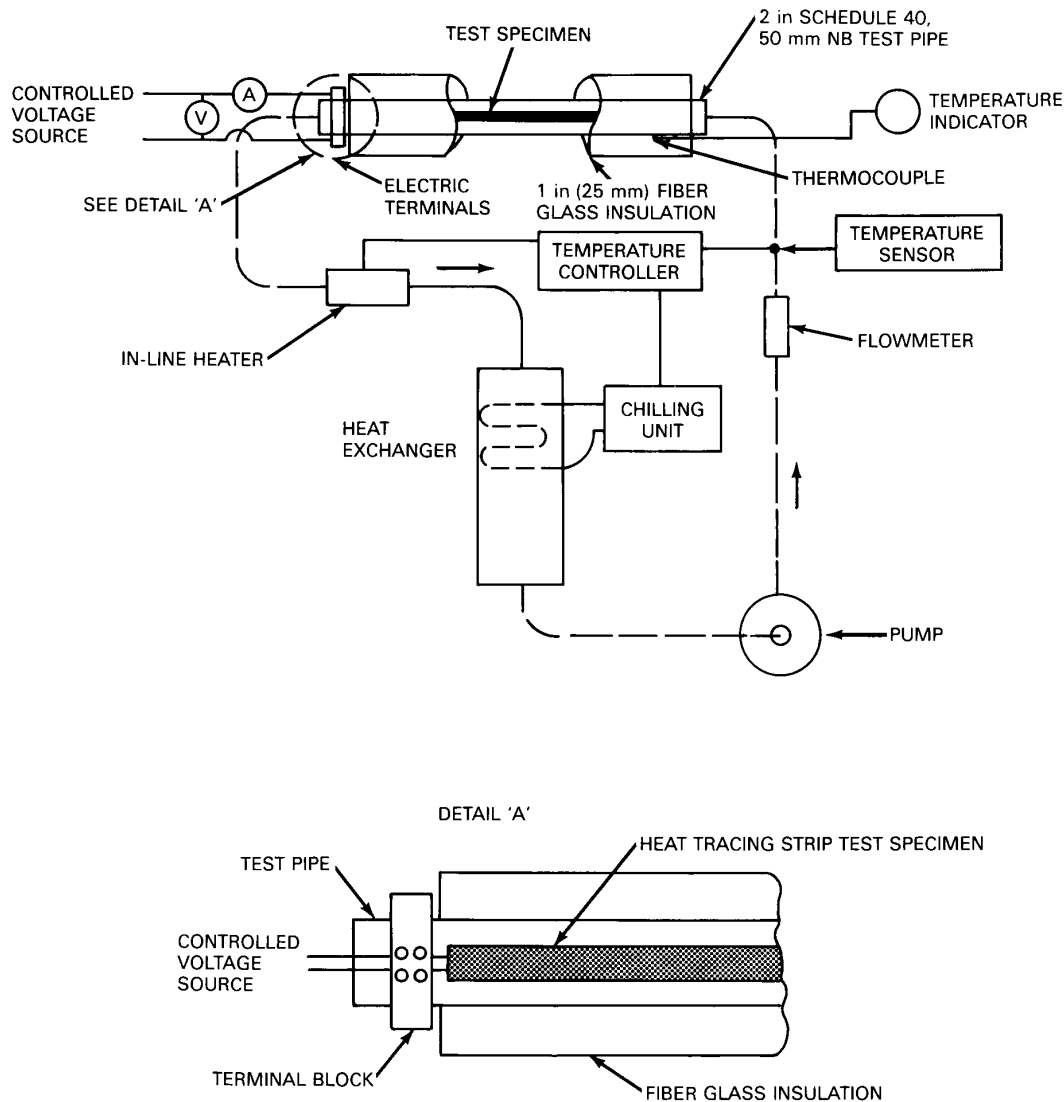


Fig 3
Verification of Rated Output

A suitable heat transfer fluid in the liquid phase shall 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 shall be verified by thermocouples placed at the entry and exit ends of the pipe.

Flow velocity shall be sufficient so that the fluid temperature does not differ by more than 2 °C (3.6 °F) from end to end.

The thermal output of the heating cable shall be measured at three pipe temperatures over the heater operating range. The heating cable shall be powered at its rated voltage and allowed to attain equilibrium. The voltage, current, fluid temperature, and sample length shall be recorded at each test temperature. Three separate determi-