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IEEE/CSA Standard for Skin Effect Trace Heating of Pipelines, Vessels, Equipment, and Structures—General, Testing, Marking, and Documentation Requirements

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IEEE/CSA Standard for Skin Effect Trace Heating of Pipelines, Vessels, Equipment, and Structures—General, Testing, Marking, and Documentation Requirements

This document was developed under the Partner Standards Development Organization cooperation agreement between IEEE and CSA Group and was submitted to a parallel enquiry vote by both organizations.

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Abstract: General requirements, testing, markings, and documentation for skin effect trace heating systems for pipelines, vessels, equipment, and structures intended for use in general industrial applications are provided in this standard. This standard provides requirements when utilizing skin effect trace heating systems in ordinary as well as hazardous areas that have potentially explosive atmospheres.

Keywords: condensation prevention, CSA C22.2 No. 293.1, freeze protection and temperature maintenance, heating systems, IEEE 844.1, long line, process heating, re-melting solidified fluids, skin effect trace heating, structure heating, thermal insulation

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This introduction is not part of IEEE Std 844.1-2017/CSA C22.2 No. 293.1-17, IEEE/CSA Standard for Skin Effect Trace Heating of Pipelines, Vessels, Equipment, and Structures—General, Testing, Marking, and Documentation Requirements.

This is the first publication of IEEE Std 844.1™/CSA C22.2 No. 293.1, Standard for Skin Effect Trace Heating of Pipelines, Vessels, Equipment, and Structures—General, Testing, Marking, and Documentation Requirements, which is a harmonized standard jointly developed by IEEE and CSA Group.

Skin effect trace heating systems have been used for a number of years in the industry. Skin effect trace heating of pipelines, vessels, equipment, and structures in petrochemical as well as other industries is a growing portion of total heating requirements because of its advantages in heating long pipelines with temperature control.

This standard should be used in conjunction with IEEE Std 844.2™/CSA C293.2, Standard for Skin Effect Trace Heating of Pipelines, Vessels, Equipment, and Structures—Application Guide for Design, Installation, Testing, Commissioning, and Maintenance.

Since skin effect trace heating systems are interrelated with electric power, control, and alarm systems, other standards (some of which are listed in Clause 2) should be referred to when using this standard. This standard is not intended to supersede any current standards or recommended practices, and sound engineering judgment should always be used when applying this or any other standard.

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This is the first edition of IEEE Std 844.1™/CSA C22.2 No. 293.1, Standard for Skin Effect Trace Heating of Pipelines, Vessels, Equipment, and Structures—General, Testing, Marking, and Documentation Requirements, which is a harmonized Standard jointly developed by IEEE and CSA Group. It is one in a series of Standards issued by CSA Group under Part II of the Canadian Electrical Code.

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This Standard should be used in conjunction with IEEE Std 844.2™/CSA C293.2, Standard for Skin Effect Trace Heating of Pipelines, Vessels, Equipment, and Structures—Application Guide for Design, Installation, Testing, Commissioning, and Maintenance.

Since skin effect trace heating systems are interrelated with electric power, control, and alarm systems, other standards, some of which are listed in Clause 2, should be referred to when using this Standard.

This Standard is considered suitable for use for conformity assessment within the stated scope of the Standard.

This Standard was reviewed for use in Canada by the CSA Integrated Committee on Trace Heating, under the jurisdiction of the CSA Technical Committee on Wiring Products and the CSA Strategic Steering Committee on Requirements for Electrical Safety, and has been formally approved by the CSA Technical Committee.

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   b) Provide an explanation of circumstances surrounding the actual field condition; and
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   Committee interpretations are processed in accordance with the CSA Directives and guidelines governing standardization and are available on the Current Standards Activities page at **standardsactivities.csa.ca**.
5) This Standard is subject to review five years from the date of publication. Suggestions for its improvement will be referred to the appropriate committee. To submit a proposal for change, please send the following information to **inquiries@csagroup.org** and include "Proposal for change" in the subject line:
   a) Designation;
   b) Relevant clause, table, and/or figure number;
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IEEE/CSA Standard for Skin Effect Trace Heating of Pipelines, Vessels, Equipment, and Structures—General, Testing, Marking, and Documentation Requirements

1. Overview

1.1 General

This standard is divided into seven clauses that cover requirements for skin effect trace heating when installed in ordinary locations as well as in hazardous (classified) locations. Clause 1 provides the scope, purpose, and typical applications. Clause 2 lists normative references to other standards that are indispensable in applying this standard. Clause 3 provides definitions that are either not found in other standards or have been modified for use with this standard. Clause 4 establishes general system requirements for skin effect trace heating. Clause 5 provides both type and routine testing requirements for skin effect insulated conductors and other skin effect system components. Clause 6 covers marking requirements. Clause 7 details additional documentation requirements.

This standard also contains annexes. Annex A provides bibliographical references. Annex B provides additional requirements for installations that are in explosive atmospheres classified using the Division method of area classification. Annex C provides additional requirements in explosive areas classified using the Zone method of area classification. Annex D covers skin effect trace heating design verification methodologies.

1.2 Scope

This standard applies to general, testing, marking, and documentation requirements for skin effect trace heating systems rated up to and including 5 kVac and 260 °C maximum skin effect insulated conductor temperature. These heating systems are intended for installation in accordance with the CSA C22.1, Canadian Electrical Code, Part I (CE Code); NFPA 70, National Electrical Code® (NEC®) in the USA; or with any other national electrical installation code, as applicable.[1]

This standard applies to skin effect trace heating systems intended to be installed in ordinary and hazardous locations. The hazardous locations include the following:

[1]National Electrical Code and NEC are both registered trademarks of the National Fire Protection Association, Inc.

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— In Canada: Zone 1; Zone 2; Zone 21; Zone 22; or Class I, Division 2; Class II, Division 2; Class III, Division 2 as described in CSA C22.1.

— In the USA: Class I, Zone 1; Class I, Zone 2; Zone 21 and Zone 22; or Class I, Division 2; Class II, Division 2; Class III, Division 2 as described in the NEC.

This standard also applies to termination assemblies and control methods used with skin effect trace heating systems.

NOTE 1—Requirements for certification at voltages above 5 kVac or skin effect insulated conductor insulation temperatures above 260 °C may be considered under a special investigation by an accredited certification body.

NOTE 2—Information on transformer, power distribution, and controls components can be found in IEEE Std 844.2/CSA C293.2.[2]

1.3 Purpose

This standard provides testing, marking, design, and documentation requirements for skin effect trace heating systems. Skin effect heating systems are intended to

a) Maintain design temperature; and
b) Provide electrical, thermal, and mechanical durability and reliability

1.4 Typical applications

1.4.1 General

Skin effect trace heating systems provide heating for pipes, vessels, equipment, and structures in order to maintain or raise the temperature in the following typical applications.

1.4.2 Solidification prevention

Systems can be used to prevent the fluid in a line or a vessel from solidifying. These include water, aqueous solutions, crude oil, pitch, asphalt, metals, sulfur, and other chemicals. The heating system compensates for pipeline heat losses in order to maintain the temperature of the contents above the solidification point.

1.4.3 Viscosity maintenance

Systems can be used to maintain viscosity of a fluid in a pipeline or a vessel. Viscous materials such as heavy fuel and crude oil are generally heated to achieve optimum pump efficiency and pipeline sizes. Usually these materials are preheated to a temperature that provides the desired viscosity and pumped to their destination through heated pipelines designed to maintain that temperature.

1.4.4 Process heating

Systems can be used to maintain the temperature of fluids when process parameters require it. Systems can also be used to raise the temperature of process fluids flowing in the pipeline or the vessel, but they require increased heat input capacity.

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

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1.4.5 Condensation prevention

Systems can be used to prevent gaseous materials from condensing. Some gases condense at low temperature and require heating to maintain their gaseous state during transportation. If pressure is significantly reduced during gas flow, such as through a valve, increased heat input capacity might also be required.

1.4.6 Re-melting solidified fluids

Systems can be used to re-melt solidified fluids. Some heating applications do not require heat during pumping, but only supply heat to re-melt pipeline contents and bring them up to temperature prior to pumping. A typical example is an infrequently used loading or unloading pipeline.

1.4.7 Structure heating

Skin effect trace heating systems can be used on concrete foundations and concrete walls exposed to sub-freezing temperatures to prevent frost heave. They can also be used on concrete pads, concrete surfaces, or other surfaces for de-icing and snow-melting. Typical examples of frost heave prevention applications are cryogenic and low-temperature storage tanks. Typical examples of de-icing and snow-melting applications are the concrete surfaces of some automated public transportation systems.

1.4.8 Terminology

In this standard, “shall” is used to express a requirement, i.e., a provision that the user is obliged to satisfy in order to comply with the standard; “should” is used to express a recommendation or that which is advised but not required; and “may” is used to express an option or that which is permissible within the limits of the standard.

Notes accompanying clauses do not include requirements or alternative requirements; the purpose of a note accompanying a clause is to separate from the text explanatory or informative material.

Notes to tables and figures are considered part of the table or figure and may be written as requirements.

Annexes are designated normative (mandatory) or informative (non-mandatory) to define their application.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they shall be understood and used, so each referenced document is cited in the text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

ANSI/UL 60079-0:2013 (Sixth Edition) or ANSI/ISA 60079-0 (12.00.01):2013 (Sixth Edition), Explosive atmospheres—Part 0: Equipment—General requirements.[3]

ASTM D1868-13, Standard Test Method for Detection and Measurement of Partial Discharge (Corona) Pulses in Evaluation of Insulation Systems.[4]

[3]ANSI publications are available from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (http://www.ansi.org/).
[4]ASTM publications are available from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA (http://www.astm.org/).

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CAN/CSA-C22.2 No. 0, General requirements—Canadian Electrical Code, Part II.[5]

CAN/CSA-C22.2 No. 60079-0:15, Explosive atmospheres—Part 0: Equipment—General requirements.

CSA C22.1-15, Canadian Electrical Code, Part I.

CAN/CSA-C22.2 No. 60529:16, Degrees of protection provided by enclosures (IP Code).

IEC 60270:2000+A1:2015, High-voltage test techniques—Partial discharge measurements.[6]

IEEE Std 844.2-2017/CSA C293.2-17, IEEE/CSA Standard for Skin Effect Trace Heating of Pipelines, Vessels, Equipment, and Structures—Application Guide for Design, Installation, Testing, Commissioning, and Maintenance.[7]

NFPA 70, National Electrical Code®, (NEC®).[8]

NMX-J-556-ANCE-2015 • CSA C22.2 No. 2556-15 • UL 2556, Wire and Cable Test Methods.

NMX-J-235/2-ANCE-2015 • CSA C22.2 No. 94.2-15 • UL 50E, Enclosures for Electrical Equipment, Environmental Considerations.

NMX-J-543-ANCE-2013 • CSA C22.2 No. 65-13 • UL 486A-486B, Wire Connectors.

3. Definitions

For the purposes of this document, the following terms and definitions shall apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.[9] Some definitions here are used only in IEEE Std 844.2/CSA C293.2.

ambient temperature: The environmental temperature surrounding the workpiece to be heated. For a workpiece enclosed in thermal insulation and weather barrier, it is the temperature external to the thermal insulation and weather barrier.

certification: Attesting that the skin effect trace heating system has demonstrated the ability to perform in accordance with pre-established criteria.

contaminant: Any solid or liquid material that is not an intended ingredient in the electrical insulation.

controlled design: A control method that uses a temperature control device to limit the maximum workpiece temperature of the skin effect trace heating system.

[5]CSA Group publications are available from CSA Group (Standards Sales), 178 Rexdale Boulevard, Toronto, Ontario, Canada M9W 1R3 (shop.csa.ca).
[6]IEC publications are available from the Sales Department of the International Electrotechnical Commission, Case Postale 131, 3, rue de Varembé, CH-1211, Genève 20, Switzerland/Suisse (http://www.iec.ch/). IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (http:// www.ansi.org/).
[7]IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08854, USA (http://standards.ieee.org/).
[8]The NEC is published by the National Fire Protection Association, Batterymarch Park, Quincy, MA 02269, USA (http://www.nfpa.org). Copies are also available from the Institute of Electrical and Electronics Engineers, Inc., 445 Hoes Lane, Piscataway, NJ 08854, USA (http://standards.ieee.org/).
[9]*IEEE Standards Dictionary Online* is available at: http://dictionary.ieee.org.

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distributed temperature sensor: A temperature sensor that has the ability to measure many temperature points spatially along an extended length.

down-hole heating: The application of a trace heating element inside a well.

end termination: The location opposite the power connection where the skin effect insulated conductor is connected to the ferromagnetic envelope.

ferromagnetic envelope: A carbon steel tube or pipe and any enclosure with magnetic properties designed to contain the skin effect insulated conductor. When connected to an ac electrical supply, the resulting magnetic fields of the conductor and tube attract and cause the tube current to concentrate on the inner skin of the heat tube, which produces heat through I^2R. The amount of heat produced in the heat tube is a result of the current and resistivity of the heat tube. *Syn:* **heat tube.**

ferromagnetic material: A material that, in general, exhibits hysteresis phenomena and whose permeability is dependent on the magnetizing force.

heat loss: A quantitative value for the rate of thermal energy flow from a workpiece to the surrounding ambient.

heat sink: A part that conducts and dissipates heat away from the workpiece being heated. Heat sinks, as related to skin effect trace heating systems, can be workpiece supports, valve operators, etc.

insulated splice: Electrically insulated field or factory skin effect conductor connections that are located within the skin effect trace heating circuit and are exposed to the same environment as the skin effect insulated conductor.

jumper/jumpering: A technique used for the purpose of providing non-heating electrical continuity of the skin effect trace heating circuit around equipment such as a valve or flange in a pipeline. In this technique, the ferromagnetic envelope is discontinued. Electrical continuity of the circuit is maintained by the use of suitable conductors connected in series with the skin effect insulated conductor and the ferromagnetic envelope.

maintain temperature: The specified temperature of the fluid, process material, or workpiece that the heating system is designed to hold at equilibrium under specified design conditions. *Syn*: **maintenance temperature**.

manufacturer: The entity that owns the certificate for the system.

maximum ambient temperature: The highest specified ambient temperature in which the skin effect trace heating system can be expected to operate.

maximum continuous exposure temperature: The highest allowable temperature that the skin effect insulated conductor (de-energized) can be continuously exposed to as declared by the manufacturer.

maximum maintain temperature/maximum continuous operating temperature (skin effect trace heater energized)**:** The specified maximum heated workpiece temperature that the skin effect trace heater can operate continuously on as declared by the manufacturer.

maximum/minimum allowable temperature: The maximum/minimum temperature permitted by the user for the process, fluid, pipe, or structure.

maximum sheath temperature: The maximum temperature of the outermost continuous covering of the skin effect insulated conductor under any specified operating conditions.

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maximum withstand temperature: The maximum operating or exposure temperature, whichever is higher, as declared by the manufacturer that does not adversely affect the thermal stability of the skin effect trace heater and any insulated splices.

minimum ambient temperature: The lowest specified ambient temperature at which the heat loss calculations are based and the skin effect trace heating system is expected to perform according to the specified requirements.

minimum installation temperature: The minimum temperature at which the skin effect trace heating system can be installed.

permeability (μ): The ratio of the magnetic flux density to the corresponding magnetizing force.

pipeline: A length of pipe, including pumps, valves, flanges, control devices, strainers, or similar equipment.

potentially explosive atmospheres: A mixture with air, under atmospheric conditions, of flammable substances in the form of gas, vapour, dust, fibres, or flyings that, after ignition, permits self-sustaining propagation.

power connection: The location at the beginning of the skin effect trace heater where power is supplied to the skin effect conductor and power is returned from the ferromagnetic envelope.

pre-insulated pipe: Sections of pipe where heat tube, insulation, and weather barrier are factory or field installed prior to final field assembly of the heated pipeline.

production annulus: The space between the production tube and the innermost wellbore casing of a well.

production tube: The pipe or tube inside of a casing serving as a flow line through which typically oil, water, or gas mixtures are brought to the surface.

rated output: The power per unit length of the skin effect trace heater at its rated voltage, length, and the heated workpiece temperature.

rated voltage: The voltage assigned by the manufacturer to which operating and performance characteristics are referred.

routine test: A test or series of tests carried out on skin effect insulated conductors after manufacture on a routine basis.

runaway temperature: The highest workpiece temperature that occurs when the trace heating system is continuously energized at the maximum ambient temperature.

skin effect insulated conductor: The dielectrically insulated conductor located inside the ferromagnetic envelope which delivers power to the far end of the ferromagnetic envelope.

skin effect trace heater: A trace heater where a conductor inside a ferromagnetic envelope material generates heat via current flow in the conductor and ferromagnetic envelope.

skin effect trace heater circuit: A single skin effect heater circuit consisting of an insulated skin effect conductor inside a ferromagnetic envelope, with a single power connection and end termination point.

skin effect trace heating system: The skin effect trace heater, associated power, splice and end termination boxes, temperature and power controls, power distribution, and power transformer required to functionally achieve skin effect heating.

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stabilized design: A design where the temperature of the trace heater, by design and use, stabilizes below the high-limit temperature, under specified adverse conditions, without the need for a protective system to limit the temperature.

structure: A foundation, wall, rail surface, or other surface that requires heat to be supplied for the purposes of controlling temperature within a specified range.

temperature controller: A device or combination of devices incorporating a means for sensing heated workpiece temperature and controlling power to the skin effect trace heater so as to maintain the heated workpiece within a specified range.

temperature limiting device: A safety device incorporating a means for sensing heated workpiece temperature and switching power off to the skin effect trace heater before the maximum specified heated workpiece temperature is exceeded.

thermal insulation: Material having air- or gas-filled pockets, void spaces, or heat-reflective surfaces that, when properly applied, reduces the transfer of heat from the heated workpiece.

type test: A test or series of tests carried out on the skin effect insulated conductor or system, representative of a type, to determine compliance of the design, construction, and manufacturing methods within the requirements of this standard.

very low frequency (VLF) test: Testing method that utilizes ac signals in the frequency range from 0.01 Hz to 1 Hz.

vessel: A container such as a barrel, drum, or tank for holding fluids or other material.

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.

workpiece: An object to which a skin effect trace heater is applied, such as pipelines, vessels, structures, or other equipment.

4. General requirements

4.1 Principle of operation

A skin effect heating system consists of a single insulated conductor run inside a ferromagnetic envelope. A source of ac power is connected between the skin effect insulated conductor and the ferromagnetic envelope at the power connection (i.e., the start of the skin effect trace heater). The far end of the skin effect conductor is connected to the ferromagnetic envelope at the end opposite from power source. Current flows from the power source through the skin effect insulated conductor to the far end and returns through the inner skin of the ferromagnetic envelope. The basic skin effect trace heating system is illustrated in Figure 1.

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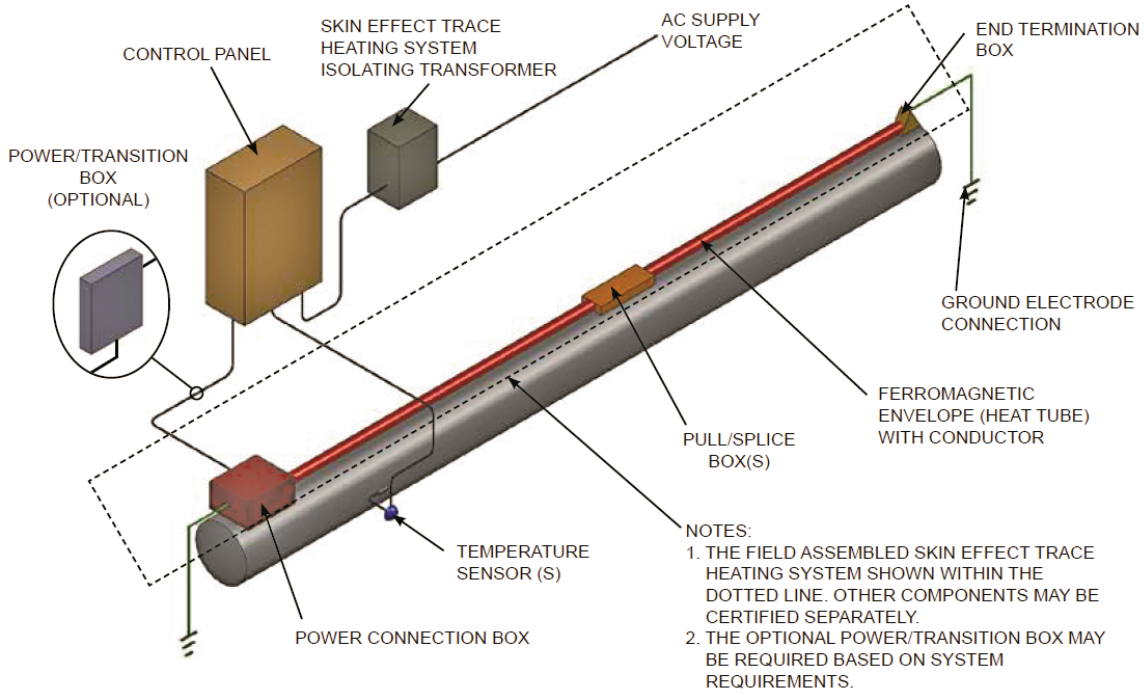


Figure 1—Skin effect trace heating system

In skin effect trace heating, heat is generated in the ferromagnetic envelope wall by the return current. Additional heat is produced by the I^2R loss in the insulated conductor. The inductive interaction between the current in the skin effect insulated conductor and the return current in the ferromagnetic envelope, along with the ac skin effect in the ferromagnetic envelope, results in the current in the ferromagnetic envelope being concentrated in a thin layer at its inner surface.

A distinctive feature of the skin effect trace heating system is that there is no measureable voltage on the outer surface of the ferromagnetic envelope.

4.2 System

4.2.1 General

Skin effect trace heating systems within the scope of this standard shall be designed and constructed so as to provide electrical, thermal, and mechanical durability and reliable performance.

4.2.2 Skin effect insulated conductor

4.2.2.1 Test requirements

All skin effect insulated conductors covered by this standard shall comply with the testing requirements in Clause 5. Installation instructions shall be provided based on documentation requirements included in Clause 7.

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