BS EN 62395-2:2013

BSI Standards Publication

Electrical resistance trace heating systems for industrial and commercial applications

Part 2: Application guide for system design, installation and maintenance

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National foreword

This British Standard is the UK implementation of EN 62395-2:2013. It is identical to IEC 62395-2:2013. It supersedes DD CLC/TS 62395-2:2010 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PEL/27, Electroheating.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Published by BSI Standards Limited 2013

ISBN 978 0 580 77528 4
ICS 25.180.10

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 December 2013.

Amendments/corrigenda issued since publication

Date	Text affected

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 62395-2

December 2013

ICS 25.180.10

Supersedes CLC/TS 62395-2:2010

English version

Electrical resistance trace heating systems for industrial and commercial applications - Part 2: Application guide for system design, installation and maintenance
(IEC 62395-2:2013)

Systèmes de traçage par résistance électrique pour applications industrielles et commerciales -
Partie 2: Guide d'application pour la conception, l'installation et la maintenance du système
(CEI 62395-2:2013)

Elektrische Widerstands-Begleitheizungen für industrielle und gewerbliche Zwecke -
Teil 2: Anwendungsleitfaden für Systementwurf, Installation und Wartung
(IEC 62395-2:2013)

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Europäisches Komitee für Elektrotechnische Normung

CEN-CENELEC Management Centre: Avenue Marnix 17, B - 1000 Brussels

Ref. No. EN 62395-2:2013 E

Foreword

The text of document 27/927/FDIS, future edition 1 of IEC 62395-2, prepared by IEC/TC 27 "Industrial electroheating and electromagnetic processing" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 62395-2:2013.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2014-07-14
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2016-10-14

This document supersedes CLC/TS 62395-2:2010.

EN 62395-2:2013 includes the following significant technical changes with respect to CLC/TS 62395-2:2010:

- this document has been changed from a Technical Specification to a European Standard;
- design considerations for trace heating on sprinkler systems have been expanded and a figure has been added to illustrate how to avoid undue shadowing of spray patterns from insulated sprigs close to sprinkler heads;
- specific details of design considerations for trace heating for emergency eyewash units and safety showers have been added.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

Endorsement notice

The text of the International Standard IEC 62395-2:2013 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60079-30-1:2007	NOTE	Harmonized as EN 60079-30-1:2007 (not modified).
IEC 60079-30-2:2007	NOTE	Harmonized as EN 60079-30-2:2007 (not modified).
IEC 60335-2-83:2001	NOTE	Harmonized as EN 60335-2-83:2002 (not modified).
IEC 60335-2-83:2001/A1:2008	NOTE	Harmonized as EN 60335-2-83:2002/A1:2008 (not modified).
IEC 60335-2-96:2002	NOTE	Harmonized as EN 60335-2-96:2002 (not modified).
IEC 60335-2-96:2002/A1:2003	NOTE	Harmonized as EN 60335-2-96:2002/A1:2004 (not modified).
IEC 60335-2-96:2002/A2:2008	NOTE	Harmonized as EN 60335-2-96:2002/A2:2009 (not modified).

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 60519-1	-	Safety in electroheating installations - Part 1: General requirements	EN 60519-1	-
IEC 62395-1	2013	Electrical resistance trace heating systems for industrial and commercial applications - Part 1: General and testing requirements	EN 62395-1	2013

CONTENTS

INTRODUCTION

IEC 62395-1 provides the essential requirements and testing appropriate to electrical resistance trace heating equipment used in industrial and commercial applications. While some of this work already exists in national or international standards, this standard has collated much of this existing work and added considerably to it.

IEC 62395-2 provides detailed recommendations for the system design, installation, maintenance and repair of electrical resistance trace heating systems in industrial and commercial applications which can include piping, vessels, roofs and concrete slab heating applications.

It is the objective of IEC 62395 that, when in normal use, electrical trace heating systems operate safely under their defined conditions of use, by

a) employing heaters of the appropriate construction so as to meet the test criteria and requirements detailed in IEC 62395-1. The construction includes a metallic sheath, braid, screen or equivalent electrically conductive covering;
b) operating at safe temperatures when designed, installed, and maintained in accordance with IEC 62395-2;
c) having at least the minimum levels of overcurrent and earth-fault protection required in IEC 62395-1 and IEC 62395-2.

ELECTRICAL RESISTANCE TRACE HEATING SYSTEMS FOR INDUSTRIAL AND COMMERCIAL APPLICATIONS —

Part 2: Application guide for system design, installation and maintenance

1 Scope

This part of IEC 62395 provides detailed recommendations for the system design, installation, maintenance and repair of electrical resistance trace heating systems in industrial and commercial applications. This standard does not include or provide for any applications in potentially explosive atmospheres.

This standard pertains to trace heating systems that may comprise either factory fabricated or field-assembled (work-site) units, and which may be series or parallel trace heaters, or surface heaters (heater pads or heater panels) that have been assembled and/or terminated in accordance with the manufacturer's instructions.

The products covered by this standard are intended to be installed by persons who are suitably trained in the techniques required and that only trained personnel carry out especially critical work, such as the installation of connections and terminations. Installations are intended to be carried out under the supervision of a qualified person who has undergone supplementary training in electric trace heating systems.

This standard does not cover induction, impedance or skin effect heating.

Trace heating systems can be grouped into different types of installations. These are characterized by different requirements for testing and are usually certified for a specific type of installation or application. Typical applications for the different types of installation are as follows:

a) Installations of trace heating on pipes, vessels and associated equipment. Applications include:
   - freeze protection and temperature maintenance;
   - hot water lines;
   - oil and chemical lines;
   - sprinkler systems.
b) Outdoor exposed area installations of trace heating. Applications include:
   - roof de-icing;
   - gutter and downspout de-icing;
   - catch basins and drains;
   - rail heating.
c) Installation with embedded trace heating. Applications include:
   - snow melting;
   - floor warming;
   - frost heave prevention;
   - underground thermal energy storage systems;
   - door frames.

d) Installations of trace heating internal to conduit or piping. Applications include:
   – snow melting – in conduit;
   – floor warming – in conduit;
   – frost heave prevention – in conduit;
   – underground thermal energy storage systems – in conduit;
   – internal trace heating of potable water lines;
   – enclosed drains and culverts.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60519-1, *Safety in electroheating installations – Part 1: General requirements*

IEC 62395-1:2013, *Electrical resistance trace heating systems for industrial and commercial applications – Part 1: General and testing requirements*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60519-1 and IEC 62395-1:2013 apply.

NOTE General definitions are given in the International Electrotechnical Vocabulary, IEC 60050. Terms relating to industrial electroheat are defined in IEC 60050-841.

4 Surface heating of vessels and piping systems

4.1 Application description

4.1.1 General

Piping and vessels often utilise surface-mounted trace heating systems to maintain water above freezing-point and to maintain process fluids and gases at given temperature levels. The trace heaters compensate for heat losses to the environment that are reduced but not eliminated by thermal insulation.

4.1.2 Environmental conditions

Attention should be directed to the surrounding environmental conditions, especially for systems that are exposed to sunlight (ultraviolet exposure), coastal atmospheres (corrosive salt spray and high humidity), and chemical atmospheres such as oil refineries and chemical plants.

Equipment subject to ultraviolet exposure may degrade due to surface oxidation, which can possibly lead to surface embrittlement and cracking. Corrosive atmospheres can affect the same exposed surfaces and can accelerate degradation of surfaces that are also susceptible to ultraviolet exposure. Chemical exposure can affect all equipment, whether covered by thermal insulation or not.

The trace heating equipment for piping and vessels is often protected from corrosion and ultraviolet exposure to some degree by the thermal insulation. However, these systems can have components that are exposed to the environment such as electrical connection components and weather barrier around the thermal insulation. The selection of trace heating equipment shall include a review of the suitability of equipment to the expected environmental conditions.

4.1.3 Trace heating systems considerations

Trace heating systems can range from simple pipe freeze protection in commercial buildings to process temperature maintenance and heat-up applications in large complex piping/vessel systems in industrial facilities. The details required for design can vary based on the complexity of the application. Control systems and requirements for monitoring can also vary depending on the control and design requirements.

Trace heating equipment should be chosen that is suitable for the application. For example, plastic piping has a much lower maximum exposure temperature than metallic piping. The trace heating and control system shall keep the piping temperature within the allowed range.

Higher temperature processes shall utilize trace heating and thermal insulation equipment that are suitable for the maximum exposure temperatures.

4.2 Design information – General

4.2.1 General

The requirements for system design include the development of basic heat loss (load) requirements, installation instructions for electrical, control and monitoring requirements, and trace heating system layouts for large, detailed, complex installations such as industrial facilities. While each design component requires individual treatment, the final system shall be evaluated as an integration of these component parts.

Trace heating system design shall conform to all IEC requirements for the use of electrical equipment and to the requirements of this standard. Consideration should be given to the maintenance of the trace heating systems to maintain energy efficiency and to routine testing of the installed systems for safe and proper operation.

Persons involved in the design and planning of electric trace heating systems should be suitably trained in all techniques required.

4.2.2 Electrical system design

The evaluation of electrical resistance heating systems includes an initial assessment of energy requirements and the associated electrical distribution equipment. The selection of the type of trace heating equipment and the control equipment affects the requirements of the electrical system design. Additional information is given in 4.4.

4.2.3 Control and monitoring

4.2.3.1 General

Controls for trace heating systems are often specified to reduce total energy usage and/or to maintain particular processes within a narrow band. Monitoring systems are used to verify correct system operation and in many cases to provide an indication of electrical problems or temperatures that are out of range. Subclause 4.2.3.2 describes the basic types of controls and monitoring and 4.2.3.3 defines critical applications relative to the control systems. Specific design of control systems is given in 4.5.

4.2.3.2 Recommendations for control

The recommendations for control and monitoring are defined by the type of application.

a) Type I

A Type I control is for applications where the temperature is maintained above a minimum point. Large blocks of power may be controlled by means of a single control device, such as ambient sensing, and an electrical distribution panel board. Heat input may be provided unnecessarily at times and wide temperature excursions should be tolerable. Energy efficiency may be improved through the use of dead-leg control techniques (see 4.5.10).

b) Type II

A Type II control is for applications where the temperature should be maintained within a moderate band. Control by pipe-sensing mechanical thermostats is typical.

c) Type III

A Type III control is for applications where the temperature should be controlled within a narrow band. Electronic pipe-sensing controllers using thermocouple or resistance-temperature detector (RTD) units facilitate field (work site) calibration and provide maximum flexibility in the selection of temperature alarm and monitoring functions. Heat input capability may be provided to preheat an empty pipe or raise the fluid temperature, or both, within a specified range and time interval. Type III systems require strict adherence to flow patterns and thermal insulation systems.

4.2.3.3 Control and monitoring for critical applications

If failure of any part of the trace heating system can result in a safety or operability problem, then the trace heating system may be considered to be critical to the application. The temperature control and circuit monitoring requirements of an application may be defined according to the temperature control types described in 4.2.3.2, together with the control level as described in Table 1.

Table 1 – Application types

Is trace heating a critical component for the application?	Desired accuracy of temperature control		
	Above a minimum point Type I	Within a moderate band Type II	Within a narrow band Type III
Yes = Critical (C–)	C – I	C – II	C – III
No = Non-critical (NC–)	NC – I	NC – II	NC – III

When trace heating is critical to the application, circuit monitoring for correct operation, malfunction alarms, and back-up (redundant) trace heaters should be considered. Redundant trace heaters may allow maintenance or repairs to be performed without a process shutdown and may be used to enhance reliability. Redundant controllers can be specified to be automatically activated in the event of a fault being indicated by the monitoring/alarm system.

4.2.4 Trace heating system design

Trace heaters should be selected to provide sufficient power for

a) compensation of heat loss when maintaining a specified temperature of an application, see the calculation method in 4.3.4; and/or

b) raising the temperature of a workpiece and its contents when specified, within a specified time period, see the calculation method in 4.3.6.

The evaluation should provide an electrical system with sufficient capacity to deliver the required power at the specified minimum ambient temperature. The system heat requirements should be multiplied by a safety factor as determined on the basis of 4.3.5. Additional specific design recommendations are described in 4.6.

4.2.5 Design information documentation

Design information may be compiled and provided in the form of specifications, layouts, and other system documentation and drawings. Any or all of the following may be applicable:

- thermal design parameters;
- system flow diagram;
- equipment layout drawings (plans, sections, etc.);
- pipe drawings (plans, isometrics, line lists, etc.);
- piping specifications;
- thermal insulation specifications;
- equipment detail drawings (pumps, valves, strainers, etc.);
- electrical drawings (one lines, elementaries, etc.);
- bill of materials;
- electrical equipment specifications;
- equipment installation and instruction manuals;
- equipment details;
- thermal insulation schedules;
- process procedures that would cause elevated pipe temperatures, that is, steam out or exothermic reactions.

4.3 Thermal system design

4.3.1 General

Trace heater selection includes the determination of the maximum possible system temperature under worst-case conditions. The evaluation shall ensure that the maximum system temperature does not exceed the maximum withstand temperature rating of the workpiece or the thermal insulation. The trace heating supplier should also provide recommendations for these applications, including product performance and installation guidelines.

The trace heater sheath temperature and/or the maximum workpiece temperature may be reduced by, for example, the use of multiple tracers to reduce the power produced per unit length or by the selection of the temperature control system.

Subclause 4.3 reviews design parameters, thermal insulation considerations, system heat loss, safety factors, heat-up considerations, selection of trace heater, design calculations, sheath temperature calculations, design documentation, start-up at low ambient temperatures, long trace heater circuits, and chimney effect.

4.3.2 Design conditions

The following general design conditions and application inputs are typically needed prior to commencing with the system design. Additional information that may be required for particular applications is detailed in 4.6.

a) System parameters:
   1) pipe and vessel maintain temperature;
   2) minimum ambient temperature;
   3) insulation thickness and type;
   4) pipe diameters, lengths, and routing (vertical, horizontal, oblique) or vessel dimensions;
   5) pipe type:
      i) non-metallic;
      ii) metallic;
   6) components such as pumps, strainers, flanges, valves, and supports;

7) maximum process temperature (due to process, steam cleaning, etc.);
8) flow characteristics:
   i) pressurized;
   ii) gravity;
9) design wind velocity.

b) Electrical considerations:
   1) voltage supply;
   2) circuit locations;
   3) power distribution system.

4.3.3 Thermal insulation

4.3.3.1 General

The selection, installation and maintenance of thermal insulation should be considered a key component in the performance of an electrical trace heating system. The thermal insulation system is normally designed to prevent the majority of heat loss with the trace heating system compensating for the remainder. Therefore, problems with thermal insulation have a direct impact on the overall system performance.

The principal areas for consideration are as follows:

– selection of an insulating material;
– selection of a weather barrier (cladding);
– selection of the economic insulation thickness;
– the double insulation method.

4.3.3.2 Selection of insulating material

The following are important aspects to be considered when selecting an insulation material. These factors should be considered and the selection optimized according to the following design criteria:

– temperature rating;
– thermal conductivity of the insulation;
– mechanical properties;
– chemical compatibility and corrosion resistance;
– moisture resistance;
– health risks during installation;
– fire resistance;
– toxicological properties when exposed to fire;
– costs.

Insulating materials commonly available include:

– expanded silica;
– mineral fibre;
– cellular glass;
– urethane;
– fibreglass;
– calcium silicate;
– polyisocyanurate;

– perlite silicate.

For soft insulants (mineral fibre, fibreglass, etc.), actual pipe size insulation may be used in many cases by banding the insulation tightly. Care should be taken to prevent the trace heater from being buried within the insulation, which may cause damage to the trace heater or may restrict proper heat transfer. As an alternative, the next larger pipe size insulation that can easily enclose pipe and electric trace heater is also acceptable. Rigid insulation (calcium silicate, expanded silica, cellular glass, etc.), may be pipe-size insulation if customized to fit the longitudinal joint. In all cases, the insulation type, size and thickness should be clearly specified.

Insulation for valves, flanges, pumps, instruments, and other irregularly shaped equipment are typically custom fit for the particular configuration. This may be fabricated from block, insulation segments or flexible removable covers.

Insulating cements or fibrous materials should be used to fill cracks and joints. Where used for total insulation of an irregular surface, a proportionally thicker layer of insulating cement may be applied to achieve the desired insulating capability. When using insulating cement, install a barrier over the trace heater to prevent the insulating cement from isolating the trace heater cable from the workpiece (creating excessive heater temperatures).

Embedding the trace heater in insulation cements should generally be avoided.

4.3.3.3 Selection of weather barrier (cladding)

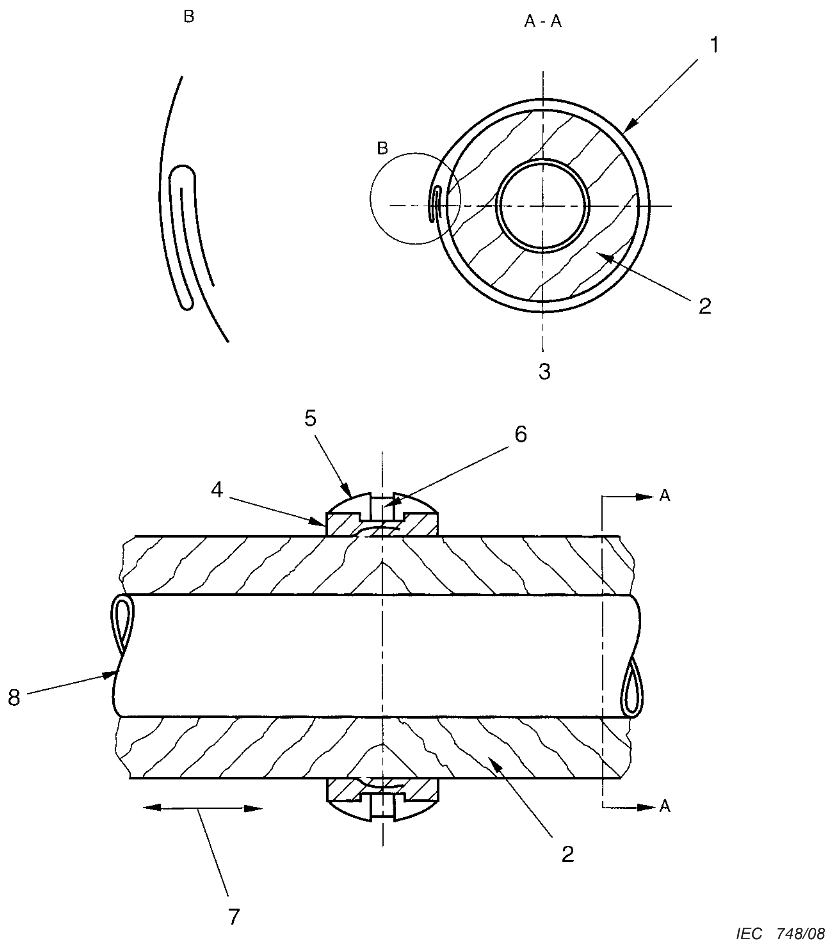
Proper operation of an electrically trace heated system depends upon the insulation being dry. Electric tracing normally has insufficient heat output to dry out wet thermal insulation. Some insulation materials, even though removed from the piping and force dried, never regain their full insulating capability once they have been wet.

Straight piping should be weather-protected with metal or polymeric jacketing or a mastic system. When metal jacketing is used, it should be smooth with formed, modified “S” longitudinal joints. The circumferential end joints should be sealed with closure bands and supplied with sealant on the outer edge or where they overlap (see Figure 1).

Jacketing that is overlapped or otherwise closed without sealant is not effective as a barrier to moisture. A single, unsealed joint can allow a considerable amount of water to leak into the insulation during a rainstorm.

The type of weather barrier should be determined based on the following:

– effectiveness in excluding moisture;
– corrosive nature of chemicals in the area;
– fire protection requirements;
– durability to mechanical abuse;
– cost.



Key

1 Metal jacket	5 Closure band
2 Insulation	6 Insulated strap
3 Metal jacket insulated pipe	7 Movement
4 Mastic sealer	8 Pipe

Figure 1 – Thermal insulation – Weather-barrier installation

4.3.3.4 Sealing of weather barrier penetrations

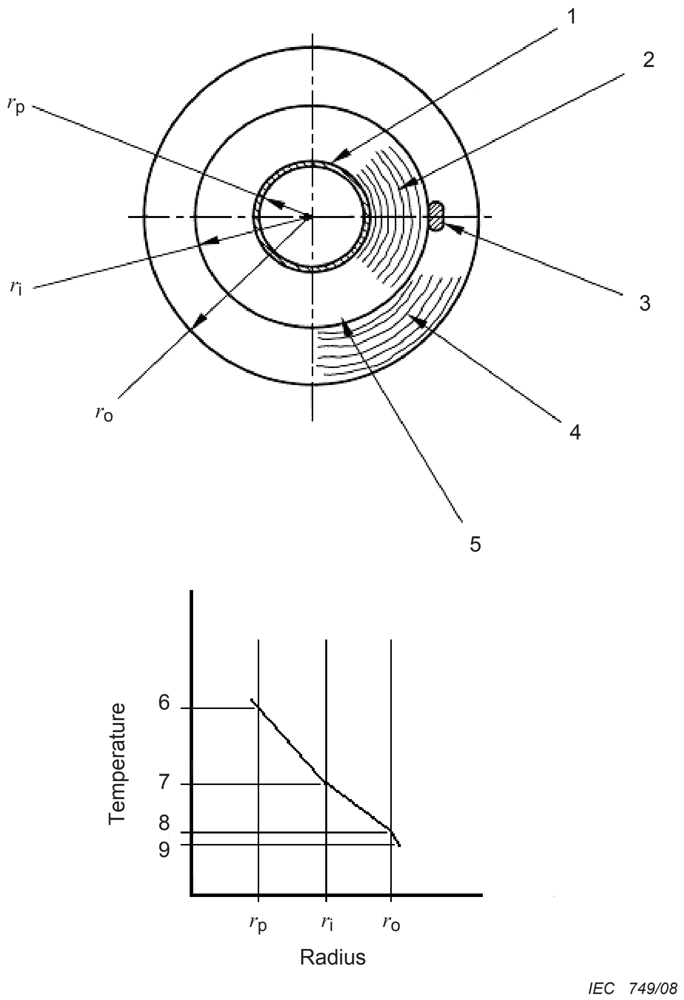
Quality caulking of weather barrier penetrations is required to prevent water ingress and contamination of thermal insulation systems. Structural supports and trace heater connection kits are examples of such penetrations. Low quality caulking materials dry out and crack, allowing gaps for water ingress.

4.3.3.5 Selection of economical thickness

At a minimum, an economic evaluation of the insulation considers the initial costs of the materials and installation against the energy saved over the life of the system. It should be noted that the actual insulation thicknesses do not always correspond exactly to the nominal insulation thickness. When choosing the insulation size, considerations should be made as to whether or not the actual pipe-size insulation is suitable for accommodating both pipe and trace heater.

4.3.3.6 Double insulation method

The double insulation technique may be employed when the pipe temperature exceeds the maximum allowable temperature of the trace heater. A typical application is prevention of the freezing of condensate in high-temperature steam lines when these lines are not in use. The trace heater is located between two layers of insulation surrounding the pipe. The essence of the double-insulation technique is to determine the correct combination of inner and outer insulation type and thickness that results in an acceptable interface temperature for the trace heater. The inner layer of thermal insulation circumferential end joints should be installed with gaskets to prevent opening of gaps as piping heats up. Gaps may cause high temperatures to reach and damage the trace heater. The installation is illustrated and a typical temperature profile is indicated graphically in Figure 2. It should be noted that the maximum ambient temperature conditions should be considered in this determination.



Key

1 Pipe
2 Inner insulation layer
3 Heat tracer
4 Outer insulation layer
5 Metal foil (aluminium)
6 Pipe temperature
7 Interface temperature
8 Outer insulation surface temperature
9 Ambient temperature

Figure 2 – Typical temperature profile

4.3.4 Heat loss determination

The heat loss of a workpiece can be calculated from the following formula incorporating both conduction and convection parameters:

$$q = \frac{(T_p - T_a)}{\frac{1}{\pi D_1 h_i} + \frac{\ln\left(\frac{D_2}{D_1}\right)}{2\pi k_1} + \frac{\ln\left(\frac{D_3}{D_2}\right)}{2\pi k_2} + \frac{1}{\pi D_3 h_{co}} + \frac{1}{\pi D_3 h_o}} \quad (1)$$

where

- q is the heat loss per unit length of pipe in watts per metre (W/m);
- T_p is the desired maintenance temperature in degrees Celsius (°C);
- T_a is the minimum design ambient temperature in degrees Celsius (°C);
- D_1 is the inside diameter of the inner insulation layer in metres (m);
- D_2 is the outside diameter of the inner insulation layer in metres (m) (inside diameter of the outer insulation layer when present);
- D_3 is the outside diameter of the outer insulation layer when present in metres (m);
- k_1 is the thermal conductivity of the inner layer of insulation evaluated at its mean temperature (W/mK);
- k_2 is the thermal conductivity of the outer layer of insulation, when present, evaluated at its mean temperature (W/mK);
- h_i is the inside air contact convection coefficient from the pipe to the inner insulation surface when present (W/m^{2}K);
- h_{co} is the inside air contact convection coefficient from the outer insulation surface to the weather barrier when present (W/m^{2}K);
- h_o is the outside air film convection coefficient from the weather barrier to ambient (W/m^{2}K) (typical values for this term range from 5 W/m^{2}K to 50 W/m^{2}K for low-temperature applications below 50 °C);
- ln is the natural log to base e.

The degree of accuracy of the calculation depends on the degree of definition of the system parameters.

The basic formula given in (1) can be reduced to the following form for pipes and tubes when only the conduction parameters are taken into account and when only one thermal insulation layer is present:

$$q = \frac{2\pi k\,(T_p - T_a)}{\ln\left(\frac{D_2}{D_1}\right)} \quad (2)$$

Vessel heat losses often require a more complex analysis to determine total heat loss. The trace heating supplier should be consulted.

For ease of product selection, trace heating suppliers often furnish simple charts and graphs and/or computer programs to determine heat losses for variously maintained temperatures and insulations, which usually include a safety factor.

The preceding relationships assume that the thermal insulation system densities, volumes, conductivities and heat losses are constant over the temperature range of interest. Although the model is representative of a straight pipeline, it does not have provisions for equipment such as pumps and valves. Non-insulated or partially insulated pipe supports or equipment require additional heat input to compensate for the higher heat loss.

4.3.5 Design safety factor

Since heat-loss calculations based on theoretical values do not account for imperfections associated with actual work site installations, a safety factor should be applied to the calculated values. The safety factor should be based upon the user's requirement: this typically increases the heat loss by 10 % to 25 %. A more detailed evaluation should include the following:

a) thermal insulation degradation;
b) supply voltage variations;
c) branch wiring voltage drop;
d) trace heater voltage drop;
e) increased radiation and convection on higher temperature applications;
f) quality of installation of thermal insulation.

4.3.6 Heat-up considerations

In certain plant operations, it may be necessary to specify that the trace heating system is capable of raising the temperature of a static product within a certain time period. The heat-up time (in seconds) of a trace heated system on piping may be calculated by use of the following formula.

$$t = H \ln\left\{\frac{q_c - U(T_i - T_a)}{q_c - U(T_f - T_a)}\right\} + \frac{P_1 V_{c1} h_f}{q_c - U(T_{sc} - T_a)} \qquad (3)$$

where

U is the heat loss per unit length of pipe per degree of temperature difference:

$$U = \frac{1}{\dfrac{1}{\pi D_1 h_i} + \dfrac{\ln\left(\dfrac{D_2}{D_1}\right)}{2\pi K_1} + \dfrac{\ln\left(\dfrac{D_3}{D_2}\right)}{2\pi K_2} + \dfrac{1}{\pi D_3 h_{co}} + \dfrac{1}{\pi D_3 h_o}} \qquad (4)$$

H is the thermal time constant, which is the total energy stored in the mass of pipe, fluid, and insulation per degree of temperature divided by the heat loss per unit length per degree temperature differential, as follows:

$$H = \frac{P_1 C_{p1} V_{c1} + P_2 C_{p2} V_{c2} + 0{,}5 P_3 C_{p3} V_{c3}}{U} \qquad (5)$$

where

P_1 is the density of the product in the pipe (kg/m^3);
C_{p1} is the specific heat of the product (J/kgK);
V_{c1} is the internal volume of the pipe (m^3/m);
P_2 is the density of the pipe (kg/m^3);
C_{p2} is the specific heat of the pipe (J/kgK);
V_{c2} is the pipe wall volume (m^3/m);
P_3 is the density of insulation (kg/m^3);
C_{p3} is the specific heat of the insulation (J/kgK);

V_{c3} is the insulation wall volume (m^3/m);

T_i is the initial temperature of the pipe (°C);

T_f is the final temperature of the fluid and the pipe (°C);

T_a is the ambient temperature (°C);

T_p is the desired maintenance temperature (°C);

t is the desired heat-up time in seconds (s);

U is the heat loss per unit length of pipe per degree of temperature (W/mK);

H is the thermal time constant in seconds (s);

T_{sc} is the temperature at which the phase change occurs (°C);

h_f is the latent heat of fusion for the product (J/kg);

q_c is the output of the trace heater(s) (W/m).

It may be necessary to evaluate the heat requirement separately for a phase change in heat-up applications.

4.3.7 Selection of trace heater

4.3.7.1 General

Basic selection criteria for trace heaters shall include the following.

– The maximum withstand temperature of trace heaters shall be greater than the maximum possible workpiece temperature (which may be greater than the normal operating temperature).
– Trace heaters shall be suitable for operation in the environmental conditions specified, for example, a corrosive atmosphere or a low ambient temperature.
– Trace heaters shall meet the requirements of IEC 62395-1:2013 for use in the particular application.

Site-fabricated trace heaters are permissible provided that:

– installation personnel are competent in the special techniques required;
– trace heaters pass the field (site work) tests specified;
– trace heaters are marked in accordance with the requirements of IEC 62395-1:2013.

It is necessary to determine the maximum allowable power density for each circuit design, such that temperature limits are not exceeded. This is typically determined by theoretical formulae and then adjusted as necessary based on the trace heating supplier's empirical data. The limiting value of maximum allowable power density for each trace heater is either the value chosen from the supplier's data or that specified for the system, whichever is the lower. The power density may be reduced if needed by the use of multiple tracing.

The actual installed load should be not less than the design loading and the actual power density not greater than that obtained above. Multiple tracing or spiralling of a single trace heater may be required. The type of trace heater and the values of installed load and power density should be recorded in the system documentation.

4.3.7.2 Specific types of trace heaters

Trace heaters are generally defined by their electrical characteristics.

Series trace heaters typically use the electrical conductor as the heating element, in such a way that the voltage supply and circuit length become critical parameters in the design of each circuit. Series trace heaters with polymeric insulation are particularly suited for installations with long circuit lengths. Series trace heaters with mineral insulation (MI) and metallic sheaths are particularly suited for very high process temperature and high watt-density applications.

Parallel trace heaters typically consist of two parallel conductors with a separate polymeric or metallic heating element that draws voltage from the conductors. These are characteristically used for freeze protection and for temperature maintenance of complex piping installations. The constant wattage type typically has a spirally wound metallic heating element. The PTC type (positive temperature coefficient, see 4.3.7.4) typically consists of a polymeric heating element extruded between the conductors. The power-limiting type typically falls between the previous types, with higher output at higher operating temperatures than the PTC type, and with lower maximum sheath temperatures than the constant wattage type.

4.3.7.3 Selecting the trace heater

When selecting trace heaters the objective should be to minimize the overall installed cost while ensuring the overall reliability and maintainability of the system. It is important to first define the characteristics of different applications.

- Complex piping systems consist of relatively short runs of pipe with frequent tees as well as inline valves and pumps that also require trace heating. While variations occur depending on the control requirements, the average circuit length is typically less than 30 m.
- Interconnecting piping systems are those connecting different areas of an industrial facility and are generally much longer than complex piping. The lengths may be up to 1 500 m and have little inline equipment or branch flow paths.
- Product transfer lines are found in applications like barge-unloading lines and in tank farms.

4.3.7.4 Trace heater performance and equilibrium conditions

Figure 3 shows examples of power output curves for a constant wattage trace heater and for two PTC (positive temperature coefficient) trace heaters with different slope characteristics. The figure also indicates the heat loss through the thermal insulation for a given ambient temperature (in this example –20 °C), and how the heat loss increases as the workpiece temperature increases. In this case the heat loss at the desired maintenance temperature of 10 °C is 15 W/m. The figure indicates that the trace heater shall supply a minimum of 15 W/m regardless of the type of trace heater selected.

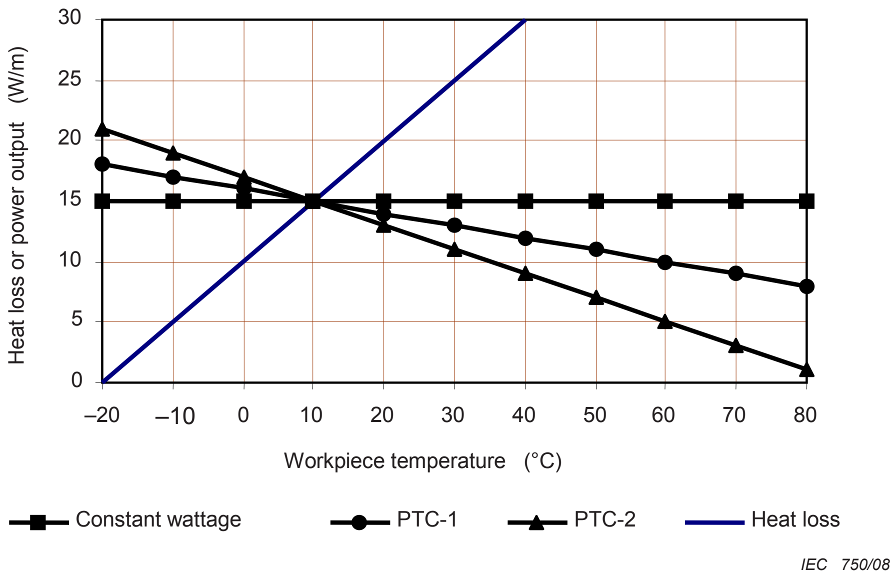


Figure 3 – Equilibrium conditions for workpiece maintenance

Figure 4 shows the same example but from the perspective of evaluating the upper limits. The heat loss line is now plotted for the highest ambient temperature (in this case 40 °C). Also, the trace heater output levels have been increased to illustrate maximum output tolerance. The intersection points (where heat loss is equal to heat input) indicate the highest possible workpiece temperature and the power outputs at these conditions. For example, the potential maximum workpiece temperature for the constant wattage trace heater is 73 °C, and the heat loss and potential maximum trace heater output level are at equilibrium at 17 W/m. Both PTC-1 and PTC-2 indicate somewhat lower maximum workpiece temperatures due to the decreasing slope of the output curves. PTC-2 indicates a potential maximum workpiece temperature of 56 °C, and the heat loss and potential maximum trace heater output level are at equilibrium at 8 W/m. This approach may be used when evaluating the upper limit operating conditions for the stabilized design approach.

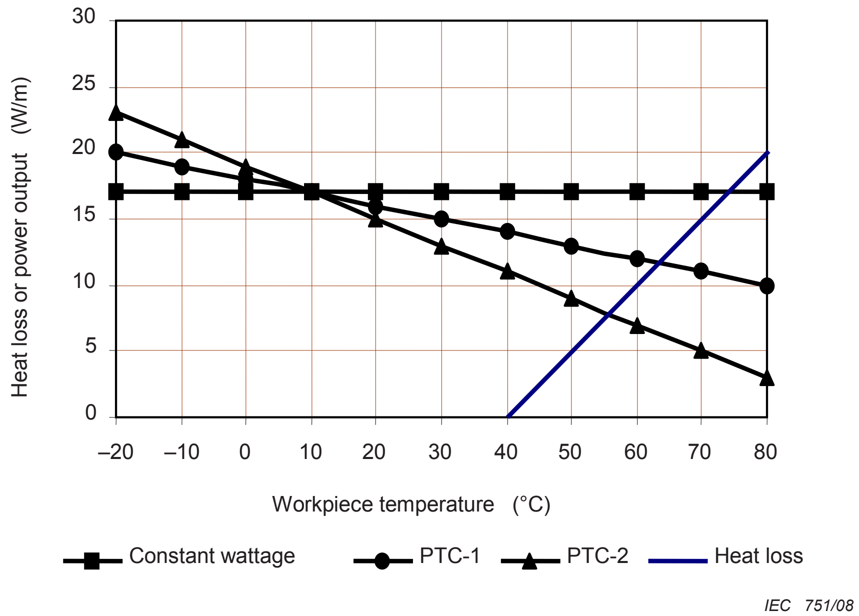


Figure 4 – Equilibrium conditions for upper limit evaluation

The power output levels of different trace heaters are typically provided by the trace heater supplier in the product literature and/or in a design program. In most cases, the output curves for the PTC trace heater types are defined based on empirical data from test fixtures similar to the test in 5.2.10 of IEC 62395-1:2013.

4.3.8 Design calculations

4.3.8.1 General

The following characteristics of a trace heating system design should exist for the trace heating system to meet the specified requirements.

a) The output of trace heaters shall be greater than the system heat loss including a suitable safety factor. This can be achieved by installing a single trace heater with suitable output, by using multiple passes, or by spiralling if needed to keep the output level as low as possible.

b) Potential variations in voltage supply and other system parameters should be determined and compensated for by a safety factor.

c) The upper limit characteristics of the system (for example, amperage, heater and workpiece temperatures) shall be evaluated for applications where process temperature accuracy is critical, that have a wide range of ambient temperatures, that have no temperature controller, or that utilize ambient sensing control.

4.3.8.2 Stabilized design

Stabilized design is based on the principle of determining the maximum workpiece and trace heater surface temperatures under a worst-case set of conditions. This is a calculation of the equilibrium conditions that occur when the heat input equals the system heat loss. The worst-case set of conditions includes:

a) maximum ambient temperature, typically assumed to be 40 °C unless otherwise specified;
b) no wind (still air);
c) use of a conservative or minimum value for the thermal conductivity of the thermal insulation;
d) no temperature control as per the design or to simulate a failed temperature controller;
e) the trace heater is operated at its stated operating voltage plus 10 %;
f) the trace heater is assumed to be operating at the upper limit of the manufacturing tolerance, or at the minimum specific resistance for series trace heaters.

This set of circumstances is illustrated graphically in Figure 4. Testing for stabilized design is defined in 5.2.13 of IEC 62395-1:2013. Typically, the maximum surface temperature of the trace heater is calculated from formulae derived from the evaluation of empirical data, or by the theoretical approach described below. Many trace heating suppliers have design programs that calculate the maximum surface temperature on the basis of these worst-case parameters.

4.3.9 Theoretical sheath temperature calculations – Metallic pipe applications

The maximum possible pipe temperature is calculated at maximum ambient temperature with the trace heater continuously energized. The formula for calculating the maximum potential pipe temperature is a rearrangement of the terms of the heat loss formula.

$$T_{pc} = \frac{Q_{sf}}{\pi}\left[\frac{1}{D_1 h_i} + \frac{\ln\left(\frac{D_2}{D_1}\right)}{2k} + \frac{1}{D_2 h_{co}} + \frac{1}{D_2 h_o}\right] + T_a \qquad (6)$$

where

T_{pc} is the maximum calculated pipe temperature (°C);

NOTE The maximum process pipe temperature can sometimes exceed the calculated value.

Q_{sf} is the upper tolerance trace heater output (W/m);
k is the thermal conductivity of the insulation at its mean temperature (W/mK);

Other terms are defined in earlier formulae. Iterative techniques may need to be applied to the calculation of Formula (6) in order to arrive at T_{pc}, since the thermal conductivity of the insulation and the trace heater output may be a function of pipe temperature.

The sheath temperature of a trace heater may be calculated as follows:

$$T_{sh} = \frac{Q_{sf}}{UC} + T_{pc} \qquad (7)$$

where

T_{sh} is the trace heater sheath temperature (°C);
C is the trace heater circumference (m);

U is the overall heat transfer coefficient (W/m^{2}K).

The overall heat transfer coefficient is different for each trace heater type, installation method and system configuration. It is a combination of conductive, convective and radiation heat transfer modes. The value of U can vary from 12 W/m^{2}K for a cylindrical trace heater in air (primarily convective) to 170 W/m^{2}K or more for a trace heater applied using heat transfer aids (primarily conductive). Upon request, the trace heating supplier should provide the U-factor for given applications, or furnish calculated or experimentally determined sheath temperatures.

The actual power output of the trace heater should not exceed the stated upper tolerance output, and the operating sheath temperature should not exceed the calculated maximum sheath temperature.

4.3.10 Theoretical sheath temperature calculations – Non-metallic pipe applications

For non-metallic pipe applications, the pipe wall thermal resistance should be considered, as the non-metallic pipe is a poor heat transfer medium. These materials may have a thermal conductivity (k-factor) 1/200 of that of steel, and a substantial temperature difference may develop across the pipe or tank wall depending on the trace heater power density. This higher than normal temperature (when compared to tracing metallic pipes and vessels) may have two adverse effects:

a) the non-metallic pipe maximum allowable temperature may be exceeded;

b) the trace heater maximum allowable sheath temperature may be exceeded.

c) The sheath temperature of the trace heater under normal operating conditions is in principle obtained from Formula (7). However, in obtaining U, the effect of the thermal resistance of the pipe wall should be included. The overall heat transfer coefficient for plastic pipe is

$$\frac{1}{U_\mathrm{p}} = \frac{1}{U_\mathrm{m}} + \frac{L}{k_\mathrm{p}} \qquad (8)$$

where

U_p is the overall heat transfer coefficient for a non-metallic pipe (W/m^{2}K);

U_m is the overall heat transfer coefficient for a metallic pipe (W/m^{2}K);

L is the pipe wall thickness in metres (m);

k_p is the thermal conductivity of the pipe wall material (W/mK).

Because of the additional thermal resistance of the non-metallic pipe wall, a temperature difference exists across the pipe wall; that is, the outside pipe wall and fluid temperature are not the same as in the case of metallic pipe. Therefore, the fluid temperature should be considered.

For non-metallic pipe,

$$T_\mathrm{sh} = \frac{Q_\mathrm{sf}}{U_\mathrm{p} C} + T_\mathrm{f} \qquad (9)$$

where

Q_sf is the upper tolerance trace heater output (W/m);

T_f is the fluid temperature (°C).

Formula (9) is a conservative simplification of a complex problem that involves criteria beyond the scope of this standard. The individual trace heating supplier should provide sheath temperature design information for specific applications.

The actual power output of the trace heater should not exceed the stated upper tolerance output, and the operating sheath temperature should not exceed the calculated maximum sheath temperature.

4.3.11 Design documentation

Trace heater circuits shown on a drawing should depict their physical location, configuration, and relevant data, along with the associated piping systems. The drawing and/or design data should include the following information:

a) piping and vessel system designation;
b) pipe size, vessel dimensions, and material type;
c) piping or vessel location and/or line (identifying) number;
d) trace heater designation or circuit number;
e) location of power connection, end seal, and temperature sensors as applicable;
f) trace heater number;
g) design data such as:
   1) temperature to be maintained;
   2) maximum process temperature;
   3) minimum ambient temperature;
   4) maximum exposure temperature (when applicable);
   5) maximum sheath temperature;
   6) heat-up parameters (when required);
   7) length of piping;
   8) trace ratio of trace heater per length of pipe;
   9) extra length of trace heater applied to valves, pipe supports, and other heat sinks;
   10) length of trace heater;
   11) operating voltage;
   12) watts per unit length of trace heater at desired maintenance temperature;
   13) heat loss at desired maintenance temperature per unit length of pipe;
   14) watts, total;
   15) circuit current, start-up and steady state;
   16) thermal insulation type, nominal size, thickness, and *k*-factor;
   17) bill of material.

The drawing should also indicate the power distribution panel number or designation, the alarm and control equipment designation, and set points.

4.3.12 Start-up at low ambient temperatures

When trace heating systems are started at very low ambient temperatures, there may be initial current surges that could cause nuisance tripping of current protective devices. The rating and characteristics of current protective devices should be appropriate for the trace heating systems where low ambient start-up conditions may occur. Reference should be made to the trace heating supplier’s instructions for additional details and recommendations in these cases.

4.3.13 Long trace heater circuits

Parallel trace heaters exhibit a variation in power output, which reduces incrementally along the length of the circuit.

The power density at the end of the circuit is less than the nominal value due to the voltage drop in the conductors. The length of the circuit shall therefore be evaluated such that the performance of the heating circuit is not compromised.

Conversely, at the start of the circuit, the tracer produces a power density that is greater than the nominal value. This is because the heating effect of the resistor is supplemented by heat produced in the conductors. Again, the length of the circuit shall be evaluated such that limiting temperatures are not exceeded.

This variation in power output along the length of the tracer should be considered in determining the location of temperature sensors.

4.3.14 Chimney effect

Long, vertical piping runs, where close temperature control is needed, may require two or more control circuits. Due to convection, a substantial temperature difference from the bottom to the top of the vertical run may occur. The maximum control circuit length for a long, vertical run depends on the maintenance temperature tolerance and the fluid characteristics inside the pipe. The trace heating supplier typically provides specific design information for these situations.

4.4 Electrical design

The electrical system shall conform to applicable international, national, and local codes in addition to the requirements given in this standard. In addition to the proper sizing of the electrical power requirements and distribution equipment, attention should be paid to branch circuit protection. Heater start-up currents and their duration at the minimum start-up temperature should be considered.

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

Where conduit is used for power connection, a low point drain in the conduit leading to the power connection box is recommended.

Permanent tagging and identification shall be defined and later installed as specified in 4.7.10.

4.5 Control and monitoring system design

4.5.1 General

Control and monitoring systems shall meet the minimum requirements for the application, according to the process level and process temperature accuracy defined in 4.2.3.

The control and monitoring equipment should ensure that any high-limit temperature is not exceeded. It may also provide necessary isolation, and monitoring of fault conditions, over-current protection, and residual current protection if required. It is essential that integration of the trace heating system with plant operational and safety requirements, as defined by the trace heating system designer, is fully implemented.

The control system should open the circuit if a malfunction occurs in the sensor or the control device. Control may be provided in certain cases by sensing parameters other than temperature, such as electrical current. Specific requirements for controlled designs are found in 4.4 of IEC 62395-1:2013.

4.5.2 Mechanical controllers

Mechanical controllers, such as thermostats, utilize two alternative principles: a bimetallic element or the expansion of a fluid confined within a bulb or a bulb and capillary. Changes in temperature cause positional displacement which actuates electrical contacts to open or close the circuit.

Mechanical controllers are rugged; however, the short sensing element prevents remote panel mounting, and field calibration is cumbersome.

Selection of the mechanical controller shall take into account the maximum and minimum temperature rating of the sensor and its component parts, any corrosive conditions and its positional sensitivity to which it may be subjected.

4.5.3 Electronic controllers

The sensors of electronic controllers typically comprise resistance temperature detectors (RTDs), platinum resistance thermometers (PRTs), thermistors, thermocouples (T/Cs), or other temperature sensing devices. The controllers can be located several hundred metres away from the sensor and are often located in the control and distribution panel for ease of operator and maintenance access.

These controllers electronically process the sensor signal in order to switch an electro-mechanical relay or solid-state device for on-off or phase control.

4.5.4 Application suitability

Freeze protection systems having control Type I may only require an on/off switch with indicator light or an ambient sensing mechanical thermostat controlling a number of trace heater circuits. For improved energy efficiency and accuracy for control Types II or III, a temperature control system sensing the workpiece temperature may be considered.

Most process temperature applications are considered controls of Type II or III that require sensing of pipe temperature; these are typically provided with at least a mechanical thermostat.

For critical applications and/or where temperatures are to be controlled within a narrow band (Type III), alarm functions such as annunciation of high and low process temperature and trace heating circuit failure may be required. When specifications require it, electronic controls should be used. Systems are often provided with continuity, earth fault, and system diagnostic alarms and high-limit temperature switching. Depending on the system requirements, high-limit signals may be configured to operate an alarm and/or to operate the circuit protection device.

Type III control approaches are recommended for fire sprinkler systems and safety showers, with alarm annunciation when earth-fault circuit protection interrupts the circuit. Low temperature alarms are required for fire sprinkler lines. For further requirements, refer to local and national regulations (for example, high limit alarm for safety showers).

See Table 2 for Type II and III control and monitoring recommendations.

Table 2 – Recommendations for monitoring and control – Type II and III control

Type	Control				Monitoring				
	Manual On/Off	Ambient	Line sensing		Low temperature	High temperature	Earth fault	Trace heater supply voltage	High/low current
			Mechanical	Electronic					
Type II									
Potable water ≤150 mm	M	R	—	—	—	—	—	—	—
Potable water >150 mm	M	—	R	—	—	—	—	—	—
Drains	M	R	—	—	—	—	—	—	—
Hot water	M	—	—	—	—	—	—	R	—
Grease		—	M	—	—	—	—	—	—
Fuel oil		—	M	—	—	—	—	—	—
Type III									
Safety showers/ Eyewash units		—	M	R	R	M		R	—
Fire sprinklers		M	—	M[a]	M	—	M[b]	M	M
	M = Minimum required R = Recommended								

[a] The controller should be of a type that monitors its operation and alarms upon failure of system functions. Alarm output should be a type that changes state upon alarm or loss of controller supply voltage. Alarm output shall be connected to a fire detection alarm system.

[b] The earth-fault monitor should alarm.

4.5.5 Location of controllers

Electronic controllers are often grouped in a common cabinet. Where possible, temperature controllers should be sited to allow free and easy access for convenient maintenance and calibration.

4.5.6 Location of sensors

The following points should be considered in determining the location of sensors.

a) The number and location of sensors is determined by the requirements of the design criteria. Sensors should be positioned at points that are representative of the maintain temperature.

b) Where two or more trace heaters meet or join, sensors should be mounted 1 m to 1,5 m from the junction.

c) If a trace heating circuit includes both piping and in-line heat sinks or heat sources, the sensor should be located on a section of pipe in the system approximately 1 m to 1,5 m from the in-line heat sinks or heat sources.

d) Where a pipeline heating circuit runs through areas with different ambient temperatures (such as inside and outside a heated building), two sensors and associated controls may be required to control pipeline temperatures properly.

e) In complex piping systems, the material flow patterns should be evaluated for all possible circumstances before selecting the sensor location. Detailed information on this evaluation is given in 4.5.9 and 4.5.10.

f) The temperature sensor for control should be located to avoid direct temperature effects from the trace heater. The sensor should be securely mounted to ensure good thermal contact with the workpiece.

g) The temperature sensitivity of certain process materials and certain types of piping materials may warrant both a control and high-limit temperature device. The control sensor should be located at least 90° around the circumference from the trace heater. The high-limit sensor is also typically located at 90° from the trace heater but not adjacent to the other sensor. The controller for this sensor should have a set point at the material or system maximum allowable temperature, minus a safety margin.

4.5.7 Alarm considerations

4.5.7.1 General

The primary function of an alarm circuit is to alert operating personnel that the trace heating system may be operating outside the design limits and shall therefore be checked for possible corrective action. The type and function of the various alarm systems depend on the requirements of the system (see 4.2.3). Any, or all, of the alarms may be incorporated in data-logging equipment. Characteristics of the most common devices are listed in 4.5.7.2 to 4.5.7.4.

4.5.7.2 Trace heating circuit alarm

A trace heating circuit alarm is used to detect loss of current, voltage, or continuity of the trace heating circuit, and includes (but is not limited to) the following devices:

a) current-sensing device which monitors the trace heater current and signals an alarm if the current drops below a pre-set minimum while the temperature switch is closed;

b) voltage-sensitive device, which monitors voltage at the end of the trace heater (usually a parallel-type heating cable) or monitors voltage on a return wire;

c) resistance-sensing or continuity-sensing devices which monitor the trace heating circuit when the system is de-energized. Usually, a low-voltage signal or pulse is transmitted into the trace heater and monitored.

4.5.7.3 Temperature alarms

Low and high temperature alarms are often incorporated with a temperature controller, or fitted as separate devices, and have the following functions.

a) Low-temperature alarm: this indicates that the piping or vessel trace heating system temperature has fallen below a pre-set minimum and that subsequent cooling may be beyond acceptable operating design criteria.

b) High-temperature alarm: this indicates that the piping or vessel trace heating system temperature has exceeded a pre-set maximum temperature and that subsequent heating may be beyond acceptable operating design criteria.

4.5.7.4 Other alarms

Other available alarms include (but are not limited to) the following devices.

a) Auxiliary contact alarm: the alarm is used to indicate when an auxiliary switch is closed and power is being supplied to the trace heating circuit. It provides information to the operator to confirm proper operation of the contactor, but does not ensure proper operation of the trace heating circuit if a secondary contactor is open or if the trace heater has lost continuity.

b) Residual current protective devices: devices with a nominal 120/240 V a.c. operating voltage, and a single, selected current trip level that are also available with alarm contacts. These devices monitor the electrical circuit earth-leakage current. If the total exceeds the selected device's trip current, the device will trip, indicating a failure and interruption of the power to the circuit. Additionally, these monitoring devices are available with an alarm-only function.

c) Switch-actuated alarm: the alarm is usually initiated by an auxiliary alarm switch on the temperature controller.

d) Current-sensing apparatus: the apparatus consists of a temperature control bypass switch and an ammeter or current-sensitive relays and alarms.

e) Diagnostic alarm: this alarm is initiated by a diagnostic circuit within the electronic controller, signalling failure of an internal control or data processing logic circuit.

4.5.8 Integrated control

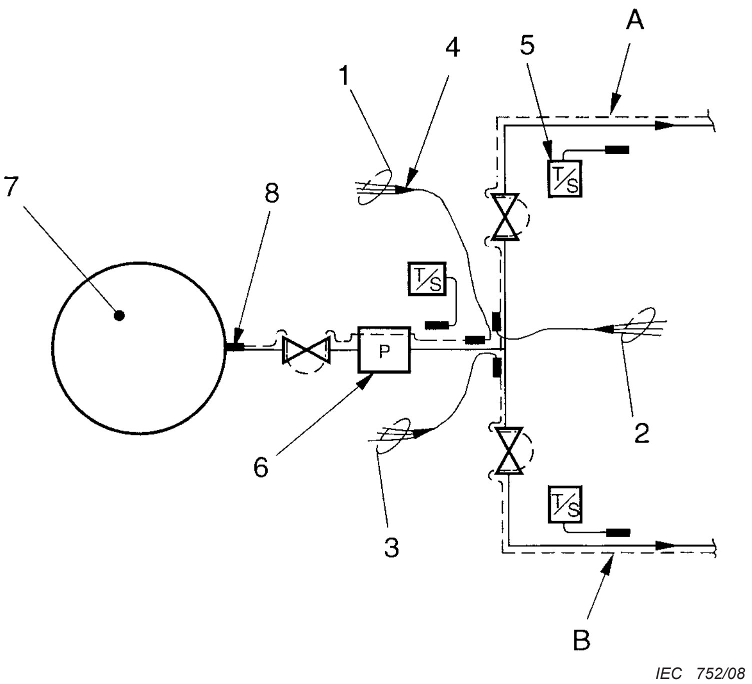
Trace heating system control and alarm circuitry may need to be integrated with a central (master) control and monitoring system. Careful consideration should be given in the selection of equipment that is compatible in both the control and supervisory functions to ensure successful and reliable data transfer.

4.5.9 Flow pattern analysis

Where critical temperature control is required, all possible flow conditions in the piping network should be considered in determining the trace heating circuit segments. This is illustrated by the heated tank example shown in Figure 5. All three trace heating circuits with separate controls are necessary to maintain the piping system at its desired maintenance temperature. When the heated product flows from the tank through pipe A, circuit No. 1 and circuit No. 2 are de-energized, and circuit No. 3, which is heating the non-flowing line, remains energized. If all three circuits are combined into one, using only one control, the non-flowing line A or B is de-energized and drops below the desired maintenance temperature.

A bypass around a control valve is another common occurrence where additional circuits are needed, as shown in Figure 6.

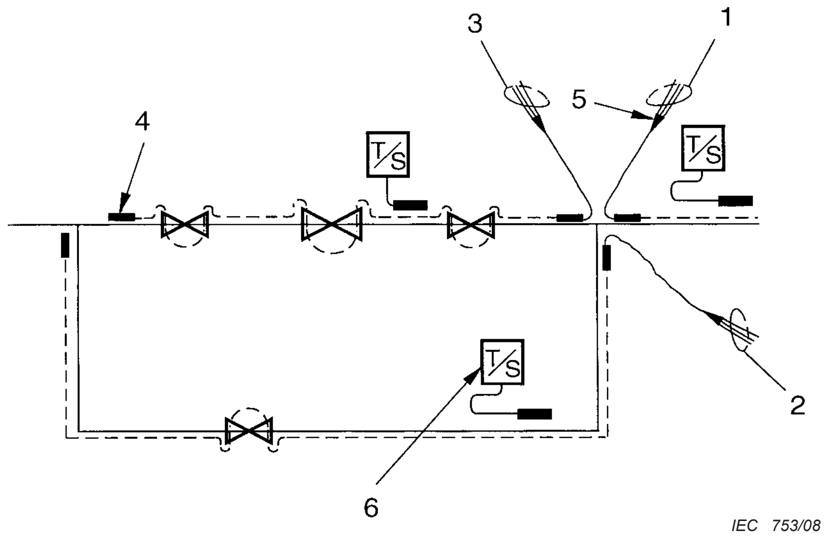
These are two examples of piping systems for which the circuit design needs close attention. Dead legs and manifold systems also require careful arrangements of the trace heating devices and their associated controls.



Key

A	Pipe A	B	Pipe B
1	Circuit No. 1	5	Temperature sensor
2	Circuit No. 2	6	Pump
3	Circuit No. 3	7	Heated tank
4	Cold end termination	8	Hot end termination

Figure 5 – Heated tank example



Key

1	Circuit No. 1	4	Hot end termination
2	Circuit No. 2	5	Cold end termination
3	Circuit No. 3	6	Temperature sensor

Figure 6 – Bypass example

4.5.10 Dead-leg control technique

This is a technique that is sometimes used for the temperature control of very complex piping networks and manifold systems. It can also be used where the total number of temperature controllers is to be kept to a minimum at the expense of some energy savings and control accuracy. The technique consists of locating or fabricating a section of pipe that

a) has a static flow condition at all times;
b) has the same heat loss as the other piping to be controlled. Then, regardless of flow conditions, all sections will be heated. All sections that have static flow conditions at the same time will have the proper amount of heat required as the ambient temperature varies. Pipe sections that have flow may be heated unnecessarily. The merits of the dead-leg approach lie mainly in the trade-off in energy savings against savings on initial costs. Caution should be exercised when using this technique with temperature sensitive products.

Care should be taken that, first, the dead-leg section for control is long enough so that its temperature is not affected by flow in the adjoining piping, and, second, that the temperature sensor is located on the portion that is thermally independent of flow conditions.

4.6 Special design considerations

4.6.1 General

Special design conditions may exist for some applications. Subclauses 4.6.2 to 4.6.5 describe these possible conditions for freeze protection systems, sprinkler systems for fire suppression, hot water systems and specialty lines.

4.6.2 Freeze protection systems

The following considerations may apply to freeze protection systems.

a) In applications where the trace heater is located in a channel, the limiting channel temperature should be specified, and the designer should account for potential higher sheath temperatures. PTC trace heaters typically exhibit a lower output under these conditions.
b) If energy conservation is a concern, ambient proportioning or line sensing controllers are recommended for relatively large pipe sizes (~150 mm and larger) and for locations that are at, or near, freezing for weeks at a time.

4.6.3 Sprinkler systems, fire suppression

There are both wet and dry type fire suppression sprinkler systems. The wet type utilizes water-filled piping, while the dry type has a control valve that floods the branch piping when a sprinkler head or other sensor is activated.

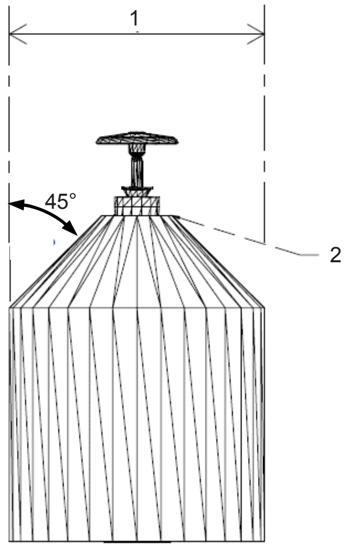
Wet systems are simple and reliable but may not be allowed for fire suppression systems in some areas subject to freezing conditions. Therefore, dry systems are often specified for areas subject to freezing, but these can have problems with reliability. In particular, control valves may leak causing the system to flood or freeze, or may not open after remaining closed for an extended period of time. In addition, pipe scale can create a maintenance nuisance, and a system that has been activated should be completely dried out before being reset.

Trace heating systems can be used to protect wet systems in areas with occasional freezing temperatures, and in areas where dry systems are typically used. The systems typically include a monitoring function for trace heater operation, a failsafe temperature control, and means to prevent overheating of the trace heater and piping system.

Multiple pipe segments may be controlled by a single controller since the system is non-flowing.

The following lists some of the design considerations for trace heating systems for these applications.

a) System will normally be non-flowing.
b) Multiple pipe segments may be controlled by a single controller using ambient control.
c) System installation details shall specify trace heating installation on branch lines with sprinkler heads.
d) System installation details shall specify thermal insulation thickness to balance the heat loss of the system and power output of the trace heating.
e) Sprigs are typically 25 mm diameter with 20 mm thick thermal insulation. The insulation may be oversized to accommodate the heating cable installation, resulting in no greater than 75 mm installed outer diameter (e.g. 25 mm diameter sprig, insulated with 34 mm inside diameter, 20 mm thick insulation, OD = 74 mm).
f) System installation details of upright sprinkler systems shall specify sprig height and/or arm-over distance to overcome spray pattern obstruction.
g) For upright sprinklers only, the sprinkler heads shall be insulated up to the top of the reducing bushing with a taper of 45° to avoid spray pattern obstruction, as detailed in Figure 7.
h) Products shall be certified for fire suppression system supply piping only or for branch and supply lines.
i) The product ratings shall include the minimum sprinkler temperature rating that is suitable for use with the trace heating system.
j) A low-temperature alarm, with contacts for a remote alarm, shall be provided for each fire sprinkler line trace heating circuit. The recommended set-point is 2 °C.
k) High temperature alarm with contacts for a remote alarm shall be provided for each fire sprinkler line trace heating circuit. The recommended set point is between 38 °C and 43 °C.
l) Trace heating systems for fire sprinkler systems shall be permanently connected to the power supply.
m) For fire sprinkler systems, the thermal insulation shall be non-combustible and protected with a sealed exterior non-combustible cover that will maintain its integrity when exposed to water discharge.
n) If a separate high-temperature limit controller is required to de-energize the trace heating, it shall have automatic reset and annunciation.
o) For trace heating systems intended for use with plastic piping in fire sprinkler systems, the manufacturer shall specify plastic piping materials that are intended to be used with the system.



Key

1 45° taper recommended when insulation diameter is greater than 75 mm

2 Insulation is flush with top of reducing fitting

Figure 7 – Fire sprinkler sprig: tapered thermal insulation

4.6.4 Hot water services/tempered water

System design temperatures for hot water systems are indicated in Table 3. The trace heating supplier should verify the operating temperature and the maximum system temperature. If the piping system operates at temperatures in excess of 65 °C or experiences temperatures in excess of 85 °C at start-up, the trace heating supplier should specify the proper trace heater selection.

The trace heater should be selected and the system designed such that the maximum withstand temperatures of all piping materials in contact with the heating system are not exceeded.

Line sensing temperature control is recommended for areas where the ambient temperature variation is greater than 3 °C, where vertical risers extend more than 3 m, and to maintain temperatures of 80 °C or higher.

Table 3 – Recommendations for hot water services and tempered water temperatures

Application	Temperature [a] °C
Safety showers and eyewashes	16 to 35
Hot water service without mixing valves	40
Nursing homes and hospitals	40 and 46
General purpose	49 to 60
Laundry service	71
Kitchen sanitization	82
[a] Consult local codes for specific application temperature requirements.	

For disinfecting, a minimum of 55 °C is typically required for hot water services with mixing valves. It is recommended that the control system be evaluated for reliability, ease of calibration, narrow differential temperature band, and alarm indication.

4.6.5 Safety shower design requirements

The application of heating devices to safety showers and eyewash stations involves unique concerns in addition to the general practices associated with industrial pipe heating applications described in 4.2 through 4.5. Because these are applied as part of overall safety systems for personnel, attention to water temperature and reliability of operation is important. In addition, these applications require more precise temperature control to maintain a narrow range of water temperatures, unlike most pipe heating systems.

Trace heating for emergency eyewash units, safety showers, and associated supply piping shall be correctly designed to prevent freezing or to maintain a tempered water system. For safety of personnel, the water shall not exceed a maximum temperature as determined by local codes or standards (see Table 3). Specific maintenance temperatures may be required for emergency eye wash units and safety showers in some applications. Items to be considered include the following:

a) Prevention of scalding during use requires attention to design factors beyond normal consideration.
b) These same design considerations shall be applied to the supply piping for the stations.
c) It is recommended to minimize or eliminate the safety factor applied to heat loss calculations to limit the possible maximum run away pipe temperature.
d) Tempered water systems should be designed to maintain in the range of 16 °C to 35 °C.
e) Tempered water systems should be capable of supplying 1 135 l to 1 700 l of water and 75 l/min to 114 l/min of water for 15 minutes.
f) Type III pipe temperature controllers are required for tempered water system designs (see Table 2).
g) Type III high-limit temperature control with high-limit alarm are also required (per Table 2).
h) Freeze protection designs may group several similar shower/wash stations and control them with a single ambient controller with Type III control and alarm functions.
i) Recommended monitoring functions include low-temperature alarm, loss-of-voltage alarm, and year-around periodic energisation of the heater to verify circuit integrity.
j) Consider control sensor location to minimize the effects of hot spots in supply piping resulting from long vertical runs and from solar gain in outdoor overhead piping.
k) Long vertical runs or stretches of piping with high solar gain may require the use of separate circuits to prevent wide ranges in water temperature over the entire length of the supply system.
l) Where possible, terminations and controls should be located outside the spray pattern of the shower head.
m) Tempered water designs shall have some method to deal with algae and bacterial growth, typically through periodic flushing or recirculation.
n) In extremely cold climates, consideration has to be given to hypothermia of washed personnel (possible use of an enclosed wash station) and to the prevention of discharged water freezing and creating a hazard in the discharge area.

4.6.6 Specialty lines

NOTE Systems intended for use in explosive atmospheres are covered by IEC 60079-30-1 and IEC 60079-30-2.

The following considerations may be applicable to specialty lines.

a) When necessary, the outermost trace heater jacket or sheath should be resistant to potential exposure to the materials in the piping system.

b) When double containment piping is provided, the trace heater should be applied to the outer surface of the containment pipe under the thermal insulation.

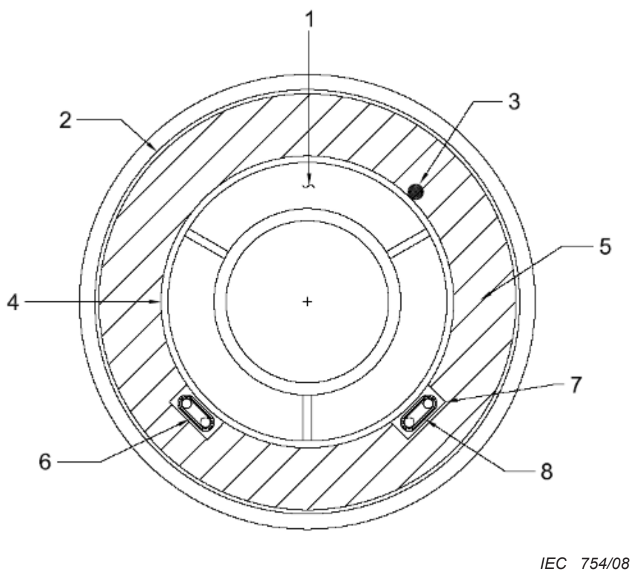
c) When double containment piping is prefabricated/pre-insulated, a channel should be provided on the outer surface of the containment pipe. See Figure 8. The trace heating supplier should specify thermal output and maximum sheath temperature. Splicing should be avoided. If required, it is recommended that splices be made in suitable enclosures and sealed.

d) Line sensing temperature control with the sensor 90º from the trace heater is recommended.

e) For underground pre-insulated pipe, the heat loss is based on the temperature difference between the minimum soil temperature and the maintain temperature.

f) The trace heater should be mounted on the bottom of the piping or culvert for systems that rely on gravity flow. Refer to Figure 9a. Line sensing temperature control with the sensor located 50 mm from the trace heater is recommended.

g) For a similar system with plastic piping, the trace heater watt density should be considered. Two lower wattage trace heaters are often used at four and eight o'clock instead of one trace heater at six o'clock. Refer to Figure 9b. The temperature sensor should be located at the six o'clock position between the trace heaters.



Key

1	Containment (dead air space)	5	Rigid foam insulation
2	Weather barrier	6	Second trace heater (optional)
3	Temperature sensor	7	Channel
4	Containment piping	8	Trace heater

Figure 8 – Double containment system

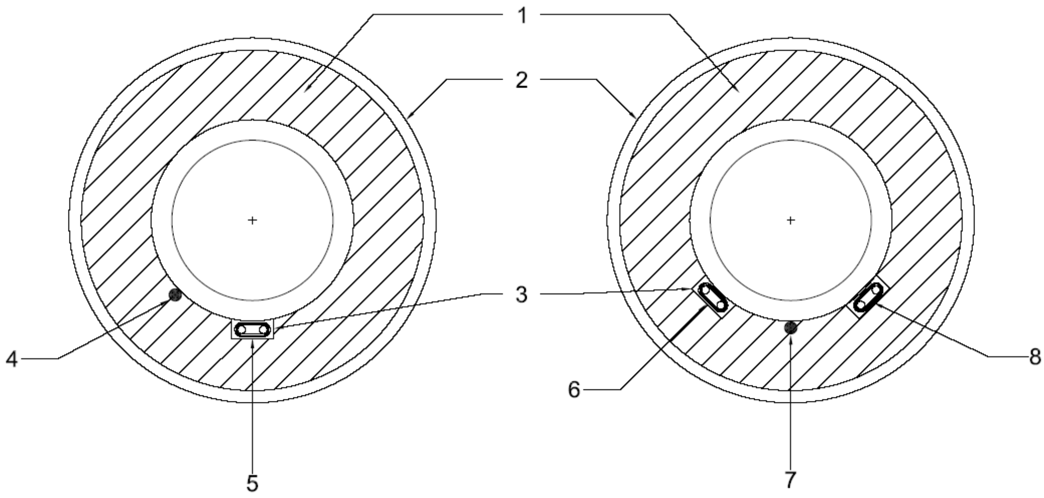


Figure 9a – One trace heater **Figure 9b – Two trace heaters**

Key

1 Rigid foam insulation
2 Outer jacket
3 Channel
4 Temperature sensor
5 Trace heater at 6 o'clock
6 Second trace heater at 8 o'clock
7 Temperature sensor
8 First trace heater at 4 o'clock

Figure 9 – Gravity flow piping systems

4.7 Installation

4.7.1 General

Each electric trace heating system is designed to meet the requirements of the particular application. Because the system comprises a number of components integrated at the site, it is necessary to ensure that the original design parameters are still valid. Correct installation, appropriate testing, and maintenance according to the installation procedures are essential for satisfactory performance and safety. The supplier of the trace heating system should provide specific instructions for the trace heaters and the various types of system components.

Not all of the following procedures are applicable for every installation; consult with the trace heating supplier for specific recommendations. Each aspect of the installation should be checked after completion.

4.7.2 Personnel aspects

Persons involved in the installation and testing of electric trace heating systems should be suitably trained in all the special techniques required. Installation should be carried out under the supervision of a qualified electrician who has undergone supplementary training in electric trace heating systems. Only specially trained personnel shall carry out especially critical work, such as the installation of connections and terminations.

4.7.3 Preparatory work

Installation of the trace heating system should not begin until all piping runs and pieces of equipment have been pressure-tested and all related instrumentation has been installed. The workpiece surface on which the trace heater is to be installed should be free from rust, grease, oil, etc. Any sharp protrusions such as weld splatter, cement splash, etc., should be removed. All coatings or finishes applied to the heated surfaces should be suitable for the intended duty. The installation of the trace heating system should be coordinated with the workpiece, thermal insulation and instrumentation work in order to ensure a scheduled completion date. Scheduling for the installation of thermal insulation should not occur until the electrical trace heating has been completely installed and tested.

The equipment to be traced should be verified such that the length of piping and the number of vessels, valves, flanges and components agree with the design drawings. If a change is made to the equipment to be traced, the schedule of trace heating materials should be reviewed and revised if necessary.

Upon receipt of trace heating components, the correct type and quantities of materials should be checked and documented. In addition, receipt of installation instructions and the certificate of conformity or declaration of conformity from a notified body, as required, should be verified.

Series resistance trace heaters should be checked to ensure that the installed lengths correspond to the design length and loading.

For parallel circuit trace heaters, the total circuit length should not exceed the supplier's recommendations.

Materials should be stored in protected, dry areas. Materials are to be released only as required on the jobsite, so as to avoid any unnecessary handling and inadvertent damage.

4.7.4 Preliminary installation of trace heating circuits

A pre-installation checklist similar to that of Annex A is recommended; the table as shown indicates specific guidelines for the preliminary installation. The following list includes supplementary considerations.

a) Trace heaters and preassembled connections should be visually checked for damage. Continuity and insulation checks should be made as a final check. Insulation resistance should be measured in accordance with 4.7.5.
b) Individual controls should be tested to ensure correct calibration, and correct operation regarding set points, operating temperature range, and temperature span.
c) Vendor fabricated and assembled control panels should include documentation certifying that all wiring, layout and functions are correct and that they have been tested. Upon receipt of the control panels at the work site, a general inspection should be made to confirm that no damage has occurred in transit.

4.7.5 Insulation resistance test

Insulation resistance shall be measured from trace heater conductors to the metallic covering with a minimum 500 V d.c. test voltage. However, it is recommended that higher test voltages be used; mineral insulated trace heaters should be tested at (but not exceeding) 1 000 V d.c., and polymeric insulated trace heaters should be tested at 2 500 V d.c. Prior to installation, the measured insulation resistance shall not be less than 20 MΩ.

4.7.6 Installation of trace heater systems

4.7.6.1 General

Trace heaters should be attached in accordance with the supplier's instructions, in a manner to avoid damage due to impact, abrasion or vibration. Special care should be taken at flanges, valves and other fittings to orient trace heaters to avoid damage from sharp or jagged surfaces. The installation should include sufficient material to accommodate movement and vibration of the piping and equipment.

The installer should understand the importance of the tracing system to provide uniform heating of the piping and other equipment, noting that equipment with greater surface area or heat sinks require additional tracing. Trace heaters should be installed to provide as intimate a contact as is reasonably possible to the surface to be heated. Where such contact is not possible, such as on valves, a suitable heat-conductive covering of temperature rated metal foil or other heat-conducting materials may be used.

The trace heater should not be folded, twisted, or allowed to overlap, cross or touch itself unless this is specifically permitted in the instructions. Attention should be given to the minimum bending radius as stated in the manufacturer’s instructions.

In the installation of trace heating systems, only certified components may be used. Otherwise, the system certification will not apply.

4.7.6.2 Installation of trace heaters

Typically trace heaters are installed on a one to one basis, (e.g. with one meter of trace heater to one meter of pipe). When the design calls for multiple passes of trace heaters, the trace heaters should be equally spaced around the circumference of the pipe. Additional lengths of trace heater should be provided to compensate for the additional heat losses at pipe supports, hangers, anchors, etc.

While straight runs are preferred for ease of installation and maintenance, spiral tracing may be specified in certain situations. Spiral pitch marking should be made on the pipe and equipment before applying the trace heater in a uniform spiral, starting at the power supply point and maintaining slight tension in the trace heater as it is applied. In no circumstances should the spacing be less than the minimum declared by the supplier.

Spiral tracing runs should be applied in such a way that valves, etc., can be easily removed or replaced. If excess or insufficient trace heater exists at the end of the section to be heated, the spiral pitch should be shortened or lengthened to retain a uniform spiral generally in accordance with the design.

Additional lengths of trace heater should be allowed in the design to compensate for the additional heat losses at valves, flanges, strainers, pumps, etc. These lengths should be applied in accordance with the supplier’s instructions including any necessary allowances, such as those for spiral or multiple pass tracing.

Trace heating should be installed in such a way that it can be removed to allow replacement of seals and servicing of the inline equipment without damage. Where trace heaters cross possible sources of leaks, for example, flanges, they should be positioned to minimize their contact with such sources.

Fixing materials should be suitable for the maximum exposure temperature and the environmental conditions. For straight tracing runs, they should be located at intervals not exceeding 300 mm, and for spiral tracing runs, not exceeding 2 000 mm. Additional fixings should be applied at bends, flanges and other obstructions. Metal bands should only be used to fix solid metal sheath trace heaters to piping and equipment, and tightened to maintain contact with the surface to be heated. Over-tightening may damage the trace heater.

For non-metallic pipes, the trace heater may be covered continuously with aluminium tape along the entire trace heater length to enhance thermal coupling to the pipe.

The test procedure from 4.7.5 shall be conducted on all trace heaters after installation.

4.7.6.3 Installation of connections and terminations

Junction boxes should have suitable ingress protection and should be located as closely as possible to the trace heater exit point while allowing for any pipe expansion. Junction box lids should not be left open at any time. The boxes should be mounted in such a way that the trace heater cannot suffer damage between the point at which it emerges from the insulation and the point of entry into the junction box. Unused entries on junction boxes shall be blanked off with suitable plugs.

The connection kits and end terminations should be securely fitted in accordance with the supplier's instructions, protected to prevent physical damage, and positioned to prevent the ingress of water or other contaminants that could adversely affect their use or suitability. Factory terminated equipment should be inspected to ensure that such terminations are complete, properly tagged and/or marked in conformity to Clause 6 in IEC 62395-1:2013. It is important for the installer to verify that temperature ratings of the connections and terminations are suitable for the operating conditions.

When mineral insulated trace heaters are terminated at the job site, the cut ends should be sealed immediately to prevent any moisture ingress. Installation shall be made in accordance with the trace heater supplier's documentation.

If provided, seals and/or cable glands shall be certified. Glands shall be installed according to the instructions required by the certification.

Trace heaters that have been installed and not terminated shall be sealed to prevent ingress of moisture and protected from damage pending completion of the termination.

The test procedure from 4.7.5 shall be conducted on completed trace heating circuits prior to making the final connection to the incoming power conductors.

4.7.6.4 Jointing, splicing and modifications

Jointing, splicing and modifications to the trace heater should be carried out on site only when specified by the trace heater supplier and then only in strict accordance with the supplier's instructions. This applies particularly to any modifications to trace heaters where any change in unit length would alter the power density of the trace heater and affect the sheath temperature. Modifications should be recorded in the system documentation.

4.7.6.5 Earthing requirements

Any metallic covering shall be bonded to the earthing system. If intended to provide a ground path, the connections shall be suitable to carry the required fault current. The chemical resistance of the metallic covering shall be considered if exposure to corrosive vapours or liquids might occur.

High electrical resistance materials, such as stainless steel braids and sheaths, may not provide effective ground paths. Consideration should be given to alternative grounding means or supplemental grounding protection.

4.7.6.6 Conductor terminations

Terminals shall be of sufficient size and rating to accept the conductors, which may be solid or stranded wires or foils. Care should be taken in stripping back insulation to avoid damaging the conductors.

Compression-type connectors or ferrules shall be of the correct size and of an approved type for the conductor concerned. Compression tools should be suitable for the specific types of fittings and be in good condition.

4.7.6.7 Preparation of documentation

The type, length and electrical data of each trace heater circuit should be recorded in the final documentation. The connection points should be recorded in the documentation.

4.7.7 Installation of control and monitoring equipment

4.7.7.1 General

The installer is usually responsible for installing the control and monitoring and distribution panels. These provide, as a minimum, over-current and earth-leakage protection as well as a means of isolation. Some form of temperature control or limitation is usually provided to ensure safe temperatures or for energy efficiency purposes. It is important that the controller is set in such a way that the heater sheath temperature does not exceed the high-limit temperature if applicable.

The selected controllers, thermostats, sensors, and related devices shall meet the requirements of the overall system with regard to the service temperature, the IP rating, and local and national codes. The certification of trace heating systems may prescribe the use of specific components. In these cases, it is mandatory to use only parts specified by the trace heating supplier.

The sensors of temperature controllers measure the surface of the workpiece or the media temperature directly. Where sensors are mounted on surfaces, effective thermal coupling is essential. The diameter and length of the sensors can affect the temperature measurement.

Water and corrosive vapour intrusion can cause failure of temperature controllers. The controller housing should always be closed, except when required for access.

4.7.7.2 Sensor considerations

The sensor should be installed and positioned in accordance with the supplier’s instructions, in a location that provides a temperature representative of the overall circuit. The location should be away from obvious heat sinks such as pipe supports and hangers. The control sensor should be positioned so as not to be influenced by the temperature of the trace heater, and not situated in areas of external radiant heat, solar gain, process heat discharge or close to a heated building. Ambient temperature-sensing controllers should be sited in the most exposed position for the installation.

The sensor should be strapped with a good thermal contact with the pipe or equipment and protected so that thermal insulation cannot be trapped between the sensor and the heated surface. Care should be taken not to damage the capillary tube, thermocouple or RTD leads, or to distort the sensor and thereby cause calibration error. The leads are typically run under the thermal insulation, but care should be taken to ensure that they emerge from the insulation in a manner that does not allow the ingress of moisture.

Where direct media temperature sensing is required, the sensor should be located in thermowells at suitable positions, for example, above potential sludge levels in vessels.

For line sensing control on non-metallic pipes, the sensor should be placed 25 mm to 50 mm away from the trace heater and fastened to the pipe with aluminium tape. The aluminium tape should not create a thermal path from the trace heater to the sensor.

4.7.7.3 Controller operation, calibration, and access

The settings of the temperature controllers and safety temperature limiters should be reviewed during commissioning. Depending on the setting possibilities offered by the safety temperature limiters, it is recommended that the limiters be sealed against tampering.

The temperature controller and sensor loop should be calibrated at commissioning if there is indication of a problem (e.g. damage or unusual readings). The controller should be set to the required temperature and re-calibrated from the factory setting if necessary. A function check should be made by adjusting the temperature setting until the controller is seen to energize the trace heater. All measured data should be documented.

4.7.8 Necessary modifications

It may be advisable to verify the surface temperatures of the workpiece to the prescribed designs. If the temperatures measured deviate from the admissible surface temperatures or from the design figures, corrective measures should be taken and the system modified if necessary.

4.7.9 Installation of the thermal insulation system

4.7.9.1 General

Installation of thermal insulation should conform to all applicable national standards and local regulations. It is imperative that the thermal insulation is applied as soon as possible after the installation and testing of trace heaters. The following checks and procedures should be confirmed.

a) Verification should be made that the type, inside diameter and thickness agree with the values used in selection of the trace heaters. If the insulation thickness differs from the specification, it may not be possible to maintain either the design, operating or surface temperature.
b) Temporary weather protection should be provided during storage, handling and installation to avoid the risk of moisture being trapped in the thermal insulation beneath its final weather-protective coating or jacket.

4.7.9.2 Installation of the thermal insulation materials

Thermal insulation should be applied to all sections of the pipe and equipment, including flanges, valves, pipe supports, bends, T-junctions, etc. If expansion joints or bellows are installed in the system, provision should be made for their thermal insulation in such a manner that it does not impair the thermal efficiency of the trace heating system.

Oversized thermal insulation may be required in order to ensure that the trace heater and equipment are adequately covered. Other considerations include the following:

a) It is necessary to maintain adequate distances between the pipes and between pipes and parts of the structure in order to permit installation of the thermal insulation.
b) It is essential to verify that the insulation thickness equals the specified nominal thickness at all points. Care should be taken not to embed the trace heater in the insulation, because this could cause an increase in sheath temperature. If the specified insulation size does not fit correctly, the next greater insulation thickness can be used in order to accommodate the trace heater.
c) All penetrations should be sealed to prevent the ingress of moisture. Wherever possible, cut-outs should be prepared in advance and should be in the lower 180° segment of the thermal insulation. The thermal insulation should be applied in such a way that permits absolutely tight entry of the trace heaters and thermal sensors or capillary tubes.
d) The thermal insulation should be cut and tightly fitted to avoid air gaps. Segment joints should be staggered on the horizontal plane to minimize convective heat loss.
e) During application of the insulation, care shall be taken not to damage the electric trace heaters. The positions of trace heaters, temperature sensors and other devices should not be altered.
f) The use of metal foil should be considered for covering the trace heater on valves and other irregularly shaped equipment to prevent the thermal insulation from surrounding the trace heater.
g) Care should be taken to avoid high halide content thermal insulation materials over trace heaters with an exposed stainless steel sheath or braid.

4.7.9.3 Cladding

Where metal cladding is specified, particular care should be taken to ensure that bare edges of metalwork do not come into direct contact with the trace heater or its components.

Areas of greatest risk are as follows:

a) Flanges: metalwork should be cut back and the exposed face of the thermal insulation finished with a suitable non-absorbent compound.
b) Valves: a preformed insulating jacket should be cut over-length and carried on to adjacent pipework cladding.
c) Pipe bends, elbows or tees: care should be taken not to force the adjacent straight pipe section of cladding into the bend and thereby risk damage to the trace heater.

Bends with rolled edge interlocking sections are preferred. A non-hardening sealer should be used between the overlapped sections of metallic weather barriers of jackets. Where rivets or self-tapping screws are used, care should be taken to ensure that any drill or screw selected for use is not long enough to penetrate the thickness of the thermal insulation and damage the underlying trace heater.

Warning labels should be affixed to the cladding at intervals not to exceed 6 m to advise that an electric trace heating system is installed beneath the thermal insulation. These labels should also be placed on the cladding over each valve or other piece of equipment that may require periodic maintenance.

4.7.9.4 Field (site work) circuit insulation resistance test

The test procedure from 4.7.5 shall be conducted on all trace heater circuits after installation, with the requirement that the measured insulation resistance shall not be less than 5 MΩ.

4.7.9.5 Visual inspection

The visual inspection should ensure that

a) no moisture can penetrate the insulation as a result of weathering (correct position of overlaps or lock beading);
b) sliding connections (or the like) on weather cladding are sufficiently flexible to absorb any expansion movement;
c) the screws selected for fastening the weather cladding are short enough to exclude any possibility of damage to trace heaters or to temperature sensors;
d) the entry cut-outs in the weather cladding for trace heaters, temperature sensors, etc., are dimensioned so as to render contact impossible. Especially in the case of branches, the cladding should be cut sufficiently wide;
e) the cladding joints and thermal insulation entries are properly sealed with an elastic, non-hardening sealant that is resistant to chemical attack and decay, and is dimensionally stable.

4.7.9.6 Documentation

The thermal insulation and cladding material, size, and thickness should be documented.

4.7.10 Installation of electrical power

System electrical connections and connection to electrical distribution equipment shall be made by trained individuals (electricians for large installations) in accordance with the material supplier’s instructions and applicable local and national codes.

Permanent tagging and identification shall be completed as follows and verified for compliance with the marking requirements of IEC 62395-1:2013:

a) branch circuit breaker;
b) monitor and alarm apparatus;
c) trace heater power connection;
d) circuit number and set point for each temperature controller.

Marking shall be carried out in accordance with IEC 62395-1:2013 for each trace heating circuit on the respective junction box.

4.7.11 Commissioning

4.7.11.1 General

The trace heating system should be commissioned after the thermal insulation has been installed and the electrical distribution is completed. This should include functional checks and updating of documentation as described in 4.7.11.2 and 4.7.11.3. The trace heater commissioning record given in Annex B should be completed and retained.

4.7.11.2 Functional check

The following procedure should be adopted:

a) Close all branch circuits and verify proper current. A temporary bypass may be required for the temperature control device.
b) Verify that monitor or alarm circuits operate as intended. A bypass may be required at field contacts.
c) Fill out the trace heater commissioning record (Annex B) for each circuit. This should clearly document all testing and commissioning data.
d) Record the electrical insulation resistance values for each measurement taken according to the procedure given in 4.7.9.4.
e) Record the applied voltage and current as specified by the manufacturer.
f) Verify that the calibration check at the temperature controller set-point has been performed and the controller has been set at the correct value.

4.7.11.3 Final documentation

Adequate and uniform documentation of the electric trace heating circuits is an essential precondition for economical maintenance of this equipment. This is especially important to facilitate rapid troubleshooting in the event of circuit problems. It also provides the basis for simpler, faster and less costly handling of any desired modifications and expansions by a specialist for the electric trace heating systems.

The documentation of each heating circuit of a trace heating system should include the following elements.

- Design and testing documentation for the installed system:
  a) table of contents;
  b) piping diagram showing the trace heating circuits and the location of power points, connections, splices, tees, end terminations, and temperature sensors for control and limitation;
  c) for vessels: layout of the trace heating;
  d) pipe and insulation list;
  e) individual circuit length of trace heaters;
  f) calculation and dimensioning data;

g) material list;
h) trace heater installation instructions;
i) description of and installation instructions for temperature sensors;
j) heater commissioning record (Annex B);
k) temperature profile measurement;
l) installation certificate.

- Circuit diagrams:

m) wiring and circuit diagram;
n) terminal connection diagrams;
o) switchgear with parts list;
p) installation instructions.

- Other:

q) technical descriptions and instruction manuals for the individual pieces of equipment;
r) functional diagram as agreed to with the design engineer;
s) certificates or declarations of conformity from a certification agency, as required.

4.8 Maintenance

4.8.1 General

It is necessary to provide for a routine maintenance program for inspection, recording of the condition, and the repair as required. Significant aspects of an adequate maintenance program include establishing a suitable frequency of inspection, documenting all maintenance operations, and conducting visual inspections, periodic operational checks, and reviews of the electrical protection system.

Not all of the following procedures are applicable for every installation, depending on the complexity of the application.

4.8.2 Training of maintenance personnel

Individuals involved in the inspection and maintenance of trace heating systems should be provided with sufficient training to enable familiarity with the specific types of trace heating installations that they attend. This training shall include any associated apparatus and operational and environment conditions that relate to the system installation. When any alterations or changes to the maintenance methods are affected, the necessary information shall be provided to the skilled personnel in a manner that supports their function.

Where necessary, training in the maintenance concepts should be provided together with refresher or reinforcement seminars.

Training records shall be kept with plant operation documentation.

4.8.3 Frequency of inspection

The frequency of the inspections is a function of the specific location, the type of trace heating system, and the criticality of the application. When electrical trace heating is used for freeze protection, the inspection should occur prior to the winter season. Type II systems should be inspected at least annually, and Type III systems semi-annually or more frequently as required.

4.8.4 Maintenance program documentation

Maintenance program documentation should provide sufficient information to

a) provide a history of maintenance activities with the reason for each system modification, and
b) verify the effectiveness of the frequency of inspection.

Records should be maintained on log sheets, such as the form provided in Annex C.

4.8.5 Visual evaluation

The system should be visually examined for possible damage, by inspecting the exposed components of the trace heating system. Specific areas to be reviewed include:

a) cable entries;
b) junction boxes;
c) exposed trace heating and electrical cables;
d) seal fittings at each affected power connection, tee, splice, and end termination;
e) proper tightness (torque) of electrical connections;
f) absence of moisture and proper sealing of thermostats and control cabinets;
g) thermal insulation and weather barrier;
h) indications of overheating;
i) presence of leaks, corrosion, and foreign matter.

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

4.8.6 Electrical evaluation

All circuits and controls should be checked for proper operation during inspections. Each circuit should be checked for normal current and properly applied voltage. Earth-fault equipment protective devices should be tested at least once per year with the trace heating system energized. When the trace heating is used for critical process control, operational checks should be carried out on a more frequent basis.

The electrical insulation resistance and trace heater continuity should be checked after any mechanical maintenance has been performed on pipelines, vessels, or equipment that has been heat traced. After the trace heater or total system is completely isolated from the electrical supply, insulation resistance should be measured from the trace heater conductors to the metallic covering with a minimum 500 V d.c. test voltage. The measured insulation resistance shall not be less than 20 MΩ.

For Type III applications, the trace heater performance should be verified by measuring the current draw for each circuit at 2 min to 5 min after energization and at 15 min after energization. This value should be recorded along with the local pipe temperature. If possible, the measured value should be compared to the trace heating supplier's output rating at the measured pipe temperature.

Discrepancies in measured values to prescribed values should be resolved.

4.8.7 Review of the electrical protection system

The inspections should include all connections to earthing systems, to verify that the connections are tight and have not corroded. During the periodic operational checks, the integrity of the earthing should be checked by measurement of resistance.

All controls (thermostats, indicating lights, meters, controllers, etc.) should be checked for proper operation and indication. It is necessary to check that protective devices are set as originally specified. All control devices (thermostats, indicating lights, meters, controllers, etc.), controller set points, system alarm limits, and proper operation of the controller should be checked according to the specification of the trace heating supplier.

4.9 Repair

4.9.1 General

After the cause of a circuit fault has been determined, the defects should be rectified by site repair or replacement. Site repair should be carried out only if the following conditions are satisfied.

a) Design and construction characteristics of the trace heater are maintained, for example, mechanical strength and water resistance.

b) A method of repair is recommended in the trace heating system documentation recognizing any special materials and tools.

c) No local hazards are created in carrying out the repair.

d) It does not invalidate the certificate for certified apparatus. Any repairs to certified apparatus shall be strictly in accordance with specific instructions incorporated in the certificate schedule.

4.9.2 Fault location

Specialized methods of fault location are necessary for electric trace heating systems covered by thermal insulation and metallic cladding, and advice should be sought from the electric trace heating system supplier. Faults may be characterized by mechanical damage, corrosion, overheating, or ingress of moisture.

Possible steps include the following.

a) The exact layout of the trace heating circuit can be determined from the system documentation. In addition, an "induction" instrument operating at approximately 1 000 Hz can be used to inject a signal into the electric trace heating device and the route of the device should be followed by the audible signal obtained from the instrument.

b) The type of fault should be determined, for instance, open-circuit or leakage-to-earth.

c) If there is an open circuit or low resistance to earth of less than approximately 500 Ω, a pulse echo or reflection instrument can be used with a considerable degree of success. Other faults may be located using a resistance bridge-type instrument.

4.9.3 Practicability of repair to electric trace heaters

If a trace heater has not previously been energized and mechanical damage has resulted in breakdown in electrical insulation, severed conductors or ingress of moisture, repair should normally be possible.

If the fault is found only after electrical connection and the damage is confined to a small area, visual inspection of the trace heater for 1 m on either side of the fault should be undertaken to show whether the electrical insulation is affected other than at the point of mechanical damage.

If a fault is caused by corrosive action and the damage is limited to a small area, a repair should normally be possible. However, if the electrical trace heater has been damaged at more than one point or the damaged area is extensive, the entire circuit should be replaced.

If a fault is caused by localized overheating, then repairs should be carried out only when damage is limited to a small area. Prolonged high current faults may require that the entire circuit should be replaced. If a system design fault is suspected, an evaluation of the trace heater system should be conducted.

4.9.4 Repair techniques for electrical trace heaters

Repairs can generally be made by the use of in-line splices or junction box connections as an alternative to complete circuit replacement. General procedures for repair are given in this subclause (4.9.4), but only the specific methods, materials, and tools specified by the supplier should be used.

The removal of a damaged section of trace heater should not significantly alter the performance of the trace heater from its original design characteristics. Care should be taken to ensure that an in-line splice is not subjected to stresses in operation. This may be achieved, for example, by providing an expansion loop on either side of the joint. The section 150 mm on either side of the joint should not be bent when re-applied to the workpiece and good contact should be ensured. The trace heater and repair joints should be firmly reaffixed to the workpiece to ensure good contact.

If a junction box connection is used, then the fitting of cold leads and connections into the junction box should be in accordance with the supplier's instructions.

Where trace heaters are earthed by means of a metal braid, metal sheath or foil screen, the integrity and continuity of the earth should not be impaired by the repair.

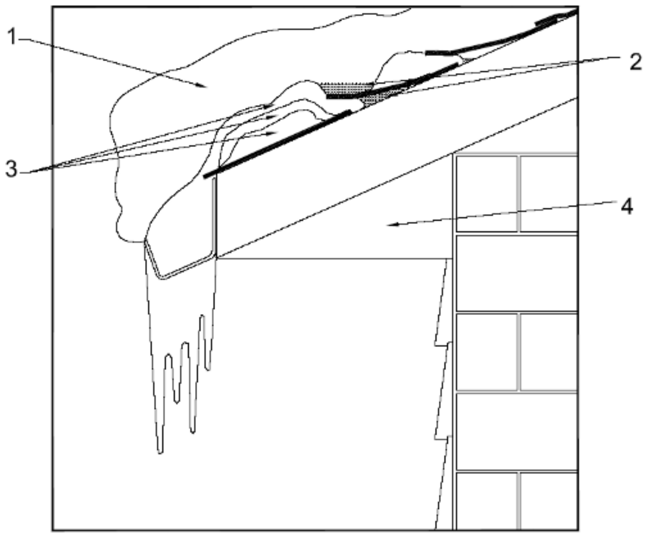
The repaired trace heater(s) should be subjected to the test described in 4.7.5 before re-installation, and the repair information should be recorded with the documentation for the circuit.

5 Roof and gutter de-icing

5.1 Application description

Roof and gutter de-icing systems maintain flow paths in gutters, downspouts and drains and prevent ice build-up (see Figure 10).

Trace heaters intended for these applications shall meet the additional requirements of 5.3 of IEC 62395-1:2013.



IEC 756/08

Key

1 Snow
2 Water build-up
3 Layered ice dam
4 Soffit

Figure 10 – Ice dam formation

5.2 Design information – General

Consideration should be given to the following points when designing a system.

a) Trace heaters and their components should be UV-resistant.

b) Splices should be avoided where possible.

c) A design typically has 1 m of trace heater per 1 m length of gutter. For gutters greater than 150 mm wide, multiple runs of trace heater are recommended.

d) Heating to downspouts is provided by loops, i.e., double-traced, extending beyond the frost line if incorporated into the drainage system (see Figure 11).

e) End terminations should be positioned so as to minimize exposure to moisture.

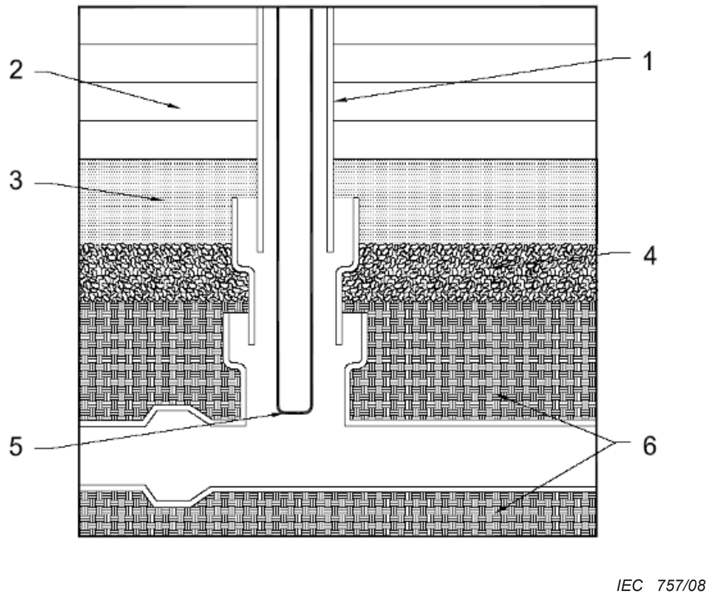
f) The manufacturer’s maximum circuit lengths should not be exceeded.

g) The manufacturer’s attachment devices for trace heater support should be used (see Figures 12, 13 and 14).

h) Trace heaters are typically rated at 15 W/m for plastic gutters/drains and up to 65 W/m for metallic systems. Self-regulating tracers are recommended where multiple tracing runs are to be installed.

i) Appropriate quantities of trace heater should be provided for eaves, valleys, and overhangs.

j) Schematic drawings should be created for each heating circuit.



Key

1 Downspout
2 Siding
3 Sand
4 Gravel
5 Trace heater loop
6 Earth

Figure 11 – Downspout to underground drain

5.3 Thermal design

The heating load required to prevent ice build-up is influenced by a combination of the geometric and dimensional characteristics of the roof and gutter system and the local weather conditions.

5.4 Electrical design

Each trace heater or trace heater branch circuit shall be provided with earth-fault protection capable of interrupting high-impedance earth faults. This may be by a earth-fault protective device having a nominal 30 mA trip rating or by a controller having both earth-fault and overload circuit protection capability. For trace heater circuits having higher leakage current, the trip level for adjustable devices should typically be set at 30 mA above the inherent capacitive leakage characteristic of the trace heater as specified by its manufacturer.

Where uninterrupted circuit operation is necessary for the safe operation of the building, equipment or processes, earth-fault detection without interruption is acceptable if alarmed in a manner to ensure an acknowledged response.

5.5 Control and monitoring system design

It is recommended that the minimum level of control for a roof and gutter de-icing system should include an ambient temperature switch (typically set to energize the system when the air temperature falls below 5 ºC) or a moisture sensing switch.

For energy conservation, both ambient and moisture sensing systems are recommended. This more sophisticated control approach is also recommended for the larger, more complex applications.

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

5.6 Special design considerations

The following special design considerations may apply when designing a roof and gutter de-icing system.

a) The trace heater should be selected and the system designed in such a way that the maximum withstand temperature of all roof and gutter materials in contact with the heating system is not exceeded.
b) The designer should specify the heating requirements for applying heat to a soffit to provide overhang de-icing.
c) Where roof drains lead into a heated area, a loop of trace heater should be installed to a typical depth of 1 m. If the drain passes through an unheated area, the loop should extend through the unheated area. (See Figure 15.)
d) For catch basins, additional trace heating should be specified to ensure adequate drainage.
e) A roof or gutter application that is not specifically mentioned in this standard should be referred to a trace heating designer.

5.7 Installation

5.7.1 General

Prior to installation, it should be verified that the trace heater supplied is in accordance with the design. The layout of the trace heaters on roofs is similar regardless of the roofing material (tile, slate, etc.). The following general procedures are recommended:

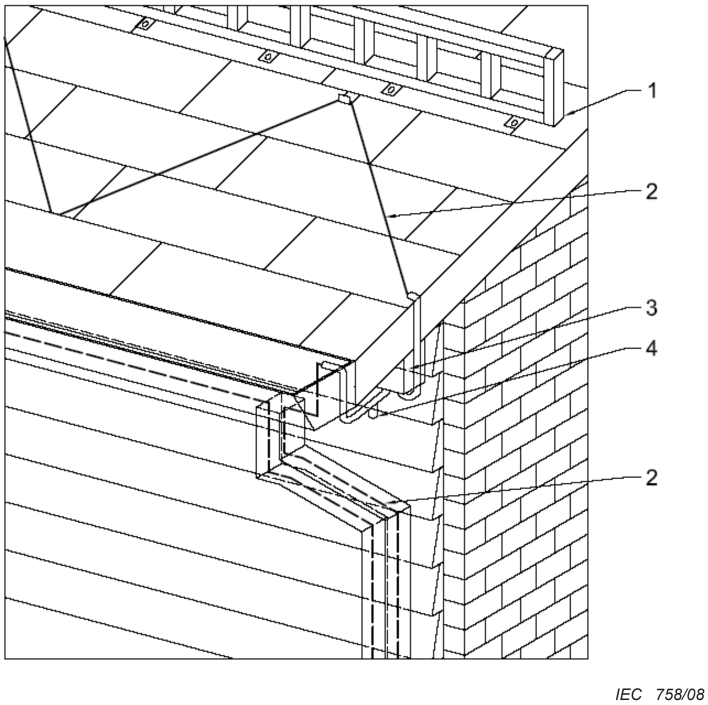
a) The workpiece should be cleared of debris.
b) A weatherproof power connection should be used.
c) The trace heater installation should begin at the power connection and be routed as shown on the designer's drawings.
d) An insulation resistance test should be conducted and the results should be recorded using a test voltage of at least 500 V d.c. However, for mineral insulated trace heaters, a maximum test voltage of 1 000 V d.c. is recommended, and for polymer-insulated trace heaters, 2 500 V d.c. is recommended. The measured value should not be less than 20 MΩ.

5.7.2 Trace heaters and component mounting

Fixing methods may vary according to the particular application. The designer or system supplier should specify the clip or bracket mounting techniques appropriate for particular types of roof and gutter applications.

In general:

a) terminate and install all trace heaters according to the manufacturer's instructions;
b) when possible, all power connections should be made in a protected location (such as under eaves). Entries should be at the bottom of a connection box and a drip loop should be provided (see Figure 12);
c) an ice/snow fence may be required above the trace heating system to prevent ice or snow slides;
d) circuit details as installed should be recorded, and as-built drawings and data should be supplied to the user;
e) all penetrations of the surface of the roof should be moisture proofed with a suitable sealant or sealing method. The trace heating installation should not affect the integrity of the roof or gutter;
f) mounting hardware should be corrosion-resistant and should not have sharp edges or burrs that could damage the trace heater.



Key

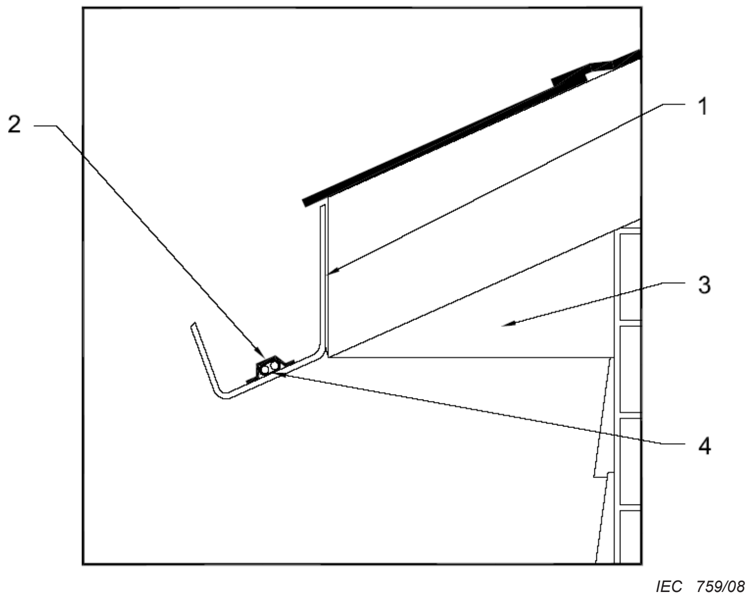
1 Snow guard

2 Trace heater

3 Junction box

4 Low point drain or drip loop

Figure 12 – Roof and gutter trace heater arrangement



Key

1 Gutter

2 Aluminium tape or clip

3 Soffit

4 Trace heater

Figure 13 – Gutter detail

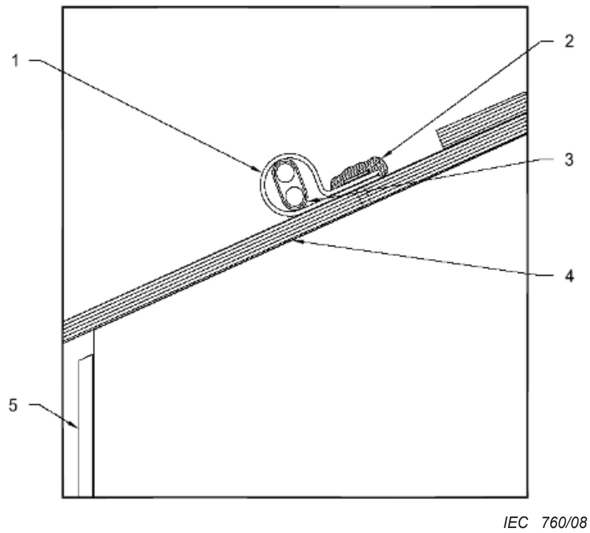


Figure 14a – Asphalt shake shingle roof

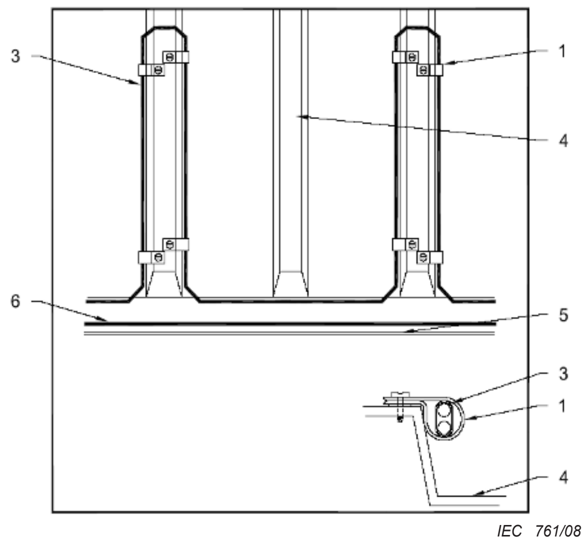


Figure 14b – Metal roof

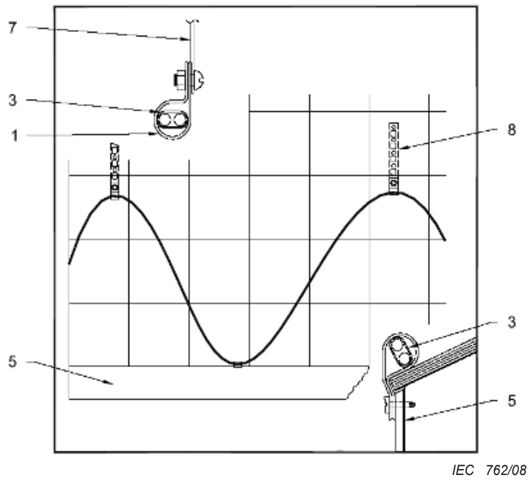


Figure 14c – Tile roof

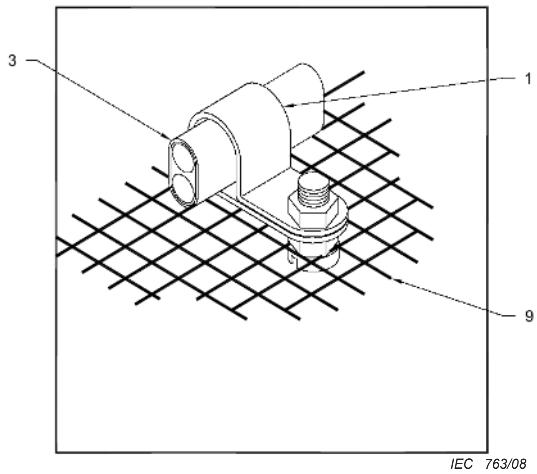
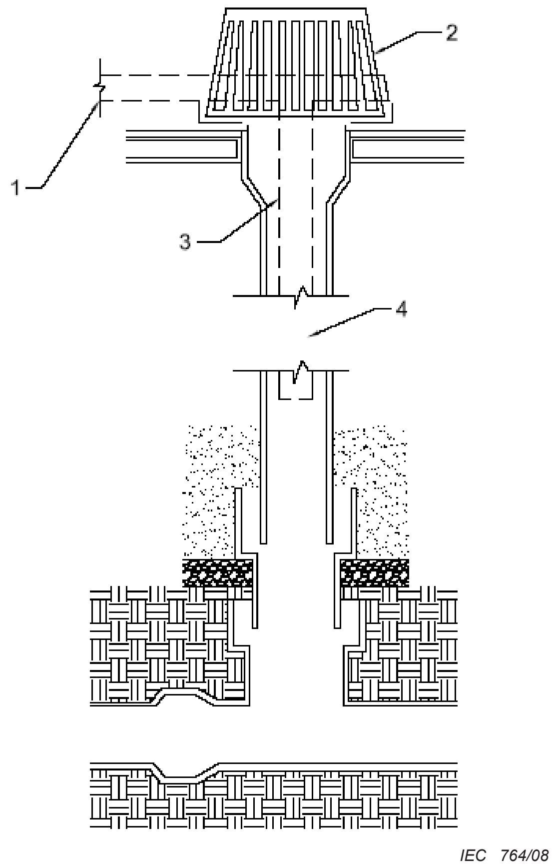


Figure 14d – Flat roof

Key

1 Clip
2 Sealant
3 Trace heater
4 Roof
5 Gutter
6 Trace heater in bottom of gutter
7 Strapping
8 Peg under tile
9 Clip adhered to flat roof surface and attached to any grid covering gutter

Figure 14 – Typical roof mounting methods



Key

1 Power connection and end seal terminate in junction box
2 Drain
3 Trace heater
4 Uninsulated attic space

Figure 15 – Drain detail for flat roof

5.8 Maintenance

Refer to 4.8. In addition, the clearing of debris from gutters and downspouts is recommended at six-monthly intervals.

5.9 Repair

Damage can often be determined by a visual inspection of the trace heaters as they remain exposed during normal operation. Repairs should be carried out according to manufacturer's instructions. It is important that a repaired system should maintain its UV resistance, mechanical properties, and its weatherproof qualities. Where this cannot be guaranteed, then replacement is recommended.

The requirements of 4.9 should be observed as appropriate.

6 Rail heating

6.1 Application description

6.1.1 General

Trace heating is often provided on rail systems to improve traction during adverse weather conditions, to allow correct operation of mechanical systems during freezing conditions and to allow electrical contact on applicable systems that can be disrupted by snow and ice accumulations.

6.1.2 Switch point heating

Junctions in trackwork where lines diverge or converge are referred to as turnouts, points, and switches. Electric point trace heating at switch points ensure that they and their associated mechanisms operate satisfactorily during adverse weather conditions.

An effective electric point heating installation shall ensure that, during freezing precipitation conditions:

a) the switch rail does not freeze or stick to the stock rail or its supports/slide plates;
b) the points and/or swing nose crossing operate correctly by preventing ice accumulation on the rail support or between the switch and stock rails.

A point heating system includes several specific locations where heating is needed for correct operation during freezing precipitation conditions. These are as follows.

1) Stretcher bar (Gauge bar)

   Stretcher bars and the area immediately below should be heated to eliminate the build-up of any snow and/or ice that could restrict movement of the switch rail mechanism.

2) Clamp lock

   Clamp lock trace heaters may be fitted inside the clamp lock, by the clamp lock manufacturer, to prevent operational faults due to freezing conditions.

3) Swing nose crossing

   On switches and turnouts, this is the point at which two rails cross over each other. The area on either side of the moving tongue of the crossing is heated to prevent snow and ice accumulation and to prevent the moving rail from freezing to the fixed rail, or its supports/slide plates.

6.1.3 Contact/live rail heating

Where traction power is supplied from a third rail, or live rail, contact between the live rail and the pick-up on the rail vehicle can be adversely affected by the build-up of ice and snow. To prevent this, an electric trace heater system may be fitted to the live rail. The trace heater is often powered by the direct current power supply used for traction power.

6.1.4 Track heating

Track surface heating encompasses such applications as main rail (permanent way), tramways, urban transit systems, monorails and APMs (Automated People Movers). The heating prevents ice and snow accumulation on the entire system or on specific areas such as high speed curves, gradients, acceleration and deceleration areas, monorail guide rails, and train stops. For APMs and similar systems, no slip is allowed between the wheels and the rail, as this can affect the position of the train at docking points. In these cases, heating may also be required on the mechanical/hydraulic braking systems.

6.1.5 Catenary/pantograph shoe heating

Traction power may be supplied from overhead catenary transmission lines in main rail, urban transit and tramway systems. Maintaining an ice-free contact between the transmission lines and the pantograph shoe is sometimes achieved by placing a trace heater in the pantograph shoe. This allows continued operation of the system, even under adverse weather conditions. Heat from the pantograph shoe may also melt accumulated ice on the transmission line during starting operations.

6.2 Design information

6.2.1 General

The design conditions vary considerably depending on the application and the geographical location. Consideration should be given to local weather conditions and the surface that is to be heated. Generally, the data given in 6.2.2 to 6.2.5 is required as a minimum.

6.2.2 Weather data

The following information is needed:

a) ambient temperature;
   1) minimum (with consideration of duration, frequency, etc.)
   2) minimum for freezing precipitation (typically in the range of -10 °C to 2 °C)
b) rate of snowfall;
   1) maximum rate
   2) average rate
c) wind velocity;
   1) maximum rate
   2) nominal rate during freezing precipitation
d) maximum wind-blown snow accumulation.

6.2.3 Rail system description

The types of materials and configurations need to be known, such as:

a) rail system type – third rail, switch rail, tramway, APMs, freight systems, others;
b) rail construction;
   1) material – steel, cast steel or iron, aluminium
   2) profile – I-beam, H-beam, box beam, others
   3) size – gauge and weight
c) running surface (steel, concrete, etc.);
d) operational requirements for rail heating system.
   1) low – typical for freight systems
   2) nominal – ensures operation under typical conditions
   3) critical – required for APMs and similar systems

6.2.4 System design

Design information is required, such as:

a) heating requirements – type of system and locations where trace heating is specified for use, e.g. turnout, crossing, stretcher bar, clamp lock, etc.;
b) number and size of each point system;
c) system layout drawings;
d) control and monitoring considerations.

6.3 Thermal design

6.3.1 Heating load determination

The heating load requirements vary with application type and local weather conditions, and method of heating. Unlike many other surface heating applications, rail system components are often un-insulated and open to the elements. In such circumstances heat loss to the atmosphere can be significant. The use of heat shields, thermal insulation (where applicable) and/or thermal conducting compounds may improve heater efficiency and therefore reduce heating requirements.

It may be impractical to design for heating loads that can cope with all weather conditions. Where extreme weather creates conditions that are beyond the capability of the installed trace heater, it is likely that mechanical snow and ice clearing devices will be required to clear the rail system. It is therefore important that the operational level is clearly established at the design phase, and that the potential need for mechanical snow and ice clearing equipment is clearly understood. Liaison with the local rail operator should establish additional details if required.

6.3.2 Typical heating load

The heating load applied to a given application can vary widely, depending primarily on the anticipated weather conditions. The safety and confidence level prescribed for the system generally defines what components and what sections of rail are heat-traced, but can also influence the amount of heat provided. Rail and track systems will generally be supplied with 50 W/m of rail to 200 W/m of rail, with certain track systems requiring up to 500 W/m. These values also apply to point heating elements such as turnouts and switch-nose crossings. Components such as stretcher bars and clamp locks will need 150 W to 300 W per unit. Pantograph shoes are typically designed in the range of 200 W to 300 W per shoe.

6.4 Electrical design

It is essential that rail trace heating systems be compatible with the primary rail electrical systems. It should be noted that, often, the metal parts of the system are bonded to earth only up to the primary of the trackside transformers, while the trace heaters are often connected to the unearthed secondary transformer windings. In such installations, it may be a requirement to avoid the use of residual current devices. Clearly, the design of protective equipment should be undertaken in consultation with the rail engineers, so as not to compromise the effectiveness of train detection and other operational and safety systems.

6.5 Control and monitoring system design

The trace heating circuit comprises track-mounted trace heating elements and associated supply cables. Special care should be taken in the design of the trace heating circuit to ensure that the signalling equipment system remains unaffected by the operation of the trace heating circuit both under normal and fault conditions.

Control options are defined by the operational level selected for the system. Low level systems may have little in the way of automated control systems, while more critical systems may be provided with options for sensing any or all of the following: ambient temperature, hot rail temperature, cold rail temperature, presence of moisture, and presence of snow. In addition, automated monitoring of these options may be provided to ensure that the rail or track temperature is maintained throughout the adverse weather conditions.

Consideration may also be given to remote data access and control from a central control station. This system may be used to control and/or determine the status of the electric trace heating system.

6.6 Special design considerations

6.6.1 Electrical considerations

The following electrical information is required.

a) Supply voltage; this may vary considerably from country to country and from application to application, usually up to 750 V.

b) Power distribution information such as single line electrical specifications including any transformers and application voltages.

c) Track signalling considerations. The heat tracing system should be designed such that it cannot interfere with the operation of track signalling circuits.

6.6.2 Finite element analysis

In view of the imprecise heating load determination above, it is recommended that finite element analysis be conducted for the proposed trace heating load and for the proposed trace heating system.

6.7 Installation

6.7.1 General

Each electric trace heating system is designed to meet the requirements of the particular application. Because the system comprises a number of components integrated at the site, it is necessary to ensure that the original design parameters are still valid. Correct installation, appropriate testing, and maintenance according to the installation procedures are essential for satisfactory performance and safety. The supplier of the trace heating system shall provide specific instructions for the trace heaters and the various types of system components.

a) Trace heaters

   In order to ensure good heat transfer, relevant parts of the rail should be clean. Trace heating system design should include expansion and contraction considerations. Trace heater cold leads should be secured in such a way as to prevent snagging on passing rail traffic and maintenance snow removal equipment.

b) Clips

   Trace heater clips are often required to hold the trace heater in position on the rail. These clips can vary in design and style depending on the type of trace heater employed and the application. Their purpose is to ensure that the trace heater remains in close contact with the rail to aid heat transfer, while at the same time allowing the trace heater to move laterally under expansion and contraction. The clip should be capable of withstanding the excessive vibration of heavy rail traffic and be sufficiently rugged to withstand the adverse environmental and operational conditions (see Figure 16).

c) Channels

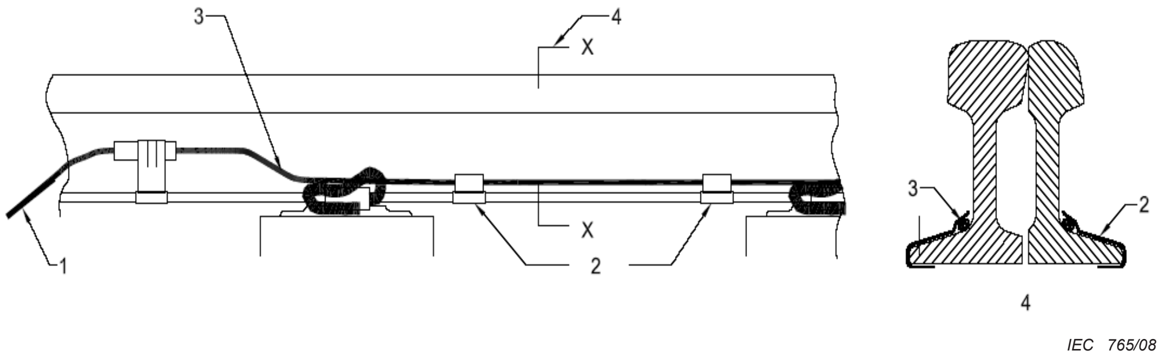
   As with the clips, channels are often supplied to assist in ensuring that the trace heater remains in close contact with the rail. These should be capable of withstanding the same adverse conditions.

d) Illustrations

   Subclauses 6.7.2 to 6.7.6 illustrate examples of some typical installations.

6.7.2 Point heating

See Figure 16 below.



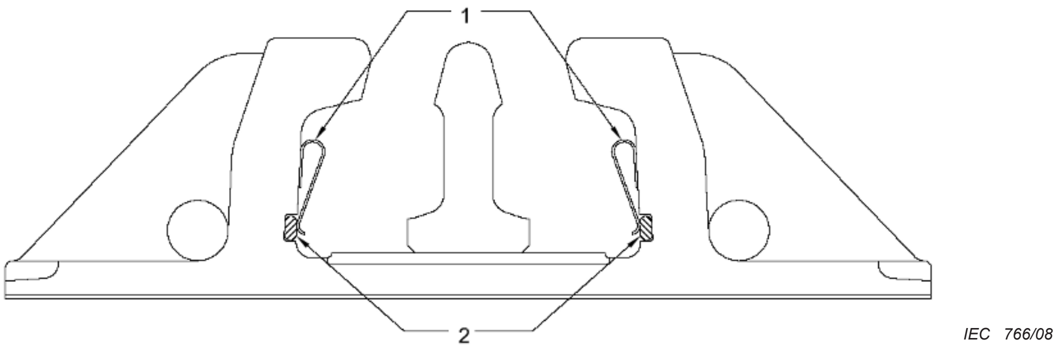
Key

1 Cold lead
2 Clip
3 Trace heater
4 X – X shows a typical cross-section

Figure 16 – Typical positioning of point trace heater on stock rail and switch rail

6.7.3 Swing nose crossing

See Figure 17 below.



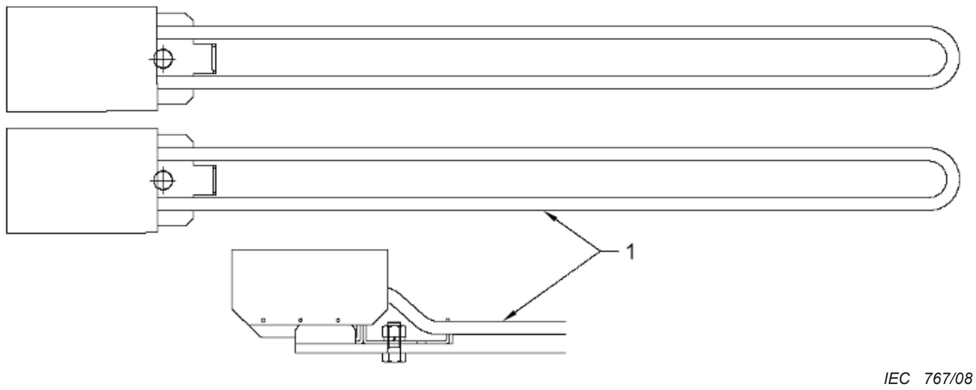
Key

1 Clip
2 Trace heater

Figure 17 – Typical positioning of trace heater on swing nose crossing

6.7.4 Clamp lock heating

See Figure 18 below.



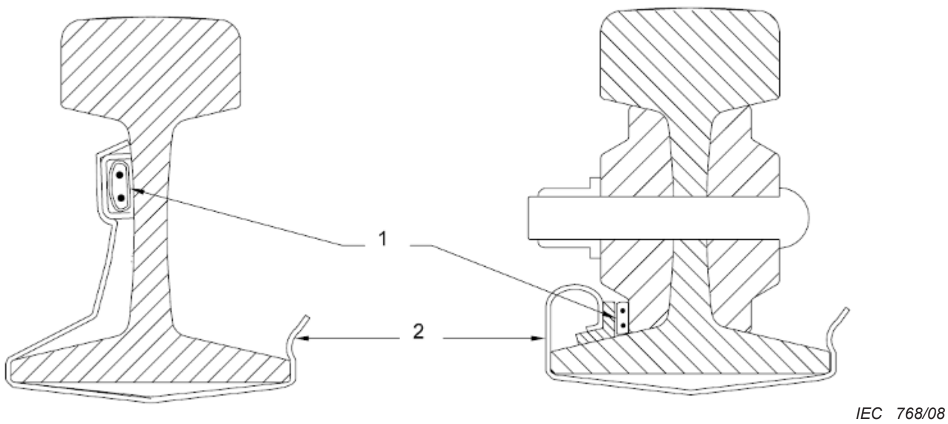
Key

1 Trace heater

Figure 18 – Typical clamp lock trace heater

6.7.5 Contact/live rail heating and track heating

See Figure 19 below.



Key

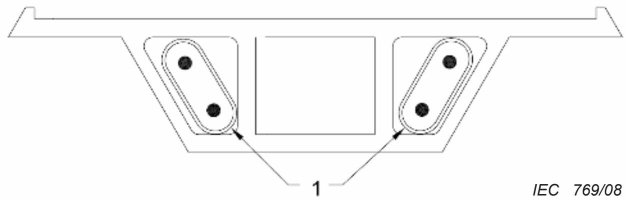
1 Trace heater

2 Clip

Figure 19 – Typical positioning of trace heater on steel and aluminium clad contact rails

6.7.6 Catenary/pantograph shoe heating

See Figure 20 below.



Key

1 Trace heater

Figure 20 – Typical positioning of trace heater in pantograph shoe

6.8 Maintenance

Refer to 4.8.

Where thermal conducting aids are part of the rail heating system, it is important to ensure that the thermal efficiency of the system is maintained.

6.9 Repair

Damage often occurs due to mechanical causes and can usually be determined by visual inspection of the trace heaters, which often remain exposed during normal operation. Repairs should be carried out according to the manufacturer’s instructions. It is important that a repaired system should maintain its UV resistance, mechanical properties, and its weatherproof qualities. Where thermal conducting aids are part of the rail heating system, it is important to ensure that the thermal efficiency of the system is maintained, by re-applying the thermal transfer system.

Where this cannot be guaranteed, then replacement is recommended.

Following any repair, compliance with the recommendations of 6.7 should be ensured, with particular reference to the requirement for trace heaters to be able to move laterally to accommodate expansion and contraction.

The requirements of 4.9 should be observed as appropriate.

7 Snow melting

7.1 Application description

Trace heating systems can be designed for the specific purpose of preventing accumulation of snow and ice in applications such as driveways, sidewalks, entrances to commercial buildings parking garage ramps and helicopter decks.

Trace heater circuits are typically directly embedded and shall therefore meet the requirements of 5.4 of IEC 62395-1:2013.

In some cases, the trace heaters may be installed in conduit for these applications and therefore shall meet the requirements of 5.5 of IEC 62395-1:2013.

7.2 Design information

7.2.1 General

The design conditions and application inputs specified in 7.2.2 to 7.2.6 are needed prior to commencing with the system design.

7.2.2 Weather data

The following information is needed:

a) minimum ambient temperature;
b) maximum rate of snowfall;
c) maximum wind velocity;
d) humidity.

7.2.3 Construction details of workpiece

The types of materials and configurations need to be known, such as:

a) material, for example, pre-cast slabs, single or dual pour concrete, asphalt etc.;
b) foundation construction and materials;
c) dimensions and layout, and additional items such as expansion joints, drains, handrails, etc., which should be available from the construction drawings.

7.2.4 Electrical considerations

The following electrical information is required.

a) supply voltage;
b) available power;
c) control and monitoring requirements.

7.2.5 System performance level

It is necessary to determine the requirement for how the system would perform in worst-case conditions. However, economic considerations may result in specifying a heat load for non-critical applications where some snow accumulation can occur.

A thorough design should be based on statistical weather data. For critical applications, it may be required to ensure a free area ratio (defined in 7.3) of 1 for perhaps 99 % of the snowfall events.

In these critical applications, additional trace heating may need to be installed to shorten the heat-up time of a workpiece. Control systems that switch on the trace heating when snowfall is sensed at sub-zero temperatures take some time to elevate the temperature of the workpiece, especially if there has been a considerable period of time with no precipitation, but with low ambient temperatures.

Table 4 indicates typical ranges of heat density requirements for levels of weather severity and application criticality.

Table 4 – Typical snow melting heat loads

Weather severity	Application criticality		
	Minimum, for example, residential walkways and driveways	Moderate, for example, commercial walkways and driveways	Maximum, for example, toll plazas, hospital emergency entrances and helicopter decks
	W/m^2		
Mild	150 to 250	250 to 350	300 to 400
Severe	200 to 300	300 to 450	350 to 500
Very severe	250 to 350	400 to 550	450 to 750

NOTE Heating load requirements are a function of climatic conditions. The ranges of values in Table 4 reflect the variation of values used in different regions.

7.2.6 Trace heater layout and component mounting

Trace heating is typically serpentined in a workpiece (as shown in Figure 21) to provide uniform heat. If the trace heating is in a conduit, it is spaced as shown in Figure 22.

a) Spacing(s) between embedded trace heaters or conduits usually range from 80 mm to 300 mm in order to obtain a relatively uniform temperature distribution across the surface. The spacing is calculated using the required power output in W/m^2 and the lineal power output of the trace heater. For example, if the application required 360 W/m^2 and the trace heater selected had a rating of 90 W/m in concrete, the resulting spacing would be 250 mm. Although the same power density could be achieved with a trace heater with 180 W/m output and 500 mm spacing, uneven distribution of heat might result, with areas directly above the trace heating being well above 0 °C and areas between trace heating runs being below 0 °C.

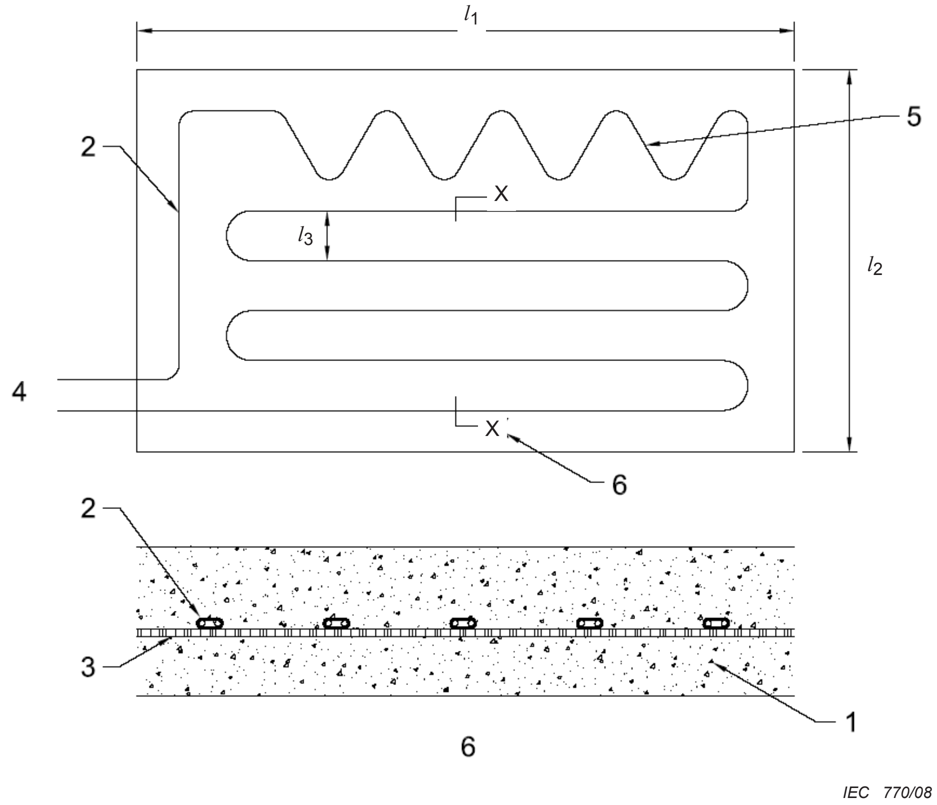
b) The recommended trace heater depth is typically 50 mm to 100 mm for concrete and 40 mm to 50 mm for asphalt. The trace heater is usually fastened to the re-bar, or wire mesh using nylon cable ties. Heater panels are an additional option when the concrete can be poured in two stages, with these being attached to the clean surface of the initial pour. Pre-punched strapping can sometimes be a convenient attachment method in two-pour applications.

c) Trace heaters should be located a minimum of 150 mm from the edge. When installed in ramps, they are usually oriented laterally across the ramp to minimize the number of crossings of crack control joints. Crossing of expansion joints should be avoided, but where an expansion joint transition is required, additional protection is necessary. See Figure 23.

d) Power connections should be located above grade where possible, with preference given to mounting junction boxes inside buildings or on structure walls (see Figure 24.) The field assembled trace heater end termination should be located inside a junction box to facilitate maintenance.

e) Snow melting installation designs should be fully documented with drawings identifying

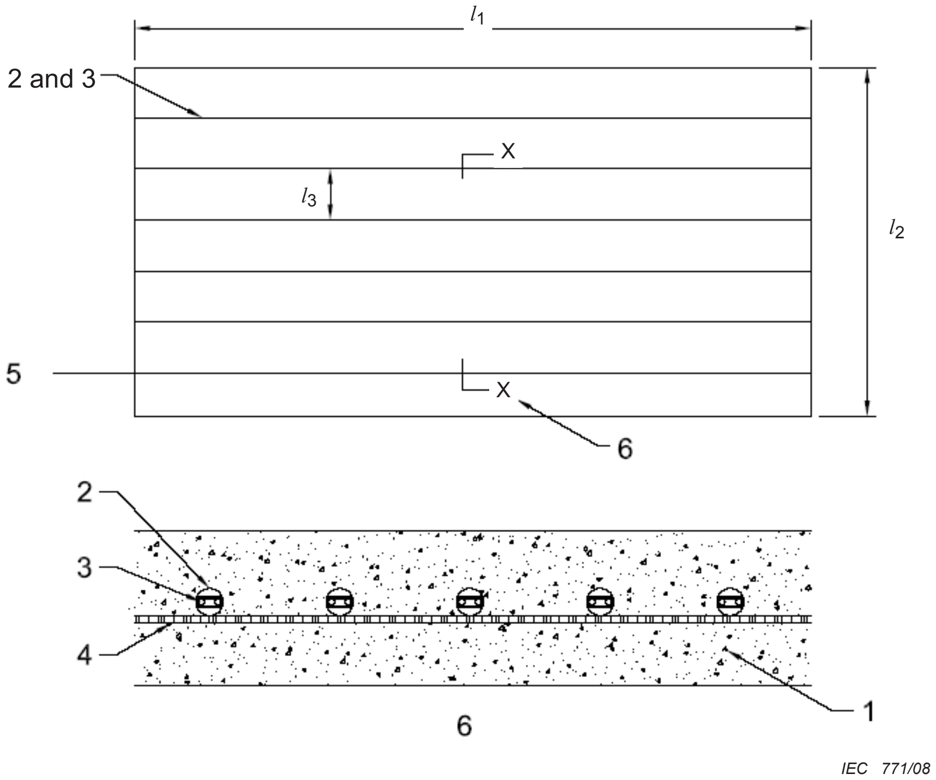
   1) trace heater type;
   2) spacing;
   3) depth;
   4) layout;
   5) location of power connection and expansion joints (if used);
   6) identification of circuit;
   7) location of additional items such as drains, sensors, etc.



Key

1 Concrete slab
2 Trace heater
3 Reinforcing bar or mesh
4 To junction box
5 Zigzag return routing only necessary for odd number of cable passes
6 X-X shows typical cross section
l_1 Length of slab
l_2 Width of slab
l_3 Spacing between trace heaters

Figure 21 – Snow melting trace heater embedded in concrete



Key

1 Concrete slab

2 Conduit

3 Trace heater

4 Reinforcing bar or mesh

5 To junction box

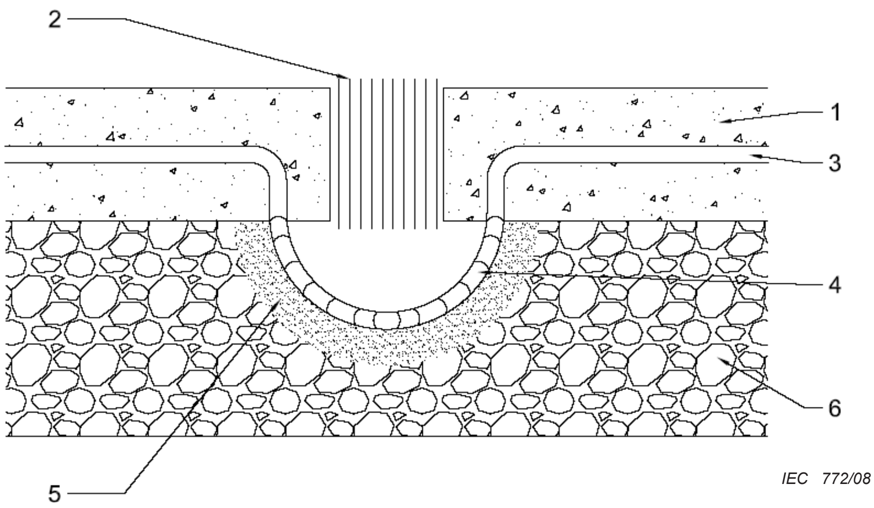
6 X-X shows typical cross section

l_1 Length of slab

l_2 Width of slab

l_3 Spacing between trace heaters

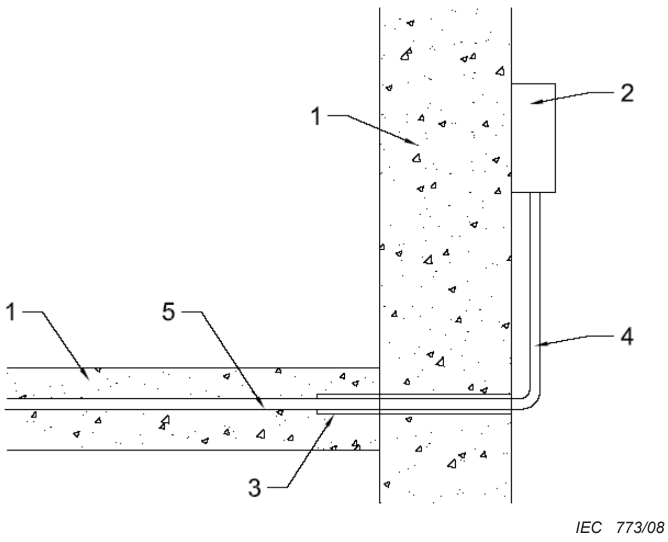
Figure 22 – Snow melting trace heater located in conduit



Key

1 Concrete slab
2 Expansion joint
3 Trace heater
4 Protective device
5 Sand
6 Compacted fill

Figure 23 – Expansion joint detail



Key

1 Concrete slab
2 Junction box
3 Conduit filled with sealing compound
4 Trace heater or power connection leads
5 Trace heater

Figure 24 – Snow melting junction box location

7.3 Thermal design – Power output (heat load) determination

The heat needed to perform the snow melting function is based on a number of elements, which are shown in Formula (10) below.

$$Q_T = A_r (Q_e + Q_c + Q_r) + Q_s + Q_m + Q_g \tag{10}$$

where

- A_r is A_{free}/A_{total};
- Q_e is the evaporation from top surface;
- Q_c is the convection from top surface;
- Q_r Is the radiation from top surface;
- Q_s is sensible heat (i.e., energy used to elevate snow and ice temperature, prior to melting it);
- Q_m is the latent heat;
- Q_g is heat loss from sides and underside by conduction.

The term A_r is the free area ratio and is usually entered as 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. A_r = 0 means that there should be no snow accumulation, but a thin layer of snow might be expected.

The calculated values provide overall power densities and do not address temperature distribution across the surface of the workpiece, which depends on the thermal conductivity of the workpiece and the trace heater's power output and spacing in the workpiece.

7.4 Electrical design

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

7.5 Control and monitoring system design

The snow melting system may be controlled by something as basic as an on/off switch and an indicator light or by a more sophisticated control system including both moisture and temperature sensors. The choice of sophistication may be influenced by the critical nature of the application. In large installations, more rigorous control systems may be justified for energy efficiency.

7.6 Special design considerations

In certain applications, some of the following special design considerations may apply.

a) When trace heaters are located in conduit or pipe, the maximum sheath temperature and thermal output should be specified or identified.

b) For applications where the trace heaters are to be embedded in asphalt, it is important to ensure that the temperature exposure rating of the trace heater is above the pour temperature of the asphalt.

c) Brick or paving stone constructions require special design consideration and the trace heaters may need to have additional mechanical protection.

d) When bare metallic sheathed trace heaters are embedded in concrete, it should be verified that the sheath material is not adversely affected by exposure to chemicals that might be in the concrete or might subsequently leech into the concrete.

e) Snow melting applications in the vicinity of aircraft hangar doors or fuel storage areas may be in areas classified as explosive atmospheres at the point where the trace heater exits the workpiece. Such applications are beyond the scope of this standard.

NOTE Trace heating systems intended for use in explosive atmospheres are the subject of IEC 60079-30-1 and IEC 60079-30-2.

7.7 Installation

Each electric trace heating system is designed to meet the requirements of the particular application. Because the system comprises a number of components integrated at the site, it is necessary to ensure that the original design parameters are still valid. Correct installation, appropriate testing, and maintenance according to the installation procedures are essential for satisfactory performance and safety. The supplier of the trace heating system shall provide specific instructions for the trace heaters and the various types of system components.

a) Snow melting installations usually result in the trace heater being embedded in concrete or asphalt. It is therefore particularly important to verify that the correct factory fabricated unit or bulk trace heater type is being installed.

b) Prior to the installation of the trace heater, the adjacent area should be inspected and any sharp objects or burrs (on the wire mesh or re-bar) should be removed or smoothed.

c) The trace heater attachment, spacing and minimum bend radius should comply with the manufacturer's specifications, and expansion joint transitions should be made following the method indicated on installation drawings.

d) When the trace heater installation is complete and prior to the placement of concrete or asphalt, the drawings should be modified to show the exact location of the trace heaters if the as-built layout has deviated from the initial drawings.

e) Prior to placement of the concrete or asphalt, an insulation resistance test should be conducted. For polymer-insulated trace heaters, 2 500 V d.c. test voltage is recommended and for mineral-insulated trace heaters, a maximum test voltage of 1 000 V d.c. is suggested. If equipment is not available to provide these test voltages, then a 500 V d.c. test voltage should be a minimum. Regardless of the test voltage, the measured value should not be less than 20 MΩ. This test should be repeated during the installation of the concrete or asphalt. If damage is detected, it should be rectified before continuing with the installation.

f) During the placement of concrete, attention should be paid to maintaining adequate clearance of the concrete delivery chute above the trace heater and maintaining a moderate concrete delivery speed to prevent the trace heater being displaced. Unnecessary foot traffic and excessive use of rakes, shovels and vibrators might also dislodge or damage the trace heaters.

g) When installing asphalt, it is important to verify that the application temperature is as anticipated and that it does not exceed the temperature rating of the trace heater.

h) Asphalt should be spread manually at the trace heater level.

i) Grades of asphalt with large aggregate are not recommended.

j) The insulation resistance reading should be recorded upon completion of the concrete pour or asphalt application.

k) The trace heaters should not be energized until either the concrete has cured or the asphalt has cooled to ambient temperature.

7.8 Maintenance

Refer to 4.8.

7.9 Repair

The repair of trace heating systems embedded in concrete requires the use of special equipment to locate the fault. Consultation with the manufacturer or a contractor specifically trained in performing this kind of repair is recommended. However, a visual inspection of the installation often reveals the cause of a failed system, where the concrete has been saw cut or drilled to take a core sample or install equipment.

8 Floor warming

8.1 Application description

Floor warming systems are intended to provide comfort by removing chill from a floor. In some cases, floor warming systems supplement or replace other forms of room heating. Floor warming is applied to areas such as bathroom floors, day-care centres, service buildings and garages.

When the trace heating is located directly in the substrate layer, it shall meet the additional requirements for embedded trace heating systems of 5.4 of IEC 62395-1:2013.

When the trace heating is installed in conduit or piping it shall meet the additional requirements of 5.5 of IEC 62395-1:2013.

NOTE Requirements for flexible sheet heating elements specifically for floor warming are specified in IEC 60335-2-96.

8.2 Design information

8.2.1 General

The design conditions and application inputs specified in 8.2.2 to 8.2.5 are necessary prior to commencing with the system design size and layout of the area involved.

8.2.2 Environmental data

The following information is needed:

a) minimum ambient temperature;
b) required maintenance temperature range.

8.2.3 Construction details of workpiece

The types of materials and configurations should be known, such as:

a) method of installation and location, for example, buried in concrete, located on, or under, a subfloor, located under ceramic tiles;
b) materials of construction;
c) subfloor construction, if relevant;
d) thermal insulation type and thickness, if any.

8.2.4 Electrical considerations

The following electrical information is required:

a) electrical inputs;
b) supply voltage;
c) available electrical power;
d) control and monitoring requirements.

8.2.5 Trace heater layout and component mounting

Trace heating is typically installed by being buried directly in concrete, by attaching to re-bar or wire mesh or alternatively being embedded in a layer of mortar between the ceramic floor tiles and wood subfloor with the trace heater fixed to an expanded metal lath, wire mesh, or pre-punched strapping at a typical depth of 20 mm, or alternatively applied direct to the lower surface of the concrete slab and held in place with rigid thermal insulation. Typical methods of laying the trace heaters are illustrated in Figure 25.

The trace heater spacing is determined from the required watt density from Figure 26 and the lineal power output of the trace heater to be used.

$$S = \frac{P}{Q} \qquad (11)$$

where

S is spacing of trace heating in m;

Q is the required heat load determined from Figure 26 in W/m^2;

P is lineal power output of the chosen trace heater in W/m.

For example, if the heat load is 100 W/m^2 and the trace heater power output is 20 W/m, then the spacing will need to be 0,2 m (i.e., 200 mm between trace heater passes or 5 passes per metre).

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

When the floor temperature is to be maintained using a temperature controller, the sensor should be located preferably in conduit midway between trace heater runs. This location facilitates ease of replacement and also provides a good representation of floor temperature.

Floor warming installations should be fully documented with drawings identifying

a) trace heater type;
b) spacing;
c) depth;
d) layout;
e) location of power connection and end seal;
f) identification of circuit;
g) location of additional items such as sensors, etc.

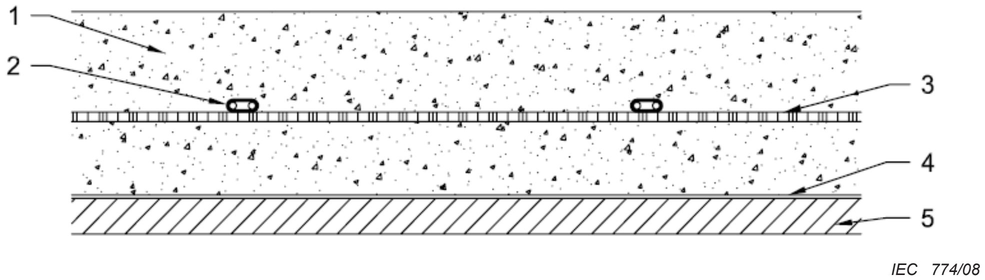


Figure 25a – In concrete

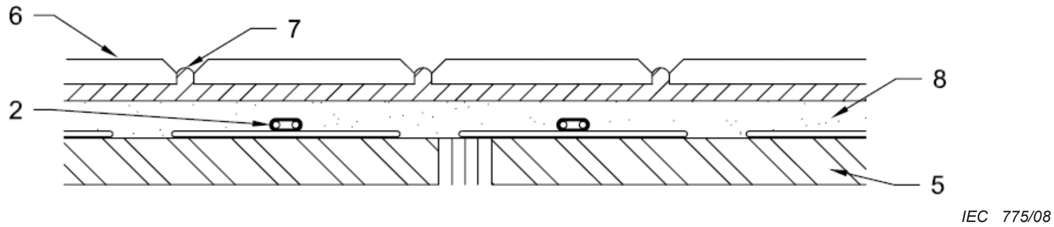


Figure 25b – Under ceramic tile embedded in mortar

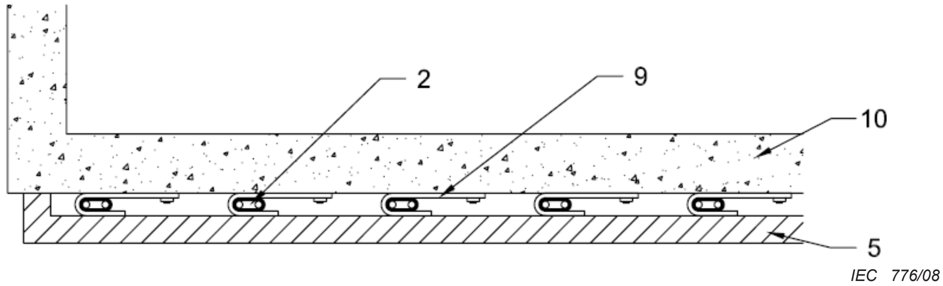


Figure 25c – Under an elevated concrete slab

Key

1 Concrete slab
2 Trace heater
3 Reinforcing bar or mesh
4 Vapour barrier (if specified)
5 Thermal insulation
6 Tile
7 Grout
8 Mortar
9 J – channel
10 Elevated concrete slab

Figure 25 – Typical floor warming trace heater mounting

8.3 Thermal design – Heat load determination

Heat loads typically between 50 W/m^2 and 160 W/m^2 are required for temperature-maintained areas such as bathrooms, office buildings and day-care centres – also depending on heat-up times when comfort heating is only required during a short period of time per day (for example, bathrooms). Increased heat loads of 150 W/m^2 to 250 W/m^2 may be required for garages and warehouse areas. Assuming relatively still air and low heat loss off the floor underside, Figure 26 shows the heat load requirements for a range of conditions.

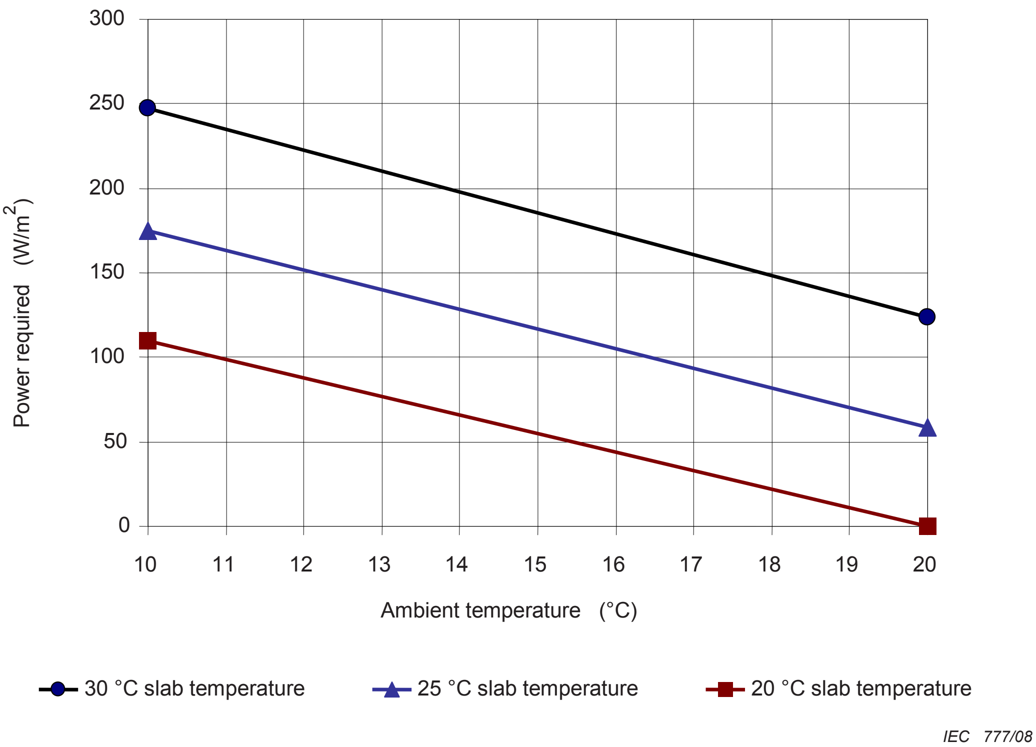


Figure 26 – Typical floor heating power requirements

8.4 Electrical design

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

Special consideration is given for areas around swimming pools and spas. Reference should be made to the local electrical code.

8.5 Control and monitoring system design

For the purposes of energy conservation, the energy consumption of the floor heating system should be controlled by either a timer-based on/off control system or a floor sensing temperature control system (or both). Room temperature control systems combined without floor temperature sensing device should only be used for trace heaters that cannot overheat by product design.

8.6 Special design consideration

When designing a floor warming system, watt densities and floor temperatures may be restricted by local regulations.

8.7 Installation

Each electric trace heating system is designed to meet the requirements of the particular application. Because the system comprises a number of components integrated at the site, it is necessary to ensure that the original design parameters are still valid. Correct installation, appropriate testing, and maintenance according to the installation procedures are essential for satisfactory performance and safety. The supplier of the trace heating system shall provide specific instructions for the trace heaters and the various types of system components.

Floor warming installations usually result in the trace heater being embedded. It is particularly important to verify that the correct factory fabricated unit or bulk trace heater type is being installed.

a) Prior to installation of the trace heater, the floor area to be heated should be clean and inspected and any debris, sharp objects and burrs (on wire mess or re-bar) should be removed and smoothed.
b) Prior to installation of the trace heater, an insulation resistance test should be conducted and results recorded using a test voltage of at least 500 V d.c. However, for mineral-insulated trace heaters, a maximum test voltage of 1 000 V d.c. is recommended, and for polymer-insulated trace heaters, 2 500 V d.c. is recommended. The measured value should not be less than 20 MΩ.
c) The trace heater should be attached to the substructure in accordance with the spacing, bending radii, and expansion joint transition methods specified on the installation drawings.
d) The insulation resistance test should be repeated and insulation resistance readings recorded after trace heater installation.
e) Upon completion of the trace heater installation and prior to surface floor placement, the drawings should be modified to reflect the as-built conditions.
f) The insulation resistance test should be repeated and insulation resistance readings recorded during floor surface installation.
g) The trace heater should not be energized until the applied floor surfaces have cured.

8.8 Maintenance

Refer to 4.8.

8.9 Repair

When trace heaters are embedded, fault location requires specialized equipment. Consultation with the manufacturer or a contractor specifically trained in performing this kind of repair is recommended.

9 Frost heave prevention

9.1 Application description

Trace heating systems perform a specific purpose below the floors of ice rinks, freezers and refrigerated storage areas. Their function is to prevent the development of a mass of ice in the substrate below the floor. If ice develops in this area, it can build up into an ice lens of considerable size that would buckle the floor above as it grows (the frost heave phenomenon). This situation is prevented by ensuring that the substrate temperatures are maintained above the freezing point across the entire area at a specific depth below the floor.

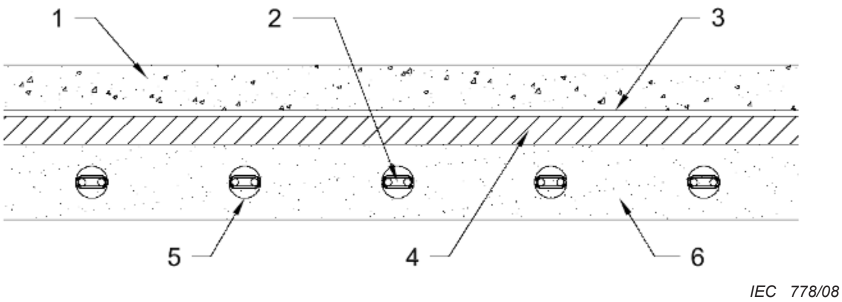
Trace heater circuits are typically directly embedded in the substrate and shall therefore meet the requirements of 5.4 of IEC 62395-1:2013.

In some cases, the trace heaters may be installed in conduits for these applications and therefore shall meet the requirements of 5.5 of IEC 62395-1:2013.

9.2 Design information

9.2.1 General

Figure 27 shows the cross-section of a typical floor structure with trace heating circuits. The information specified in 9.2.2 and 9.2.3 is necessary in order to design such installations.



Key

1 Concrete slab
2 Trace heater
3 Vapour barrier
4 Thermal insulation
5 Conduit
6 Compacted sand or concrete

Figure 27 – Typical frost heave prevention substructure

9.2.2 Construction details of the floor

The following information is necessary:

a) materials, thicknesses and thermal insulation factors of the floor materials;
b) foundation construction materials and thermal insulation factors;
c) location and type of vapour barrier;
d) overall dimensions and preferred layout of the trace heating circuits;
e) temperatures being maintained in the floor of an ice rink or in the freezer or refrigerated storage area.

9.2.3 Electrical considerations

The following electrical information is required:

a) supply voltage;
b) available power;
c) control and monitoring requirements.

9.3 Heat load determination

9.3.1 General

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

The typical heat density W/m^2 required is shown in Figure 28 as a function of minimum freezer ambient temperature and insulation barrier thickness. This is based on an effective earth temperature of 10 °C.

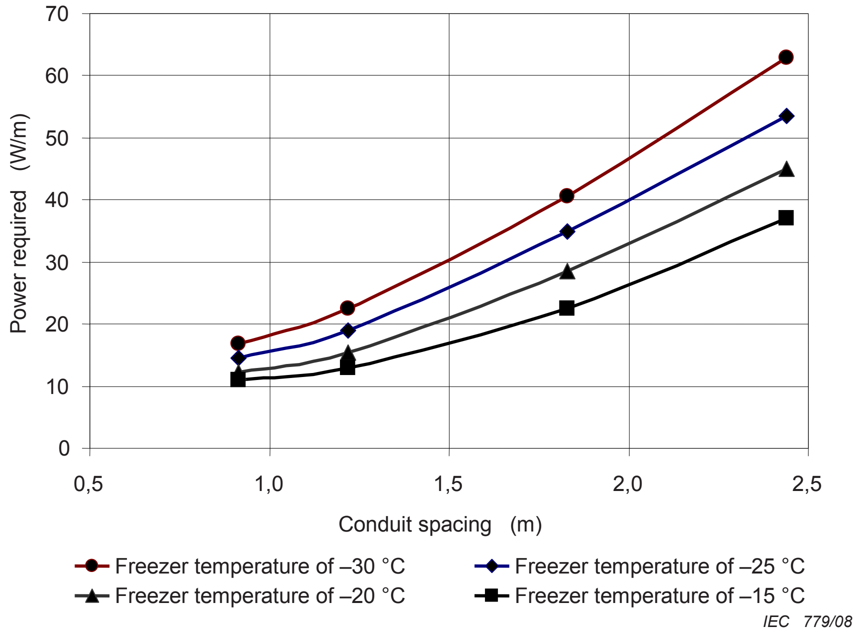


Figure 28a – Power requirements – with 100 mm insulation

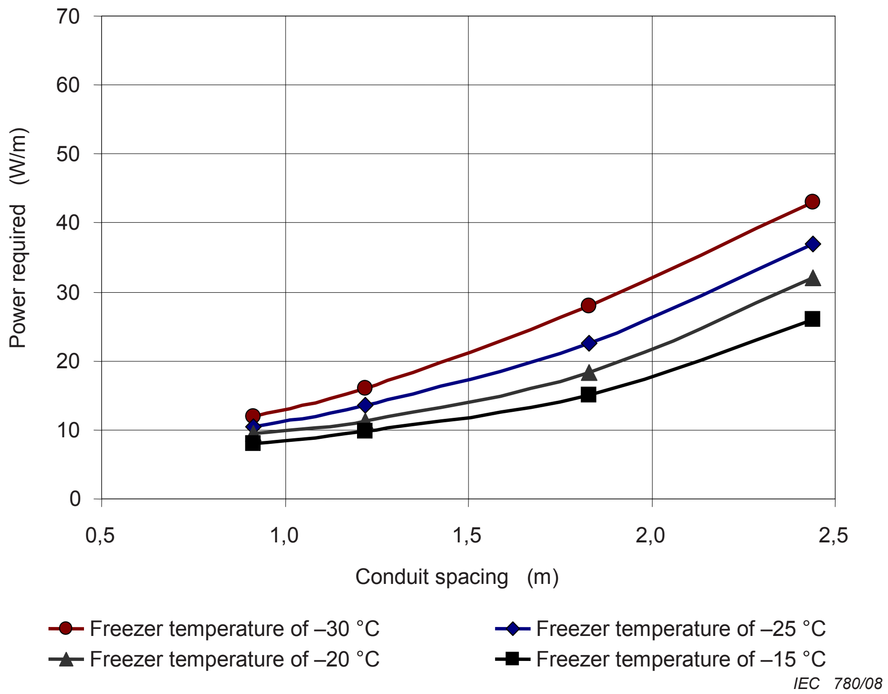


Figure 28b – Power requirements – with 150 mm insulation

NOTE These are typical values for an installation using 100 mm or 150 mm of insulation material with a *k* factor of 0,03 W/mK and a design safety factor of 50 %.

Figure 28 – Frost heave prevention power requirements

9.3.2 Trace heater layout and component mounting

To facilitate repair or retrofit of the trace heaters in the floor, the trace 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) Trace heater power connection and end terminations should be in an accessible junction box.

b) Consideration should be given to using multiple sensors and circuits in order to optimize precision of the control system. This also limits the extent of any non-functioning area. However, this should be balanced by economic considerations.

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

Based on rigid foam thermal insulation with a nominal thickness of 150 mm, a typical heat load is between 5 W/m^2 and 15 W/m^2. Due to the large number of variables in assessing the heat load, a specific design is recommended for each application.

9.4 Electrical design

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

9.5 Control and monitoring system design

9.5.1 Control options

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

9.5.2 Monitoring

Circuit monitoring to indicate any significant change in trace heater output is recommended. Earth leakage monitoring at a 30 mA level is also recommended to detect any degradation of the dielectric integrity of the trace heating circuit.

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

9.6 Special design considerations

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

a) For all below-grade applications, trace heater constructions with both a metallic covering and polymer overjacket are recommended.

b) Typical spacing when using the conduits is from 500 mm to 1 m. For wider spacing, the resulting temperature distribution should be verified.

c) Power output data of trace heaters, when installed in conduit, should be supplied by the manufacturer and taken into consideration by the designer.

d) When the trace heater is installed in conduit, the designer should verify that the thermal output and that the resulting sheath temperature is compatible with the conduit material.

e) When the trace heater is directly embedded in the substrate, the installation of redundant trace heater circuits should be considered.

9.7 Installation

Each electric trace heating system is designed to meet the requirements of the particular application. Because the system comprises a number of components integrated at the site, it is necessary to ensure that the original design parameters are still valid. Correct installation, appropriate testing, and maintenance according to the installation procedures are essential for satisfactory performance and safety. The supplier of the trace heating system shall provide specific instructions for the trace heaters and the various types of system components.

Frost heave prevention systems usually involve installing trace heater in a conduit. The following are both general and specific installation recommendations for these systems.

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

b) Prior to pulling trace heaters, any obstacles in the conduit should be removed and rough edges shall be smoothed.

c) The static pulling force should not exceed the manufacturer's recommended value. 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 trace heater manufacturer should be used.

e) The pulling force exerted on the trace heater should be by connection of a pulling eye to the braid or shield.

f) After trace heaters have been installed, an insulation resistance test should be conducted with a test voltage of at least 500 V d.c. However, for mineral insulated trace heaters, a test voltage of 1 000 V d.c. is recommended, and for polymer insulated trace heaters, 2 500 V d.c. is recommended. The measured value should not be less than 20 MΩ. The value should be recorded on a log sheet.

9.8 Maintenance

Refer to 4.8.

9.9 Repair

When trace heaters are installed in a conduit, it is preferable to replace the full length of the trace heater within a single conduit run. Splicing can be done at a pull box, but the trace heater shall never have a splice within the conduit.

10 Underground thermal energy storage systems

10.1 Application description

Trace heating can be used to provide a means of converting electrical energy to a reservoir of heat energy in the foundation area below a building. Typical applications are: beneath the floors of warehouses, health care facilities and other structures utilizing concrete floors. Underground thermal energy storage systems are particularly applicable where electrical utilities offer reduced rates for usage during off-peak periods.

In some cases, the trace heaters may be installed in conduit for these applications and therefore shall meet the requirements of 5.5 of IEC 62395-1:2013.

10.2 Design information

10.2.1 General

The design conditions and application inputs specified in 10.2.2 to 10.2.5 are needed to calculate the requirements for an underground thermal energy storage system.

10.2.2 Environmental data

The following information is needed:

a) average ambient temperature, during season when heating might be required;
b) minimum ambient temperature.

10.2.3 Construction details of building

The following information is needed:

a) intended uses of the building;
b) proposed number of zones;
c) maintenance temperature for each zone;
d) heat loss for each zone, derived from the dimensions and insulation values of walls, windows, etc.

10.2.4 Electrical considerations

The following electrical information is required:

a) voltage supply;
b) available electrical power;
c) hours of off-peak power available per day;
d) control and monitoring requirements per zone.

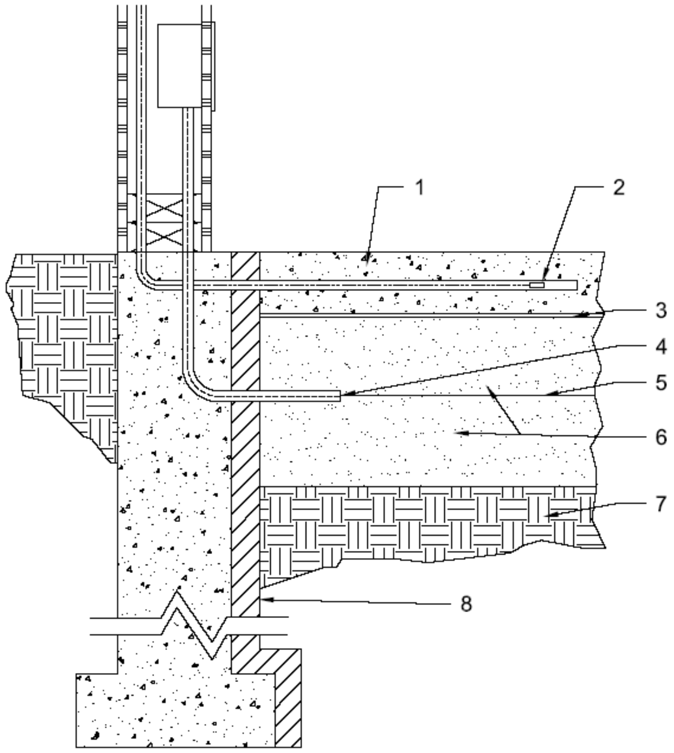
10.2.5 Trace heater layout and component mounting

Trace heaters are typically installed in compacted sand at a depth of 100 mm to 500 mm below the concrete floor, or in the concrete floor itself, where the concrete thickness is designed to store the energy for this application. Figure 29 shows a typical under-the-floor trace 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 concrete. A high-temperature sensor, if used, is located on the trace heater.

The spacing of the trace heaters is dependent upon the power output of the product selected and the amount required to replace the heat loss of each zone. It would be unusual to have a spacing of as little as 150 mm. Usually one would design the application to use a trace heater with greater power output per unit length and wider spacing.

The trace heating is spaced evenly in the area available with a clearance of about 150 mm from walls, drains, footings, and other obstructions.

Where possible, it is preferable to locate the end termination in an accessible junction box.



Key

1 Concrete slab
2 Temperature sensor
3 Vapour barrier (if specified)
4 High limit temperature sensor
5 Trace heater
6 Compacted sand
7 Heat reservoir
8 Perimeter insulation

Figure 29 – Typical underground thermal energy storage system installation

10.3 Thermal design – Heat-loss determination

The electrical power needed to provide heat for a specific application can be determined by calculating the building heat loss through walls, floors, ceilings and closed doors and windows. This is the natural building heat loss. Additional heat losses occur from the building's ventilation system and opening of doors. If allowance is not made for these additional losses, supplemental heating might be required.

10.4 Electrical design

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

10.5 Control and monitoring system design

Each heating zone should have its own temperature controller. The set point is typically in the range from 18 °C to 24 °C. Some types of trace heating require the use of a high limit temperature controller to protect the integrity of the system.

The trace heating system should be energized for a controlled period sufficient to build up the heat reservoir so that further energization is not required during periods when usage of electricity is to be avoided.

10.6 Special design considerations when trace heaters are located in sand layer

The use of a vapour barrier to retain moisture in the sand is recommended. See Figure 29.

The perimeter of the foundations area should be insulated with thermal insulation, typically 50 mm thick rigid foam sheeting, extending 1,5 m down, to minimize lateral heat loss.

10.7 Installation

10.7.1 General

Each electric trace heating system is designed to meet the requirements of the particular application. Because the system comprises a number of components integrated at the site, it is necessary to ensure that the original design parameters are still valid. Correct installation, appropriate testing, and maintenance according to the installation procedures are essential for satisfactory performance and safety. The supplier of the trace heating system shall provide specific instructions for the trace heaters and the various types of system components.

10.7.2 Installation in sand

Trace heaters that are provided for this specific application are designed for installation in a carefully prepared sand base, free of stones, debris, and organic matter. In some geographic areas, trace heaters can be placed directly in the earth by means of a trenching plough. Typical installation in sand is as follows.

a) The sand base should be installed and compacted to the desired trace heater burial depth.
b) Prior to installation, it should be verified that the trace heater is the correct factory fabricated unit or bulk cable type.
c) An insulation resistance test should be conducted with a test voltage of at least 500 V d.c. However, for mineral-insulated trace heaters a test voltage of 1 000 V d.c. is recommended, and for polymer-insulated trace heaters, 2 500 V d.c. is recommended. The measured value should not be less than 20 MΩ.
d) The trace heater is to be laced in a predetermined pattern, adhering to spacing and bending radii specified by the trace heater manufacturer. Temporary frames can be used to position and support trace heater 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 temporary frames (or positioning devices) should be removed, with care taken so that trace heater patterns are not distorted.
g) The exposed trace heater loops should be covered with sand and the entire area should be compacted.

10.7.3 Installation in concrete

When trace heaters are to be installed in concrete, it is particularly important to verify that the correct factory fabricated unit or bulk trace heater type is being installed. Other installation notes are as follows.

a) Prior to the installation of the trace heater, the adjacent area should be inspected and any sharp objects or burrs (on the wire mesh or re-bar) should be removed or smoothed.

b) The trace heater attachment, spacing and minimum bend radius should comply with the manufacturer's specifications and expansion joint transitions should be made following the method indicated on installation drawings.

c) When the trace heater installation is complete and prior to the placement of concrete, the drawings should be modified to show the exact location of the trace heaters if the as-built layout has deviated from the initial drawings.

d) Prior to placement of the concrete, an insulation resistance test should be conducted. For polymer-insulated trace heaters, a 2 500 V d.c. test voltage is recommended and, for mineral-insulated trace heaters, a maximum test voltage of 1 000 V d.c. is suggested. If equipment is not available to provide these test voltages, then a 500 V d.c. test voltage should be a minimum. Regardless of the test voltage, the measured value should not be less than 20 MΩ. This test should be repeated during the installation of the concrete. If damage is detected, it should be rectified before continuing with the installation.

e) During the placement of concrete, attention should be paid to maintaining adequate clearance of the concrete delivery chute above the trace heater and maintaining a moderate concrete delivery speed to prevent the trace heater being displaced. Unnecessary foot traffic and excessive use of rakes, shovels and vibrators might also dislodge or damage the trace heaters.

f) The insulation resistance reading should be recorded upon completion of the concrete pour.

g) The trace heaters should not be energized until the concrete has cured.

10.8 Maintenance

Refer to 4.8.

10.9 Repair

The repair of trace heating systems embedded in, or below, concrete requires the use of special equipment to locate the fault. Consultation with the manufacturer or a contractor specifically trained in performing this kind of repair is recommended.

If the installation has been designed with access to each run of trace heater, it is possible to identify and isolate a faulty run, providing that this will not result in too much current in other runs. It is important to consult the manufacturer before shortening the circuit length of series cables. Otherwise, it may be necessary to isolate all the trace heating in the faulty circuit.

In some circumstances, with certain types of trace heating, it may be possible to increase the voltage of some circuits to compensate for any circuits that have been isolated. Again, it is essential to consult the manufacturer before making such changes.

Annex A
(informative)

Pre-installation checks

Items to be checked		Remarks
1	Is the workpiece fully erected and tested and all temporary supports removed? Is the surface to be heated free from sharp edges, weld spatter and rough surfaces?	Any welding or pressure testing after the installation of a trace heater could damage the device.
2	Is the surface upon which the trace heater is to be applied normal steel or non-metallic?	If the surface is of polished stainless steel, very thin-walled pipe or non-metallic of any kind, special precautions may be necessary.
3	Do the items to be heated correspond in size, position, etc. with the design?	It is sometimes difficult to be sure that the correct pipe is being heated. A suitable line numbering system may be of assistance.
4	Has it been specified that metallic foil be installed before the application of the trace heater?	This may be used to aid heat distribution.
5	Has it been specified that metallic foil be installed after the application of the trace heater?	This may be used to prevent insulation from surrounding the trace heater or to aid heat distribution.
6	Can flow of product under normal or abnormal conditions reach temperatures greater than those that the trace heater can withstand?	This would normally be covered in the design stage; however, further discussion with staff at the plant may show that incorrect or out-of-date information has been used.
7	Is the trace heating system documentation (working drawings, designs, and instructions) available?	No change should be contemplated without reviewing the trace heating system documentation, as careful calculations are necessary to ensure safe operation.
8	Can pipes or surfaces expand and contract so as to cause stress on any part of the trace heating installation?	In this case, precautions are necessary to avoid damage.
9	Can sensors of temperature controllers be affected by external influences?	An adjacent heating circuit could affect the sensor.
10	Is the trace heater to be spiralled or zigzagged onto the workpiece, according to the design?	Check design loading per unit length of pipe (or surface area) to determine if spiral or zigzag application is necessary.
11	Are cold leads, when fitted, suitable for contact with the heated surface?	If the cold lead is to be buried under the insulation, it has to be able to withstand the temperature.
12	Is the pipework hung from a pipe rack?	In this case, special precautions are required to ensure the weatherproofing of the insulation at points of suspension.
13	Does pipework have its full complement of supports?	The addition of intermediate supports at a later stage could damage the heating system.
14	Are there sample lines/bleed lines, etc. at the plant but not on drawings?	These could obstruct or prevent the fitting of the trace heater, and a review of the trace heating system documentation may be necessary.
15	Are other parameters used in the design of the equipment as specified by the design documentation?	
16	Are the trace heaters, controllers, junction boxes, switches, cable glands, etc., suitable for the environmental conditions and are they protected as necessary against corrosion and the ingress of liquids and particulate matter?	

Annex B
(informative)

Trace heater commissioning record

Location	System	Project number	Reference drawing(s)
Line number	Trace heater number	Corrosive atmosphere	Sheath temperature limitation
Panel number	Location	Circuit number	Circuit amps/voltage
Trace heater supplier	Trace heater model	Trace heater wattage unit length/voltage rating	
Megohm meter manufacturer/model		Voltage setting	Accuracy/full scale
Megohm meter date of last calibration			
Multimeter manufacturer/model	Ohm setting	Accuracy/full scale	
TRACE HEATER TESTING	Test value/remarks	Date	Initials
NOTE The minimum acceptable insulation resistance is 20 MΩ. The minimum acceptable test voltage is 500 V d.c. However, 1 000 V d.c. is recommended for MI, and 2 500 V d.c. for polymeric trace heaters.			
1 Receipt of material on reel			
Continuity test on reel			
Insulation resistance test on reel			
2 Piping completed (approval to start trace heater installation)			
3 After installation			
4 Trace heater installed (approval to start thermal insulation installation)			
Trace heater correctly installed on pipe, vessel or equipment			
Trace heater correctly installed at valves, pipe supports, other heat sinks			
Components correctly installed and terminated (power, tee-end seal)			
Installation agrees with supplier's instructions and circuit design			
5 Thermal insulation installation complete			
Continuity test			
Insulation resistance test			
SYSTEM INSPECTED:			
6 Marking, tagging and identification complete (see IEC 62395-1:2013, Clause 6)			
7 Trace heater effectively earthed			
8 Temperature controls properly installed and set points verified			
9 Junction boxes properly marked and closed			
10 Thermal insulation weather tight (all penetrations sealed)			
11 End seals, covered splices marked on insulation outer cladding			
12 Drawings, documentation marked as-built			
Performed by:		Company	Date
Witnessed by:		Company	Date
Accepted by:		Company	Date
Approved by:		Company	Date

Annex C
(informative)

Maintenance schedule and log record

Location		System			Reference drawing(s)		
CIRCUIT INFORMATION							
Trace heater number		Circuit length			Breaker panel no.		
Power connection		Design voltage			Breaker pole(s) no.		
Tee connection		Residual current protection (type)					
Splice connection		Residual current trip setting					
Heating controller							
VISUAL							
Panel no.	Circuit no.						
	Date						
	Initial						
Thermal insulation							
Damaged insulation/ lagging							
Water seal acceptable							
Insulation/lagging missing							
Presence of moisture							
Heating system components							
Enclosures, boxes sealed							
Presence of moisture							
Signs of corrosion							
Trace heater lead discoloration							
Heating and/or high limit controller							
Operating property							
Controller set point							
ELECTRICAL							
Insulation resistance testing (bypass controller if applicable) – refer to 4.7.5 and 4.8.6 in this standard.							
Test voltage							
Megger value, MΩ							
Trace heater supply voltage							
Value at power source							
Value at field connection							
Trace heater circuit current reading							
Amps reading at (2 to 5) min at pipe temperature							
Amps reading after 15 min at pipe temperature							
Earth-fault current							
Comments and actions							
Performed by:			Company			Date	
Approved by:			Company			Date	

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1 There exists a consolidated edition 1.2 (2009) that includes edition 1 and its Amendments 1 and 2.

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