

Electrical resistance trace heating systems for industrial and commercial applications —

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

ICS 25.180.10

National foreword

This Draft for Development is the UK implementation of CLC/TS 62395-2:2010. It is identical to IEC/TS 62395-2:2008. It supersedes DD IEC/TS 62395-2:2008, which is withdrawn.

The general and testing requirements previously contained in BS EN 62086-1:2005 and BS 6351-1:1983 are now contained in BS EN 60079-30-1:2007 and BS EN 62395-1:2006.

This publication is not to be regarded as a British Standard.

It is being issued in the Draft for Development series of publications and is of a provisional nature. It should be applied on this provisional basis, so that information and experience of its practical application can be obtained.

Comments arising from the use of this Draft for Development are requested so that UK experience can be reported to the international organization responsible for its conversion to an international standard. A review of this publication will be initiated not later than three years after its publication by the international organization so that a decision can be taken on its status. Notification of the start of the review period will be made in an announcement in the appropriate issue of *Update Standards*.

According to the replies received by the end of the review period, the responsible BSI Committee will decide whether to support the conversion into an international Standard, to extend the life of the Technical Specification or to withdraw it. Comments should be sent to the Secretary of the responsible BSI Technical Committee at British Standards House, 389 Chiswick High Road, London W4 4AL.

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.

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

This Draft for Development was published under the authority of the Standards Policy and Strategy Committee on 29 August 2008

© BSI 2011

ISBN 978 0 580 72216 5

Amendments/corrigenda issued since publication

Date	Comments
30 September 2010	Supersession text added
30 June 2011	This corrigendum renumbers DD IEC/TS 62395-2:2008 as DD CLC/TS 62395-2:2010

Electrical resistance trace heating systems for industrial and commercial applications -

**Part 2: Application guide for system design, installation and maintenance
(IEC/TS 62395-2:2008)**

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/TS 62395-2:2008)

Elektrische Begleitheizungen (Trace-
Widerstandsheizungen) für industrielle
und gewerbliche Zwecke -
Teil 2: Anwendungsleitfaden für
Systementwurf, Installation und Wartung
(IEC/TS 62395-2:2008)

This Technical Specification was approved by CENELEC on 2010-10-25.

CENELEC members are required to announce the existence of this TS in the same way as for an EN and to make the TS available promptly at national level in an appropriate form. It is permissible to keep conflicting national standards in force.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Management Centre: Avenue Marnix 17, B - 1000 Brussels

CONTENTS

Foreword.....	7
1 Scope and object.....	8
2 Normative references	9
3 Terms and definitions	9
4 Surface heating of vessels and piping systems	9
4.1 Application description	9
4.1.1 General	9
4.1.2 Environmental conditions.....	9
4.1.3 Trace heating systems considerations	10
4.2 Design information – General	10
4.2.1 General	10
4.2.2 Electrical system design	10
4.2.3 Control and monitoring	10
4.2.4 Trace heating system design	11
4.2.5 Design information documentation	12
4.3 Thermal system design.....	12
4.3.1 General	12
4.3.2 Design conditions	12
4.3.3 Thermal insulation	13
4.3.4 Heat loss determination	18
4.3.5 Design safety factor.....	19
4.3.6 Heat-up considerations.....	19
4.3.7 Selection of trace heater.....	20
4.3.8 Design calculations	23
4.3.9 Theoretical sheath temperature calculations – Metallic pipe applications	23
4.3.10 Theoretical sheath temperature calculations – Non-metallic pipe applications	24
4.3.11 Design documentation	25
4.3.12 Start-up at low ambient temperatures	26
4.3.13 Long trace heater circuits	26
4.3.14 Chimney effect	26
4.4 Electrical design.....	27
4.5 Control and monitoring system design	27
4.5.1 General	27
4.5.2 Mechanical controllers.....	27
4.5.3 Electronic controllers	28
4.5.4 Application suitability.....	28
4.5.5 Location of controllers	29
4.5.6 Location of sensors	29
4.5.7 Alarm considerations	30
4.5.8 Integrated control	31
4.5.9 Flow pattern analysis.....	31
4.5.10 Dead-leg control technique	33
4.6 Special design considerations	33
4.6.1 General	33

4.6.2	Freeze protection systems.....	33
4.6.3	Sprinkler systems, fire suppression	34
4.6.4	Hot water services/tempered water	34
4.6.5	Specialty lines	35
4.7	Installation	37
4.7.1	General	37
4.7.2	Personnel aspects	37
4.7.3	Preparatory work	38
4.7.4	Preliminary installation of trace heating circuits	38
4.7.5	Insulation resistance test.....	38
4.7.6	Installation of trace heater systems	39
4.7.7	Installation of control and monitoring equipment	41
4.7.8	Necessary modifications	42
4.7.9	Installation of the thermal insulation system	42
4.7.10	Installation of electrical power	44
4.7.11	Commissioning	44
4.8	Maintenance.....	45
4.8.1	General	45
4.8.2	Training of maintenance personnel.....	45
4.8.3	Frequency of inspection.....	46
4.8.4	Maintenance program documentation	46
4.8.5	Visual evaluation	46
4.8.6	Electrical evaluation	46
4.8.7	Review of the electrical protection system	47
4.9	Repair	47
4.9.1	General	47
4.9.2	Fault location.....	47
4.9.3	Practicability of repair to electric trace heaters	47
4.9.4	Repair techniques for electrical trace heaters	48
5	Roof and gutter de-icing	48
5.1	Application description	48
5.2	Design information – General	49
5.3	Thermal design	50
5.4	Electrical design.....	50
5.5	Control and monitoring system design	50
5.6	Special design considerations	51
5.7	Installation	51
5.7.1	General	51
5.7.2	Trace heaters and component mounting	51
5.8	Maintenance.....	54
5.9	Repair	54
6	Rail heating	55
6.1	Application description	55
6.1.1	Point heating	55
6.1.2	Contact/live rail heating	55
6.1.3	Track heating	55
6.1.4	Catenary/pantograph shoe heating	55
6.2	Design information	56
6.2.1	General	56

6.2.2	Weather data.....	56
6.2.3	Surface description.....	56
6.2.4	System design.....	56
6.2.5	Performance level classification.....	56
6.3	Thermal design	56
6.3.1	General	56
6.3.2	Typical heating load	57
6.4	Electrical design.....	57
6.5	Control and monitoring system design.....	57
6.6	Special design considerations	58
6.6.1	Electrical considerations.....	58
6.6.2	Finite element analysis	58
6.7	Installation	58
6.8	Maintenance.....	61
6.9	Repair	61
7	Snow melting.....	61
7.1	Application description	61
7.2	Design information	62
7.2.1	General	62
7.2.2	Weather data.....	62
7.2.3	Construction details of workpiece	62
7.2.4	Electrical considerations.....	62
7.2.5	System performance level	62
7.2.6	Trace heater layout and component mounting	63
7.3	Thermal design – Power output (heat load) determination	67
7.4	Electrical design.....	67
7.5	Control and monitoring system design.....	67
7.6	Special design considerations	67
7.7	Installation	68
7.8	Maintenance.....	68
7.9	Repair	69
8	Floor warming	69
8.1	Application description	69
8.2	Design information	69
8.2.1	General	69
8.2.2	Environmental data.....	69
8.2.3	Construction details of workpiece	69
8.2.4	Electrical considerations.....	69
8.2.5	Trace heater layout and component mounting	70
8.3	Thermal design – Heat load determination.....	71
8.4	Electrical design.....	72
8.5	Control and monitoring system design.....	72
8.6	Special design consideration.....	72
8.7	Installation	72
8.8	Maintenance.....	73
8.9	Repair	73
9	Frost heave prevention	73
9.1	Application description	73
9.2	Design information	74

9.2.1	General	74
9.2.2	Construction details of the floor	74
9.2.3	Electrical considerations	74
9.3	Heat load determination	74
9.3.1	General	74
9.3.2	Trace heater layout and component mounting	75
9.4	Electrical design	76
9.5	Control and monitoring system design	76
9.5.1	Control options	76
9.5.2	Monitoring	76
9.6	Special design considerations	76
9.7	Installation	77
9.8	Maintenance	77
9.9	Repair	77
10	Underground thermal energy storage systems	77
10.1	Application description	77
10.2	Design information	77
10.2.1	General	77
10.2.2	Environmental data	78
10.2.3	Construction details of building	78
10.2.4	Electrical considerations	78
10.2.5	Trace heater layout and component mounting	78
10.3	Thermal design – Heat-loss determination	79
10.4	Electrical design	79
10.5	Control and monitoring system design	80
10.6	Special design considerations when trace heaters are located in sand layer	80
10.7	Installation	80
10.7.1	General	80
10.7.2	Installation in sand	80
10.7.3	Installation in concrete	80
10.8	Maintenance	81
10.9	Repair	81
Annex A (informative)	Pre-installation checks	82
Annex B (informative)	Trace heater commissioning record	83
Annex C (informative)	Maintenance schedule and log record	84
Annex ZA (normative)	Normative references to international publications with their corresponding European publications	85
Bibliography		86
Figure 1	– Thermal insulation – Weather-barrier installation	15
Figure 2	– Typical temperature profile	17
Figure 3	– Equilibrium conditions for workpiece maintenance	22
Figure 4	– Equilibrium conditions for upper limit evaluation	22
Figure 5	– Heated tank example	32
Figure 6	– Bypass example	33
Figure 7	– Double containment system	36
Figure 8	– Gravity flow piping systems	37
Figure 9	– Ice dam formation	39
Figure 10	– Downspout to underground drain	50

Figure 11 – Roof and gutter trace heater arrangement.....	52
Figure 12 – Gutter detail	52
Figure 13 – Typical roof mounting methods.....	53
Figure 14 – Drain detail for flat roof	54
Figure 15 – Typical positioning of point trace heater on stock rail and switch rail	59
Figure 16 – Typical positioning of trace heater on swing nose crossing.....	59
Figure 17 – Typical clamp lock trace heater	60
Figure 18 – Typical positioning of trace heater on steel and aluminium clad contact rails	60
Figure 19 – Typical positioning of trace heater in pantograph shoe	61
Figure 20 – Snow melting trace heater embedded in concrete	64
Figure 21 – Snow melting trace heater located in conduit	65
Figure 22 – Expansion joint detail	66
Figure 23 – Snow melting junction box location.....	66
Figure 24 – Typical floor warming trace heater mounting	71
Figure 25 – Typical floor heating power requirements	72
Figure 26 – Typical frost heave prevention substructure	74
Figure 27 – Frost heave prevention power requirements	75
Figure 28 – Typical underground thermal energy storage system installation	79
Table 1 – Application types.....	11
Table 2 – Recommendations for monitoring and control – Type II and III control	29
Table 3 – Recommendations for hot water services and tempered water temperatures	35
Table 4 – Possible trace heating load requirements	57
Table 5 – Typical snow melting heat loads.....	63

Foreword

This Technical Specification consists of the text of the Technical Specification IEC/TS 62395-2:2008 prepared by IEC TC 27, Industrial electroheating.

It was circulated for voting in accordance with the Internal Regulations, Part 2, Subclause 11.3.3.3 and was accepted as a CENELEC Technical Specification on 2010-10-25.

The following date was fixed:

- latest date by which the existence of the CLC/TS
has to be announced at national level (doa) 2011-04-25

Annex ZA has been added by CENELEC.

ELECTRICAL RESISTANCE TRACE HEATING SYSTEMS FOR INDUSTRIAL AND COMMERCIAL APPLICATIONS –

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

1 Scope and object

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 technical specification does not include or provide for any applications in potentially explosive atmospheres.

This specification pertains to trace heating systems that may comprise either factory constructed or field (work-site) assembled units, and which may be series heater cables, parallel heater cables, heater pads or heater panels that have been assembled and/or terminated in accordance with the manufacturer's instructions for connection to voltage supplies up to and including 450 V/750 V.

This Technical specification 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 with trace heating inside 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 referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-841, *International Electrotechnical Vocabulary – Part 841: Industrial electroheat*

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

IEC 62395-1:2006, *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 referenced terms and definitions are given in IEC 60519-1, IEC 62395-1 and IEC 60050-841.

4 Surface heating of vessels and piping systems

4.1 Application description

4.1.1 General

Piping and vessels are often provided with 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 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 typically has only a small range of exposure temperatures. 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.

Particular attention should be given to the materials of piping systems, as well as the trace heating systems, as related to an effective earth-leakage/ground-fault return path. The use of non-metallic, lined or coated piping systems may complicate the earth-leakage/ground-fault return path. The electrical return paths established at the time of installation may become degraded due to corrosion during long-term operation.

4.2 Design information – General

4.2.1 General

The requirements for system design varies from simply following installation instructions for freeze protection to the development of electrical, control and monitoring, 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 with the requirements of this technical specification. 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 describes the basic types of controls and monitoring and 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 a critical component of 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

- compensation of heat loss when maintaining a specified temperature of an application, see the calculation method in 4.3.4; and/or
- 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 requirements are described in 4.6.

4.2.5 Design information documentation

For plant level and other complex systems, design information is 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 insulation 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.

Insulation 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 insulating with cement, install a barrier over the trace heater to prevent the insulating cement from isolating it from the workpiece (creating excessive heater temperatures).

4.3.3.3 Selection of weather barrier (cladding)

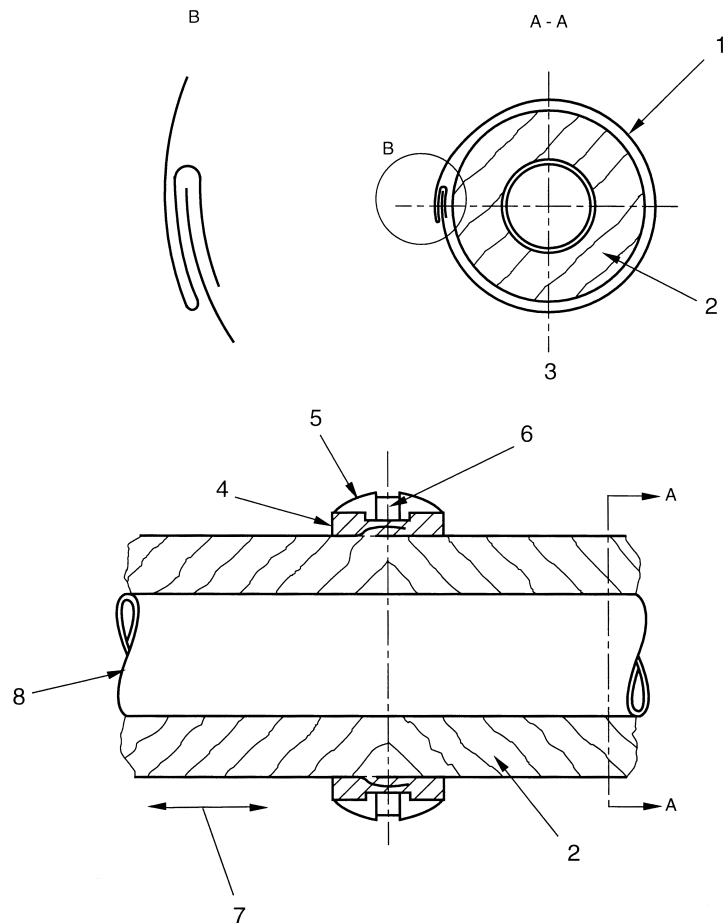
Proper operation of an electrically trace heated system depends upon the insulation being dry. Electric tracing normally has insufficient heat output to dry out wet thermal insulation. Some insulation materials, even though removed from the piping and force dried, never regain their full insulating capability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



IEC 748/08

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

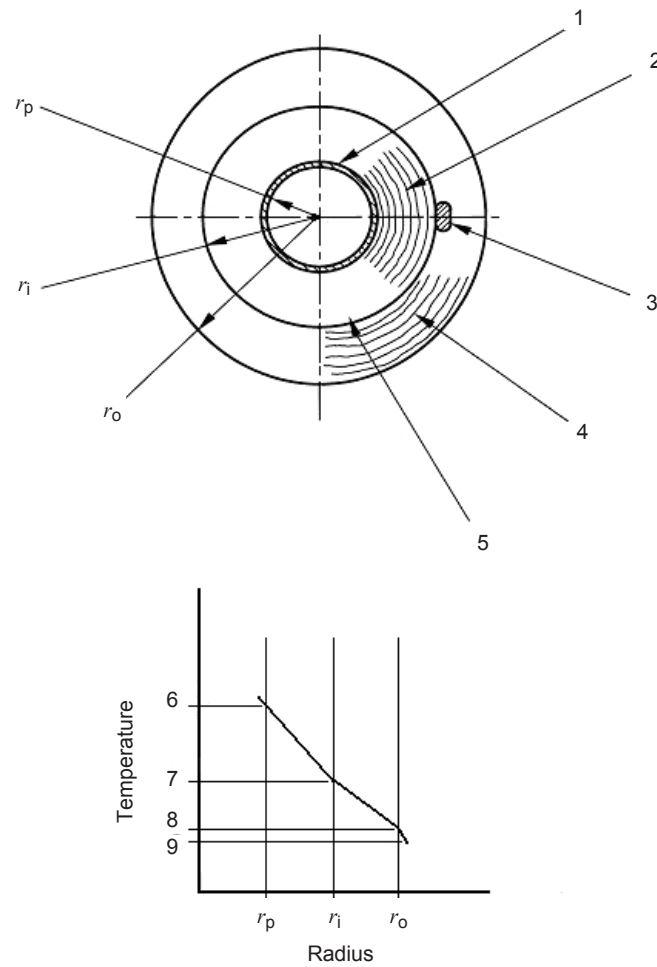
Quality caulking of weather barrier penetrations is required to prevent water ingress and contamination of thermal insulation systems. Structural supports and trace heater connection kits are examples of such penetrations. Low quality caulking materials dry out and crack, allowing gaps for water ingress.

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.



IEC 749/08

Key

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

Figure 2 – Typical temperature profile

4.3.4 Heat loss determination

The heat loss of a workpiece can be calculated from the following equation 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/m²K);
- h_{co} is the inside air contact convection coefficient from the outer insulation surface to the weather barrier when present (W/m²K);
- h_o is the outside air film convection coefficient from the weather barrier to ambient (W/m²K) (typical values for this term range from 5 W/m²K to 50 W/m²K for low-temperature applications below 50 °C).

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

The basic equation 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:

- thermal insulation degradation;
- supply voltage variations;
- branch wiring voltage drop;
- trace heater voltage drop;
- increased radiation and convection on higher temperature applications;
- 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 equation.

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

where

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

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

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:

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

where

- P_1 is the density of the product in the pipe (kg/m³);
- C_{p1} is the specific heat of the product (J/kgK);
- V_{c1} is the internal volume of the pipe (m³/m);
- P_2 is the density of the pipe (kg/m³);
- C_{p2} is the specific heat of the pipe (J/kgK);
- V_{c2} is the pipe wall volume (m³/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 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.

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 equations 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 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 $-20\text{ }^{\circ}\text{C}$), and how the heat loss increases as the workpiece temperature increases. In this case the heat loss at the desired maintenance temperature of $10\text{ }^{\circ}\text{C}$ 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.

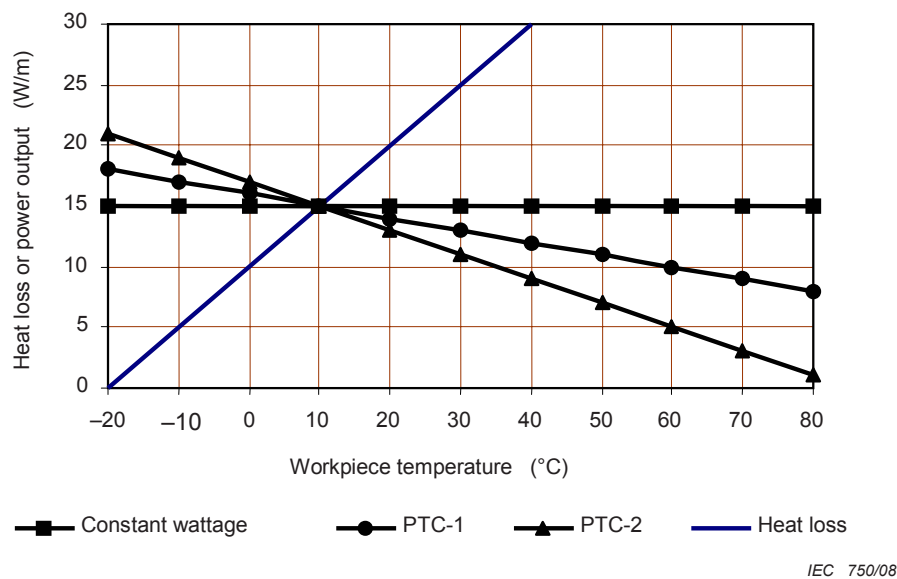


Figure 3 – Equilibrium conditions for workpiece maintenance

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.

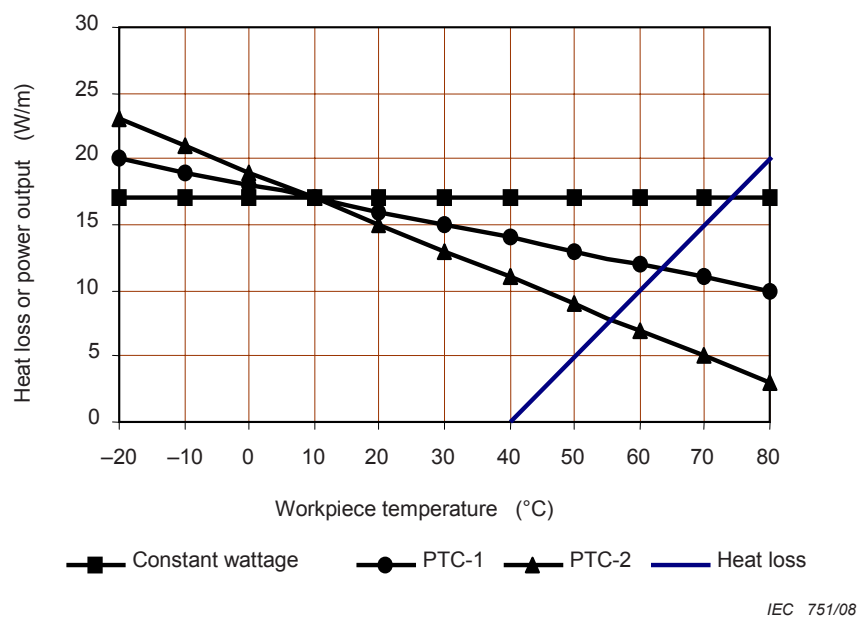


Figure 4 – Equilibrium conditions for upper limit evaluation

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 5.2.9 of IEC 62395-1 (2006).

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 5.2.11.2 of IEC 62395-1 (2006). Typically, the maximum surface temperature of the trace heater is calculated from equations 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.

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

where

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

NOTE The maximum process pipe temperature may 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 equations. Iterative techniques may need to be applied to the calculation of Equation (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:

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

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/m²K).

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/m²K for a cylindrical trace heater in air (primarily convective) to 170 W/m²K 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.

The sheath temperature of the trace heater under normal operating conditions is in principle obtained from Equation (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

$$\frac{1}{U_p} = \frac{1}{U_m} + \frac{L}{k_p} \quad (8)$$

where

U_p is the overall heat transfer coefficient for a non-metallic pipe (W/m²K);

U_m is the overall heat transfer coefficient for a metallic pipe (W/m²K);

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,

$$T_{sh} = \frac{Q_{sf}}{U_p C} + T_f \quad (9)$$

where

Q_{sf} is the upper tolerance trace heater output (W/m);

T_f is the fluid temperature (°C).

Equation (9) is a conservative simplification of a complex problem that involves criteria beyond the scope of this technical specification. 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;