

# TECHNICAL SPECIFICATION

# SPÉCIFICATION TECHNIQUE

**Electrical resistance trace heating systems for industrial and commercial applications –  
Part 2: Application guide for system design, installation and maintenance**

**Systemes 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**

<https://standards.iec.org/06/507/cd-7c61-4f32-838b-81f0dee82f8a/iec-ts-62395-2-2008>

WATERMARK



## THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2008 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester.

If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de la CEI ou du Comité national de la CEI du pays du demandeur.

Si vous avez des questions sur le copyright de la CEI ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de la CEI de votre pays de résidence.

IEC Central Office  
3, rue de Varembe  
CH-1211 Geneva 20  
Switzerland  
Email: [inmail@iec.ch](mailto:inmail@iec.ch)  
Web: [www.iec.ch](http://www.iec.ch)

### About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

### About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

- Catalogue of IEC publications: [www.iec.ch/searchpub](http://www.iec.ch/searchpub)

The IEC on-line Catalogue enables you to search by a variety of criteria (reference number, text, technical committee,...). It also gives information on projects, withdrawn and replaced publications.

- IEC Just Published: [www.iec.ch/online\\_news/justpub](http://www.iec.ch/online_news/justpub)

Stay up to date on all new IEC publications. Just Published details twice a month all new publications released. Available on-line and also by email.

- Electropedia: [www.electropedia.org](http://www.electropedia.org)

The world's leading online dictionary of electronic and electrical terms containing more than 20 000 terms and definitions in English and French, with equivalent terms in additional languages. Also known as the International Electrotechnical Vocabulary online.

- Customer Service Centre: [www.iec.ch/webstore/custserv](http://www.iec.ch/webstore/custserv)

If you wish to give us your feedback on this publication or need further assistance, please visit the Customer Service Centre FAQ or contact us:

Email: [csc@iec.ch](mailto:csc@iec.ch)

Tel.: +41 22 919 02 11

Fax: +41 22 919 03 00

### A propos de la CEI

La Commission Electrotechnique internationale (CEI) est la première organisation mondiale qui élabore et publie des normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

### A propos des publications CEI

Le contenu technique des publications de la CEI est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

- Catalogue des publications de la CEI: [www.iec.ch/searchpub/cur\\_fut-f.htm](http://www.iec.ch/searchpub/cur_fut-f.htm)

Le Catalogue en-ligne de la CEI vous permet d'effectuer des recherches en utilisant différents critères (numéro de référence, texte, comité d'études,...). Il donne aussi des informations sur les projets et les publications retirées ou remplacées.

- Just Published CEI: [www.iec.ch/online\\_news/justpub](http://www.iec.ch/online_news/justpub)

Restez informé sur les nouvelles publications de la CEI. Just Published détaille deux fois par mois les nouvelles publications parues. Disponible en-ligne et aussi par email.

- Electropedia: [www.electropedia.org](http://www.electropedia.org)

Le premier dictionnaire en ligne au monde de termes électroniques et électriques. Il contient plus de 20 000 termes et définitions en anglais et en français, ainsi que les termes équivalents dans les langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International en ligne.

- Service Clients: [www.iec.ch/webstore/custserv/custserv\\_entry-f.htm](http://www.iec.ch/webstore/custserv/custserv_entry-f.htm)

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions, visitez le FAQ du Service clients ou contactez-nous:

Email: [csc@iec.ch](mailto:csc@iec.ch)

Tél.: +41 22 919 02 11

Fax: +41 22 919 03 00

# TECHNICAL SPECIFICATION

# SPÉCIFICATION TECHNIQUE

---

**Electrical resistance trace heating systems for industrial and commercial applications –  
Part 2: Application guide for system design, installation and maintenance**

**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**

INTERNATIONAL  
ELECTROTECHNICAL  
COMMISSION

COMMISSION  
ELECTROTECHNIQUE  
INTERNATIONALE

PRICE CODE  
CODE PRIX

**XC**

## CONTENTS

FOREWORD.....	7
INTRODUCTION.....	9
1 Scope and object.....	10
2 Normative references .....	11
3 Terms and definitions .....	11
4 Surface heating of vessels and piping systems.....	11
4.1 Application description .....	11
4.1.1 General .....	11
4.1.2 Environmental conditions.....	11
4.1.3 Trace heating systems considerations .....	12
4.2 Design information – General .....	12
4.2.1 General .....	12
4.2.2 Electrical system design .....	12
4.2.3 Control and monitoring .....	12
4.2.4 Trace heating system design .....	13
4.2.5 Design information documentation.....	14
4.3 Thermal system design.....	14
4.3.1 General .....	14
4.3.2 Design conditions .....	14
4.3.3 Thermal insulation .....	15
4.3.4 Heat loss determination.....	20
4.3.5 Design safety factor.....	21
4.3.6 Heat-up considerations.....	21
4.3.7 Selection of trace heater.....	22
4.3.8 Design calculations .....	25
4.3.9 Theoretical sheath temperature calculations – Metallic pipe applications.....	25
4.3.10 Theoretical sheath temperature calculations – Non-metallic pipe applications.....	26
4.3.11 Design documentation .....	27
4.3.12 Start-up at low ambient temperatures .....	28
4.3.13 Long trace heater circuits .....	28
4.3.14 Chimney effect .....	28
4.4 Electrical design.....	29
4.5 Control and monitoring system design .....	29
4.5.1 General .....	29
4.5.2 Mechanical controllers.....	29
4.5.3 Electronic controllers .....	30
4.5.4 Application suitability.....	30
4.5.5 Location of controllers .....	31
4.5.6 Location of sensors .....	31
4.5.7 Alarm considerations .....	32
4.5.8 Integrated control .....	33
4.5.9 Flow pattern analysis.....	33
4.5.10 Dead-leg control technique.....	35
4.6 Special design considerations .....	35
4.6.1 General .....	35

4.6.2	Freeze protection systems.....	35
4.6.3	Sprinkler systems, fire suppression .....	36
4.6.4	Hot water services/tempered water .....	36
4.6.5	Specialty lines .....	37
4.7	Installation .....	39
4.7.1	General .....	39
4.7.2	Personnel aspects .....	39
4.7.3	Preparatory work .....	40
4.7.4	Preliminary installation of trace heating circuits .....	40
4.7.5	Insulation resistance test.....	40
4.7.6	Installation of trace heater systems .....	41
4.7.7	Installation of control and monitoring equipment.....	43
4.7.8	Necessary modifications.....	44
4.7.9	Installation of the thermal insulation system .....	44
4.7.10	Installation of electrical power .....	46
4.7.11	Commissioning .....	46
4.8	Maintenance.....	47
4.8.1	General .....	47
4.8.2	Training of maintenance personnel.....	47
4.8.3	Frequency of inspection.....	48
4.8.4	Maintenance program documentation .....	48
4.8.5	Visual evaluation .....	48
4.8.6	Electrical evaluation .....	48
4.8.7	Review of the electrical protection system .....	49
4.9	Repair .....	49
4.9.1	General .....	49
4.9.2	Fault location.....	49
4.9.3	Practicability of repair to electric trace heaters .....	49
4.9.4	Repair techniques for electrical trace heaters .....	50
5	Roof and gutter de-icing.....	50
5.1	Application description .....	50
5.2	Design information – General .....	51
5.3	Thermal design .....	52
5.4	Electrical design.....	52
5.5	Control and monitoring system design .....	52
5.6	Special design considerations .....	53
5.7	Installation .....	53
5.7.1	General .....	53
5.7.2	Trace heaters and component mounting .....	53
5.8	Maintenance.....	56
5.9	Repair .....	56
6	Rail heating.....	57
6.1	Application description .....	57
6.1.1	Point heating .....	57
6.1.2	Contact/live rail heating .....	57
6.1.3	Track heating .....	57
6.1.4	Catenary/pantograph shoe heating .....	57
6.2	Design information .....	58
6.2.1	General .....	58

6.2.2	Weather data.....	58
6.2.3	Surface description.....	58
6.2.4	System design.....	58
6.2.5	Performance level classification.....	58
6.3	Thermal design .....	58
6.3.1	General .....	58
6.3.2	Typical heating load .....	59
6.4	Electrical design.....	59
6.5	Control and monitoring system design .....	59
6.6	Special design considerations .....	60
6.6.1	Electrical considerations.....	60
6.6.2	Finite element analysis .....	60
6.7	Installation .....	60
6.8	Maintenance.....	63
6.9	Repair .....	63
7	Snow melting.....	63
7.1	Application description .....	63
7.2	Design information .....	64
7.2.1	General .....	64
7.2.2	Weather data.....	64
7.2.3	Construction details of workpiece .....	64
7.2.4	Electrical considerations.....	64
7.2.5	System performance level.....	64
7.2.6	Trace heater layout and component mounting .....	65
7.3	Thermal design – Power output (heat load) determination .....	69
7.4	Electrical design.....	69
7.5	Control and monitoring system design .....	69
7.6	Special design considerations .....	69
7.7	Installation .....	70
7.8	Maintenance.....	70
7.9	Repair .....	71
8	Floor warming .....	71
8.1	Application description .....	71
8.2	Design information .....	71
8.2.1	General .....	71
8.2.2	Environmental data.....	71
8.2.3	Construction details of workpiece .....	71
8.2.4	Electrical considerations.....	71
8.2.5	Trace heater layout and component mounting .....	72
8.3	Thermal design – Heat load determination.....	73
8.4	Electrical design.....	74
8.5	Control and monitoring system design .....	74
8.6	Special design consideration .....	74
8.7	Installation .....	74
8.8	Maintenance.....	75
8.9	Repair .....	75
9	Frost heave prevention.....	75
9.1	Application description .....	75
9.2	Design information .....	76

9.2.1	General .....	76
9.2.2	Construction details of the floor .....	76
9.2.3	Electrical considerations .....	76
9.3	Heat load determination .....	76
9.3.1	General .....	76
9.3.2	Trace heater layout and component mounting .....	77
9.4	Electrical design .....	78
9.5	Control and monitoring system design .....	78
9.5.1	Control options .....	78
9.5.2	Monitoring .....	78
9.6	Special design considerations .....	78
9.7	Installation .....	79
9.8	Maintenance .....	79
9.9	Repair .....	79
10	Underground thermal energy storage systems .....	79
10.1	Application description .....	79
10.2	Design information .....	79
10.2.1	General .....	79
10.2.2	Environmental data .....	80
10.2.3	Construction details of building .....	80
10.2.4	Electrical considerations .....	80
10.2.5	Trace heater layout and component mounting .....	80
10.3	Thermal design – Heat-loss determination .....	81
10.4	Electrical design .....	81
10.5	Control and monitoring system design .....	82
10.6	Special design considerations when trace heaters are located in sand layer .....	82
10.7	Installation .....	82
10.7.1	General .....	82
10.7.2	Installation in sand .....	82
10.7.3	Installation in concrete .....	82
10.8	Maintenance .....	83
10.9	Repair .....	83
Annex A (informative)	Pre-installation checks .....	84
Annex B (informative)	Trace heater commissioning record .....	85
Annex C (informative)	Maintenance schedule and log record .....	86
Bibliography	.....	87
Figure 1	– Thermal insulation – Weather-barrier installation .....	17
Figure 2	– Typical temperature profile .....	19
Figure 3	– Equilibrium conditions for workpiece maintenance .....	24
Figure 4	– Equilibrium conditions for upper limit evaluation .....	24
Figure 5	– Heated tank example .....	34
Figure 6	– Bypass example .....	35
Figure 7	– Double containment system .....	38
Figure 8	– Gravity flow piping systems .....	39
Figure 9	– Ice dam formation .....	51
Figure 10	– Downspout to underground drain .....	52

Figure 11 – Roof and gutter trace heater arrangement.....	54
Figure 12 – Gutter detail .....	54
Figure 13 – Typical roof mounting methods.....	55
Figure 14 – Drain detail for flat roof .....	56
Figure 15 – Typical positioning of point trace heater on stock rail and switch rail .....	61
Figure 16 – Typical positioning of trace heater on swing nose crossing.....	61
Figure 17 – Typical clamp lock trace heater .....	62
Figure 18 – Typical positioning of trace heater on steel and aluminium clad contact rails .....	62
Figure 19 – Typical positioning of trace heater in pantograph shoe .....	63
Figure 20 – Snow melting trace heater embedded in concrete .....	66
Figure 21 – Snow melting trace heater located in conduit .....	67
Figure 22 – Expansion joint detail .....	68
Figure 23 – Snow melting junction box location.....	68
Figure 24 – Typical floor warming trace heater mounting .....	73
Figure 25 – Typical floor heating power requirements.....	74
Figure 26 – Typical frost heave prevention substructure .....	76
Figure 27 – Frost heave prevention power requirements.....	77
Figure 28 – Typical underground thermal energy storage system installation .....	81
Table 1 – Application types.....	13
Table 2 – Recommendations for monitoring and control – Type II and III control.....	31
Table 3 – Recommendations for hot water services and tempered water temperatures .....	37
Table 4 – Possible trace heating load requirements .....	59
Table 5 – Typical snow melting heat loads.....	65



## INTERNATIONAL ELECTROTECHNICAL COMMISSION

**ELECTRICAL RESISTANCE TRACE HEATING SYSTEMS  
FOR INDUSTRIAL AND COMMERCIAL APPLICATIONS –****Part 2: Application guide for system design,  
installation and maintenance**

## FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with an IEC Publication.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

The main task of IEC technical committees is to prepare International Standards. In exceptional circumstances, a technical committee may propose the publication of a technical specification when

- the required support cannot be obtained for the publication of an International Standard, despite repeated efforts, or
- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC 62395-2, which is a technical specification, has been prepared by IEC technical committee 27: Industrial electroheating equipment.

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
27/582/DTS	27/606A/RVC

Full information on the voting for the approval of this technical specification can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of IEC 62395, under the general title *Electrical resistance trace heating systems for industrial and commercial applications*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

- transformed into an International standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

iTech Standards  
(<https://standards.itih.ai>)  
Document Preview

IEC TS 62395-2:2008

<https://standards.itih.ai/standards/iec/08f567cd-7c61-4f32-838b-81f0dee82f8a/iec-ts-62395-2-2008>

WITHDRAWN

## 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/TS 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 should 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 should include a metallic sheath, braid, screen or equivalent electrically conductive covering;
- b) operating at safe temperatures when designed, installed, and maintained in accordance with IEC/TS 62395-2;
- c) having at least the minimum levels of overcurrent and ground fault protection requirements in IEC 62395-1 (2006) (4.3).

iTech Standards  
(<https://standards.iteh.ai>)  
Document Preview

IEC TS 62395-2:2008

<https://standards.iteh.ai/standards/iec/62395-2/iec/62395-2-2008>

WITHDRAWN

# 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