

INTERNATIONAL STANDARD

NORME INTERNATIONALE



**Safety in installations for electroheating and electromagnetic processing –
Part 1: General requirements**

**Sécurité dans les installations destinées au traitement électrothermique
et électromagnétique –
Partie 1: Exigences générales**



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Safety in installations for electroheating and electromagnetic processing – Part 1: General requirements

Sécurité dans les installations destinées au traitement électrothermique et électromagnétique – Partie 1: Exigences générales

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CONTENTS

FOREWORD	7
INTRODUCTION	9
1 Scope	10
2 Normative references	10
3 Terms, definitions and abbreviated terms	14
3.1 General concepts	14
3.2 Equipment and state of equipment	16
3.3 Parts and accessories	17
3.4 Safety related concepts	19
3.5 Abbreviated terms	20
4 Classification and subdivision of equipment and installations	21
4.1 Classification by processing frequency	21
4.2 Classification by voltage	22
4.3 Subdivision of installation and equipment	23
4.3.1 Subdivision into parts	23
4.3.2 Hierarchy and structure of requirements	25
4.4 Classification of hazards and risks	25
4.4.1 Classification of hazards	25
4.4.2 Classification of risks	26
5 Risk assessment	26
6 General provisions	27
6.1 Basic considerations	27
6.2 Significant hazards	28
6.3 Physical environment and operating conditions for the installation as such and electrical equipment outside the processing equipment	28
6.4 Physical environment and operating conditions for electrical equipment caused by operation of the processing equipment	29
6.5 Power supply	30
6.6 Access	31
6.7 Ergonomic aspects	31
6.8 Transport and storage	31
6.9 Provisions for handling	32
6.10 Consumables and replaceable parts	32
7 Protection against hazards from electric shock	32
7.1 General	32
7.2 Fundamental rule of protection	32
7.3 General provisions	33
7.4 Basic protection	34
7.5 Provisions for protection in electric single fault condition	35
7.6 Protective equipotential bonding	36
7.7 Additional provisions for fault protection for frequencies above 200 Hz	38
7.8 Currents in protective conductors	39
7.9 Touch current and touch voltage	39
7.10 Conductors and insulations at high temperature	40
7.11 Non-electric faults	40
8 Protection against hazards from electric or magnetic fields	40

8.1	General.....	40
8.2	Magnetic fields.....	40
8.3	Magnetic fields below 1 Hz	41
8.4	Local electric fields	41
8.5	Requirements related to barriers and screens	41
8.6	Requirements related to objects worn, carried or held by persons	42
9	Protection against hazards from radiation	43
9.1	General.....	43
9.2	Installation or equipment generating ionizing radiation	43
9.3	Ultraviolet radiation	44
9.4	Visible and infrared radiation	44
9.5	Laser sources	45
10	Protection against hazards from thermal influences	45
10.1	General.....	45
10.2	Surface temperature limits for protection against burn	45
10.3	Hazards caused by working conditions.....	46
10.4	Temperature resistance of components.....	46
10.5	Cooling	46
10.6	Over-temperature protection	47
11	Protection against hazards from fire	48
12	Protection against hazards from fluids	48
12.1	General.....	48
12.2	Poisonous and injurious fluids.....	49
12.3	Explosion and implosion of pressurised parts or vacuum equipment	50
13	Specific requirements for components and subassemblies	50
13.1	General.....	50
13.2	Electrical equipment and conductors.....	50
13.3	Connection to the electrical supply network and internal connections.....	51
13.4	Isolation and switching	52
13.5	Sensors and actuators safeguarding moving parts	52
13.6	Motors	52
13.7	Non electric-heating means.....	52
13.8	Lighting.....	53
13.9	Structural parts and stability.....	53
13.10	Doors, windows and other openings.....	53
13.11	Transformers, inductors, capacitors	53
13.12	Handheld applicators	53
13.13	Vacuum system	54
13.14	Protective and reactive gas generator.....	54
14	Control of the installation or equipment.....	54
14.1	General.....	54
14.2	Operator control unit.....	54
14.3	Emergency stop	55
14.4	Control systems and their safety functions	55
14.5	Controlgear	56
14.6	Protective devices.....	57
14.7	Over-temperature protection devices and systems	57
14.8	Overpressure safety device.....	58

15	Protection against mechanical hazards	58
16	Protection against hazards resulting from use	59
16.1	Particular hazards in processing of food, feed, cosmetics and similar intended for human or animal consumption	59
16.2	Combination equipment	59
17	EMC	59
17.1	Radio frequency interference	59
17.2	Immunity	60
18	Verification and testing	60
18.1	General	60
18.2	Performing measurements and tests	62
18.3	Verification of requirements from references	63
18.4	Examination of drawings or calculations	63
18.5	Visual inspection	63
18.6	Measurements	63
18.6.1	Environment and operating conditions inside the processing equipment	63
18.6.2	Impedance of protective bonding	63
18.6.3	Insulation resistance measurement	64
18.6.4	Measurement of electric or magnetic fields	64
18.6.5	Touch current measurement	64
18.6.6	Measurement of ionising radiation	64
18.6.7	Measurement of non-coherent optical irradiation	64
18.6.8	Measurement of coherent optical radiation	65
18.6.9	Surface temperature measurement	65
18.6.10	Temperature of structural components subject to heat	65
18.7	Functional tests	65
18.7.1	Protection by automatic disconnection of supply	65
18.7.2	Voltage test	65
18.7.3	Dielectric test	65
18.7.4	Accessibility of live parts	65
18.7.5	Protective devices and systems	66
18.8	Numerical calculations and modelling	66
18.8.1	General	66
18.8.2	Numerical assessment of short circuit currents	66
18.8.3	Numerical assessment of electric or magnetic emission	66
18.8.4	Numerical assessment of optical radiation emission	67
19	Information for use	67
19.1	General requirements	67
19.2	Location and nature of the information for use	68
19.3	Signalling and warning devices	68
19.4	Markings, pictograms, written warnings	68
19.5	Instruction handbook	69
Annex A (normative)	List of significant hazards	73
Annex B (normative)	Limits to touch currents	79
B.1	General	79
B.2	Risk classes	80
B.3	Body model	80
Annex C (normative)	Non coherent optical radiation – Limits and risk classes	82

C.1	General.....	82
C.2	Boundary of the installation or equipment and assessment	82
C.3	Non-coherent optical radiation – Risk classes	83
C.3.1	Approach.....	83
C.3.2	Optical radiation – Risk class 0.....	83
C.3.3	Risk class 1 (low risk).....	83
C.3.4	Risk class 2 (moderate risk).....	84
C.3.5	Risk class 3 (high risk)	84
C.3.6	Pulsed equipment.....	84
C.3.7	Radiation from laser sources	84
Annex D (normative)	Electric and magnetic fields	85
D.1	General.....	85
D.2	Boundary of the installation or equipment and assessment	85
D.3	Risk classes.....	85
D.3.1	General	85
D.3.2	Risk class 0	86
D.3.3	Risk class 1 (low risk).....	86
D.3.4	Risk class 2 (moderate risk).....	86
D.3.5	Risk class 3 (high risk)	86
Annex E (normative)	Surface temperature limits	87
Annex F (normative)	EH, EPM and fire.....	88
F.1	Occurrence of fire	88
F.2	Inherently safe design measures.....	88
F.3	Safeguarding and/or complementary protective measures	88
F.4	Information for use.....	89
Annex G (normative)	Marking and warning.....	90
G.1	Electromagnetic field hazards	90
G.2	Touch currents and surfaces.....	90
G.3	Optical radiation hazards	91
G.4	Symbols and signs used for markings and warnings.....	91
Annex H (informative)	Guidelines on using this document.....	93
H.1	Guidelines	93
H.2	Examples of EH and EPM equipment.....	94
Annex I (informative)	Connection with ISO 13577 (all parts).....	95
Annex J (informative)	Requirements specific to the EU and associated countries.....	96
J.1	General.....	96
J.2	Connection with ISO 13577 series	96
Bibliography.....		97
Figure 1 – Block diagram of a typical EH or EPM installation		23
Figure B.1 – Maximum allowed touch and contact currents between 1 kHz to 100 kHz.....		79
Figure B.2 – Complex impedances of various parts of the body, 1 kHz to 6 MHz.....		81
Figure G.1 – Examples of marking for magnetic and electric fields.....		90
Figure G.2 – Examples of marking for touch current.....		90
Figure G.3 – Examples of marking for optical radiation		91
Figure J.1 – Hierarchy of standards applicable to thermoprocessing machinery		96

Table 1 – Equipment, processing frequency and safety-relevant frequency limits	22
Table 2 – Typical EH or EPM installation – Listing of parts and references	24
Table 3 – Safety classification scheme for risks to humans	26
Table 4 – Classification of thermal protective measures	47
Table 5 – Methods for the verification of requirements	61
Table A.1 – List of hazards dealt with in this document	73
Table B.1 – Risk classification for hazards from touch currents	80
Table C.1 – Risk classification for optical radiation (UV, VIS, IR)	82
Table E.1 – Surface temperature limits in normal operation	87
Table G.1 – Examples of symbols and signs for use in EH or EPM installations	91

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**SAFETY IN INSTALLATIONS FOR ELECTROHEATING
AND ELECTROMAGNETIC PROCESSING –****Part 1: General requirements**

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International Standard IEC 60519-1 has been prepared by IEC technical committee 27: Industrial electroheating and electromagnetic processing.

This sixth edition cancels and replaces the fifth edition published in 2015. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) removal of noise from the scope;
- b) clarification of EMC requirements;
- c) risk classification of hazards based on emission for all processing frequencies;
- d) clarification of boundaries between IEC 60519 (all parts) and ISO 13577 (all parts).

The text of this International Standard is based on the following documents:

FDIS	Report on voting
27/1121/FDIS	27/1123/RVD

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

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

In this document, the following print types are used:

- requirements and definitions: in roman type;
- NOTES: in smaller roman type;
- **terms** used throughout this standard which have been defined in Clause 3: **in bold type**.

A list of all parts in the IEC 605019 series, published under the general title *Safety in installations for electroheating and electromagnetic processing*, can be found on the IEC website.

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INTRODUCTION

These general requirements apply to all industrial **EH** and **EPM equipment**, unless an exception is given in the Particular requirements dealing with specific equipment in other parts of the IEC 60519 series. The provisions of other parts of the IEC 60519 series that directly apply to specific types of equipment take precedence over the provisions of this document.

Annex I and Annex J provide orientation with respect to the application of ISO 13577-1 in combination with this document.

This document presumes that the installation or equipment is operated and maintained only by personnel consisting of **skilled** or **instructed persons**.

This document is intended for verifying whether the **EH** or **EPM installation** or **equipment** meets the safety requirements of this document through design, site acceptance tests, routine tests or inspection.

Annex H provides a guide on the use of this document and a list of typical industrial **EH** and **EPM** processes.

SAFETY IN INSTALLATIONS FOR ELECTROHEATING AND ELECTROMAGNETIC PROCESSING –

Part 1: General requirements

1 Scope

This part of IEC 60519 specifies the general safety requirements for industrial installations or equipment intended for **electroheating (EH)** and **electroheating** based treatment technologies as well as for **electromagnetic processing of materials (EPM)**. This document deals with the significant hazards, hazardous situations or hazardous events relevant to industrial **EH** and **EPM equipment**, as listed in Annex A, for **normal operation** and for **single fault condition** as well as under conditions of reasonably foreseeable misuse.

This document specifies the requirements intended to be met by the **manufacturer** to ensure the safety of persons and property during the complete life cycle of the equipment from design through commissioning, operation, maintenance, inspection, to decommissioning, as well as in the event of foreseeable **single fault condition** that can occur in the equipment.

The rated voltage of **EH** and **EPM equipment** can be in the range of low voltage; details are given in 4.2.

This document does not apply to equipment and appliances within the scope of

- IEC 60079 (all parts) – i.e. equipment intended for use in potentially explosive atmospheres;
- IEC 60335 (all parts) – i.e. household, commercial and similar electrical appliances, including room heating;
- IEC 60601 (all parts) – i.e. medical electrical equipment;
- IEC 60974 (all parts) – i.e. arc welding equipment;
- IEC 61010 (all parts) – i.e. equipment for laboratory use.

This document does not provide requirements for type testing.

NOTE Industrial equipment covered by this document is typically produced as a single unit or a very small number of units; such unit usually has a very high value and can cause severe harm at disintegration.

This document does not address data security and hazards arising from neglect of security.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 60071-1:2006 ¹, *Insulation co-ordination – Part 1: Definitions, principles and rules*
IEC 60071-1:2006/AMD1:2010

¹ A consolidated version of this publication exists, comprising IEC 60071-1:2006 and IEC 60071-1:2006/AMD1:2010.

IEC 60204-1:2016, *Safety of machinery – Electrical equipment of machines – Part 1: General requirements*

IEC 60204-11:2018, *Safety of machinery – Electrical equipment of machines – Part 11: Requirements for equipment for voltages above 1 000 V AC or 1 500 V DC and not exceeding 36 kV*

IEC 60228:2004, *Conductors of insulated cables*

IEC 60335-1:2010², *Household and similar electrical appliances – Safety – Part 1: General requirements*

IEC 60335-1:2010/AMD1:2013

IEC 60335-1:2010/AMD2:2016

IEC 60335-2-24, *Household and similar electrical appliances – Safety – Part 2-24: Particular requirements for refrigerating appliances, ice-cream appliances and ice makers*

IEC 60335-2-89, *Household and similar electrical appliances – Safety – Part 2-89: Particular requirements for commercial refrigerating appliances with an incorporated or remote refrigerant unit or compressor*

IEC 60364-1:2005, *Low-voltage electrical installations – Part 1: Fundamental principles, assessment of general characteristics, definitions*

IEC 60364-4-41:2005³, *Low-voltage electrical installations – Part 4-41: Protection for safety – Protection against electric shock*

IEC 60364-4-41:2005/AMD1:2017

IEC 60364-4-42:2010⁴, *Low-voltage electrical installations – Part 4-42: Protection for safety – Protection against thermal effects*

IEC 60364-4-42:2010/AMD1:2014

IEC 60364-4-44:2007⁵, *Low-voltage electrical installations – Part 4-44: Protection for safety – Protection against voltage disturbances and electromagnetic disturbances*

IEC 60364-4-44:2007/AMD1:2015

IEC 60364-4-44:2007/AMD2:2018

IEC 60364-5-53:2001⁶, *Electrical installations of buildings – Part 5-53: Selection and erection of electrical equipment – Isolation, switching and control*

IEC 60364-5-53:2001/AMD1:2002

IEC 60364-5-53:2001/AMD2:2015

IEC 60364-5-54:2011, *Low-voltage electrical installations – Part 5-54: Selection and erection of electrical equipment – Earthing arrangements and protective conductors*

² A consolidated version of this publication exists, comprising IEC 60335-1:2010, IEC 60335-1:2010/AMD1:2013 and IEC 60335-1:2010/AMD2:2016.

³ A consolidated version of this publication exists, comprising IEC 60364-4-41:2005 and IEC 60364-4-41:2005/AMD1:2017.

⁴ A consolidated version of this publication exists, comprising IEC 60364-4-42:2010 and IEC 60364-4-42:2010/AMD1:2014.

⁵ A consolidated version of this publication exists, comprising IEC 60364-4-44:2007, IEC 60364-4-44:2007/AMD1:2015 and IEC 60364-4-44:2007/AMD2:2018.

⁶ A consolidated version of this publication exists, comprising IEC 60364-5-53:2001, IEC 60364-5-53:2001/AMD1:2002 and IEC 60364-5-53:2001/AMD2:2015.

IEC 60398:2015, *Installations for electroheating and electromagnetic processing – General performance test methods*

IEC 60417, *Graphical symbols for use on equipment* (available at <http://www.graphical-symbols.info/equipment>)

IEC 60445:2017, *Basic and safety principles for man-machine interface, marking and identification – Identification of equipment terminals, conductor terminations and conductors*

IEC 60529:1989, *Degrees of protection provided by enclosures (IP Code)*

IEC 60664-1:2007, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

IEC 60825-1:2014, *Safety of laser products – Part 1: Equipment classification and requirements*

IEC 60865-1:2011, *Short-circuit currents – Calculation of effects – Part 1: Definitions and calculation methods*

IEC 60909-0:2016, *Short-circuit currents in three-phase a.c. systems – Part 0: Calculation of currents*

IEC 60990:2016, *Methods of measurement of touch current and protective conductor current*

IEC 61000-6-2:2016, *Electromagnetic compatibility (EMC) – Part 6-2: Generic standards – Immunity standard for industrial environments*

IEC 61000-6-7:2014, *Electromagnetic compatibility (EMC) – Part 6-7: Generic standards – Immunity requirements for equipment intended to perform functions in a safety-related system (functional safety) in industrial locations*

IEC 61010-1:2010, *Safety requirements for electrical equipment for measurement, control, and laboratory use – Part 1: General requirements*

IEC 61082-1:2014, *Preparation of documents used in electrotechnology – Part 1: Rules*

IEC 61310-1:2007, *Safety of machinery – Indication, marking and actuation – Part 1: Requirements for visual, acoustic and tactile signals*

IEC 61310-2:2007, *Safety of machinery – Indication, marking and actuation – Part 2: Requirements for marking*

IEC 61310-3:2007, *Safety of machinery – Indication, marking and actuation – Part 3: Requirements for the location and operation of actuators*

IEC 61439 (all parts), *Low-voltage switchgear and controlgear assemblies*

IEC 61508-1:2010, *Functional safety of electrical/electronic/programmable electronic safety-related systems – Part 1: General requirements*

IEC 61786-1:2013, *Measurement of DC magnetic, AC magnetic and AC electric fields from 1 Hz to 100 kHz with regard to exposure of human beings – Part 1: Requirements for measuring instruments*

IEC 61786-2:2014, *Measurement of DC magnetic, AC magnetic and AC electric fields from 1 Hz to 100 kHz with regard to exposure of human beings – Part 2: Basic standard for measurements*

IEC 61936-1:2010 ⁷, *Power installations exceeding 1 kV a.c. – Part 1: Common rules*
IEC 61936-1:2010/AMD1:2014

IEC 62061:2005 ⁸, *Safety of machinery – Functional safety of safety-related electrical, electronic and programmable electronic control systems*

IEC 62061:2005/AMD1:2012

IEC 62061:2005/AMD2:2015

IEC 62271 (all parts), *High-voltage switchgear and controlgear*

IEC 62471:2006, *Photobiological safety of lamps and lamp systems*

IEC 82079-1:2012, *Preparation of instructions for use – Structuring, content and presentation – Part 1: General principles and detailed requirements*

CISPR 11:2015⁹, *Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement*

CISPR 11:2015/AMD1:2016

CISPR 11:2015/AMD2:2019

IEEE C95.1:2005, *IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz*

IEEE C95.6:2002, *IEEE Standard for Safety Levels with Respect to Human Exposure to Electromagnetic Fields, 0–3 kHz*

ISO 3864-1:2011, *Graphical symbols – Safety colours and safety signs – Part 1: Design principles for safety signs and safety markings*

ISO 6385:2016, *Ergonomics principles in the design of work systems*

ISO 7000, *Graphical symbols for use on equipment* (available at <http://www.graphical-symbols.info/equipment>)

ISO 7010, *Graphical symbols – Safety colours and safety signs – Safety signs used in workplaces and public areas*

ISO 12100:2010, *Safety of machinery – General principles for design – Risk assessment and risk reduction*

ISO 13577-1:2016, *Industrial furnaces and associated processing equipment – Safety – Part 1: General requirements*

ISO 13577-2:2014, *Industrial furnaces and associated processing equipment – Safety – Part 2: Combustion and fuel handling systems*

⁷ A consolidated version of this publication exists, comprising IEC 61936-1:2010 and IEC 61936-1:2010/AMD1:2014.

⁸ A consolidated version of this publication exists, comprising IEC 62061:2005, IEC 62061:2005/AMD1:2012 and IEC 62061:2005/AMD2:2015.

⁹ A consolidated version of this publication exists, comprising CISPR 11:2015, CISPR 11:2015/AMD1:2016 and CISPR 11:2015/AMD2:2019.

ISO 13577-3:2016, *Industrial furnaces and associated processing equipment – Safety – Part 3: Generation and use of protective and reactive atmosphere gases*

ISO 13732-1:2006, *Ergonomics of the thermal environment – Methods for the assessment of human responses to contact with surfaces – Part 1: Hot surfaces*

ISO 13849-1:2015, *Safety of machinery – Safety-related parts of control systems – Part 1: General principles for design*

ISO 13850:2015, *Safety of machinery – Emergency stop function – Principles for design*

ISO 13855:2010, *Safety of machinery – Positioning of safeguards with respect to the approach speeds of parts of the human body*

ISO 13857:2008, *Safety of machinery – Safety distances to prevent hazard zones being reached by upper and lower limbs*

ISO 14119:2013, *Safety of machinery – Interlocking devices associated with guards – Principles for design and selection*

ISO 14120:2015, *Safety of machinery – Guards – General requirements for the design and construction of fixed and movable guards*

ISO 14159:2002, *Safety of machinery – Hygiene requirements for the design of machinery*

ISO 19353:2019, *Safety of machinery – Fire prevention and fire protection*

3 Terms, definitions and abbreviated terms

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1 General concepts

3.1.1

electroheating

EH

DEPRECATED: electroheat

conversion of electric energy into heat for useful purposes

Note 1 to entry: This note applies to the French language only.

3.1.2

electromagnetic processing of materials

EPM

interaction between electromagnetic energy or forces and materials for useful purposes

Note 1 to entry: **EPM** can include but is not limited to heating.

Note 2 to entry: This note applies to the French language only.

3.1.3**electromagnetic field****EMF**

electric or magnetic field or a combination of electric and magnetic time varying field

Note 1 to entry: This note applies to the French language only.

3.1.4**electromagnetic radiation**

propagating **electromagnetic field** transporting energy

EXAMPLE Microwave radiation or optical radiation (infrared, visible and ultraviolet).

3.1.5**near-field region**

<of an electromagnetic field> region near an antenna where non-propagating **electromagnetic field** effects dominate

Note 1 to entry: The **near-field region** is further subdivided into the reactive **near-field region**, which is closest to the radiating structure and that contains most or nearly all of the stored energy, and the radiating **near-field region** where the radiation field predominates over the reactive field, but lacks substantial plane-wave character and is complex in structure.

Note 2 to entry: The non-radiating part of the **electromagnetic fields** dominates significantly in a region up to about a distance of 0,5 wavelengths from the antenna.

3.1.6**manufacturer**

producer of the **EH** or **EPM equipment** or **installation** responsible for compliance with this document

Note 1 to entry: The **manufacturer** in the sense of this document can also be a supplier, distributor, importer or authorised representative.

3.1.7**user**

party responsible for the operation and maintenance of the **EH** or **EPM equipment** or **installation**, from putting into service to de-commissioning

3.1.8**skilled person****trained person**

person with suitable education, knowledge and experience to perceive risks and to avoid hazards which can be relevant for the type of installation or equipment, including supervision of the **instructed persons**

Note 1 to entry: The term **trained person** is used in ISO 13577 (all parts).

3.1.9**instructed person**

person advised or supervised by **skilled persons**, able to perceive risks and to avoid hazards which an installation or equipment can create

3.1.10**operator**

skilled person or **instructed person** performing one or more tasks during operation, adjustment, maintenance, repair or disassembly of an installation or equipment

3.1.11**ordinary person**

person not trained or skilled to perceive risks and avoid hazards, who can be harmed by **exposure** to lower limits than **operators**

EXAMPLE A member of the general public including pregnant, elderly or disabled persons, but not children.

3.1.12

vacuum

pressure lower than 30 000 Pa

Note 1 to entry: Defined as a pressure lower than any environmental pressure on the land surface of earth.

Note 2 to entry: **Vacuum** is divided into the following pressure ranges:

- rough **vacuum** from 100 Pa to 10 000 Pa;
- fine **vacuum** from 0,1 Pa to 100 Pa;
- high **vacuum** from 10^{-5} Pa to 0,1 Pa;
- ultra high **vacuum** below 10^{-5} Pa.

3.2 Equipment and state of equipment

3.2.1

electrical equipment

set of items used to generate, convert, transmit, distribute or utilize electric energy, such as converters, transformers, capacitors, switchgear and control gear, measuring instruments, **protective devices** and wiring systems

3.2.2

electroheating equipment

EH equipment

DEPRECATED: electroheat equipment

equipment in which electric work is converted into heat for useful purposes

Note 1 to entry: This note applies to the French language only.

3.2.3

equipment for electromagnetic processing of materials

EPM equipment

equipment in which electromagnetic energy or electromagnetic force is provided for the **electromagnetic processing of materials**

Note 1 to entry: This note applies to the French language only.

3.2.4

electroheating installation

EH installation

DEPRECATED: electroheat installation

installation composed of **EH equipment**, **electrical equipment** and mechanical equipment needed for its operation and use

Note 1 to entry: This note applies to the French language only.

3.2.5

installation for electromagnetic processing of materials

EPM installation

installation composed of **EPM equipment**, **electrical equipment** and mechanical equipment needed for its operation and use

Note 1 to entry: This note applies to the French language only.

3.2.6

normal operation

operation of the installation or equipment as specified by the **manufacturer** and agreed with the **user**

3.2.7

workload

object or material being processed

Note 1 to entry: The term "load" has a different meaning. Load is used and defined accordingly in the Particular requirements of IEC 60519 (all parts), if available.

3.2.8

single fault condition

condition in which there is a fault of a single protection (but not a reinforced protection) or of a single component or a device

Note 1 to entry: If a **single fault condition** results in one or more other fault conditions, all are considered as one single fault condition.

Note 2 to entry: A **single fault condition** may or may not affect the process or the intended operation of the **EH** or **EPM installation** or **equipment**.

Note 3 to entry: An incident that stops the **normal operation**, that directly causes hazards or that leads to direct disintegration of the **EH** or **EPM installation** or **equipment** or parts of it is not a **single fault condition** in the understanding of this definition, it is then a major damage, an average, an accident.

[SOURCE: IEC Guide 104:2019, 3.8, modified – Notes 2 and 3 have been added.]

3.2.9

electric single fault condition

condition in which one means for protection against electric shock is defective or one fault is present which could cause a hazard

Note 1 to entry: **Electric single fault condition** is identical to **single fault condition** as defined in IEC 61140:2016.

[SOURCE: IEC 61140:2016, 3.1.4, modified – The original term "single fault condition" has been changed to "**electric single fault condition**" and the note has been replaced by a new one.]

3.2.10

processing frequency

DEPRECATED: output frequency

operating frequency of the **EH** or **EPM equipment** or **installation** at which the current or field is applied to the **workload**

Note 1 to entry: Specific ranges of **processing frequencies** are defined in Table 1.

3.3 Parts and accessories

3.3.1

enclosure

housing affording the type and degree of protection suitable for the intended application

[SOURCE: IEC 60050-195:1998, 195-02-35]

3.3.2

window

part of an **enclosure** that allows passage of some kind of radiation

3.3.3

barrier

physical object limiting access to equipment or the **enclosure** of that equipment, which can only be removed with the use of a tool or is interlocked

Note 1 to entry: A **barrier** can be physically separated from the equipment, but is a part of the installation.

Note 2 to entry: **Barriers** are usually transparent to the processing electric, magnetic field or radiation.

3.3.4

guard

barrier that is a part of the equipment

3.3.5

obstacle

item impeding access, which is secured to prevent unintentional removal but is removable without a tool or key

3.3.6

protective device

<electrical>

electrical device that reduces a risk

EXAMPLE Two-hand control, pressure sensitive mat or edge, trip bar and wire, light curtain, laser scanner.

3.3.7

screen

device intended to reduce the penetration of an electric, magnetic or **electromagnetic field** into a given region

[SOURCE: IEC 60050-151:2001, 151-13-09, modified – The second term "shield" has been omitted.]

3.3.8

interlock

mechanical or electrical **protective device** or system that prevents an action which can create a hazard

3.3.9

thermal cut-out

temperature protector

device switching off the equipment when the pre-determined temperature is exceeded

Note 1 to entry: **Thermal cut-outs** are not resettable and are replaced each time they have operated; **temperature protectors** are resettable.

3.3.10

handheld applicator

easily movable device providing an electric or magnetic field or **electromagnetic radiation** to a **workload**

EXAMPLE Contacting applicators being in direct contact with the **workload** to be treated; insertion applicators, to be inserted into the **workload**; coil applicators, like hand held induction coils; lamp and luminaire units, irradiating a **workload**.

Note 1 to entry: "Easily movable" implies lightweight.

3.3.11

means of access

all features of the **EH** or **EPM installation** or **equipment** which can be opened or removed and enable access to a hazard or hazard zone

Note 1 to entry: **Means of access** can be part of the **enclosure**, **obstacles** or **doors**.

Note 2 to entry: **Means of access** can be secured by an **interlock**.

3.4 Safety related concepts

3.4.1

functional test

way to test specified functions of a system without regard to its internal structure

[SOURCE: IEC TR 62059-11:2002, 3.6, modified – The note has been removed.]

3.4.2

live part

conductor or conductive part intended to be energized in **normal operation**, including a neutral conductor, but by convention not a PEN conductor or PEM conductor or PEL conductor

Note 1 to entry: This concept does not necessarily imply a risk of electric shock.

[SOURCE: IEC 60050-195:1998, 195-02-19]

3.4.3

hazardous-live-part

live part which, under certain conditions, can give a harmful electric shock

[SOURCE: IEC 60050-195:1998, 195-06-05]

3.4.4

high-voltage hazard zone

zone limited by the minimum clearance around **hazardous-live-parts** of high voltage equipment without complete protection against direct contact

Note 1 to entry: Entering the **high-voltage hazard zone** is considered the same as touching **hazardous-live parts**.

3.4.5

touch voltage

voltage between conductive parts when touched simultaneously by a person or an animal

Note 1 to entry: The value of the effective **touch voltage** may be appreciably influenced by the impedance of the person or the animal in electric contact with these conductive parts.

[SOURCE: IEC 60050-195:1998, 195-05-11, modified – The other term "(effective) touch voltage" is not used in this document.]

3.4.6

touch current

electric current flowing through the body of a person or an animal when a **touch voltage** is present and a conductive path available

3.4.7

leakage current

electric current in an unwanted conductive path under normal operating conditions

3.4.8

induced electric shock

physiological effect caused by an induced electric field inside the human body

Note 1 to entry: Effect usually observed in the **near-field region** of an **electromagnetic field**; it does not necessitate contact to a conductor. The effects are essentially the same as those of electric shock caused through contact to a conductor, for example burn or nerve reaction.

3.4.9

insulation

insulating materials ensuring proper operation of the equipment and protection against electric shock

Note 1 to entry: **Insulation** also refers to the action of insulating.

Note 2 to entry: Under certain circumstances, thermal insulating material can equally perform the function of the electrical **insulation**.

3.4.10

basic insulation

insulation of hazardous-live-parts which provides basic protection

Note 1 to entry: This concept does not apply to **insulation** used exclusively for functional purposes.

[SOURCE: IEC 60050-195:1998, 195-06-06]

3.4.11

galvanic separation

prevention of electric conduction between two electric circuits intended to exchange power and/or signals

Note 1 to entry: **Galvanic separation** can be provided for example by an isolating transformer or an opto-coupler.

[SOURCE: IEC 60050-151:2001, 151-12-26]

3.4.12

emission

<as a concept> energy sent out from a source in the form of a field, particles, a chemical agent, pressure or other physical agent

3.4.13

emission

<for assessment> detectable energy emitted from and detectable outside the boundary of an **EH** or **EPM installation** or equipment in the absence of a human or animal disturbing the field or flow of energy

3.4.14

exposure

receiving or absorbing emitted energy by a person or an animal

Note 1 to entry: The determination of absorbed energy may necessitate the presence of the exposed person or animal in the **emission**.

3.4.15

accessible emission

level of radiation or field determined at a certain distance from the **EH** or **EPM installation** or equipment and being accessible in **normal operation** or **single fault condition**

3.4.16

emission limit

maximum **accessible emission** permitted for a particular risk class

3.5 Abbreviated terms

EH **electroheating**

ELV extra low voltage (below 50 V at mains frequency)

EMC electromagnetic compatibility

EPM **electromagnetic processing of materials**

HV	high voltage (above 1 000 V at mains frequency)
IR	infrared radiation
LED	light-emitting diode
LV	low voltage (the range between 50 V and 1 000 V at mains frequency)
MW	microwave
PE	protective earthing conductor
PEL	protective earthing conductor being a line conductor as well
PEM	protective earthing conductor being a mid-point conductor as well
PEN	protective earthing conductor being a neutral conductor as well
SAR	specific absorption rate of energy
UV	ultraviolet radiation
VIS	visible radiation

4 Classification and subdivision of equipment and installations

4.1 Classification by processing frequency

EH and **EPM installation** and **equipment** is classified by its **processing frequency**. Table 1 lists the equipment types and their **processing frequency** ranges as well as safety relevant frequency limits. An **EH** or **EPM installation** may include more than one type of **EH** or **EPM equipment**.

Table 1 – Equipment, processing frequency and safety-relevant frequency limits

Equipment type	Frequency range ^a defining equipment type	Frequency range ^b used for safety limits	Hazards associated with the frequency range
Direct current ^c or stationary field	0 Hz	0 Hz or no change in polarity	Electric shock, neural stimulus, dizziness
Low frequency	> 0 Hz to < 60 Hz		Electric shock, burn, not let-go, neural stimulus
Mains frequency	50 Hz or 60 Hz		
Medium frequency	> 60 Hz to 100 kHz	> 60 Hz to 100 kHz	
High frequency	> 100 kHz to 0,3 GHz	> 100 kHz to 6 MHz	Burn, bodypart heating
		> 6 MHz to 0,3 GHz	Bodypart heating
Microwave	> 0,3 GHz to 300 GHz		
Infrared	780 nm to 1 mm	IR-C 3 000 nm to 1 mm	Burn of skin and cornea
		IR-B 1 400 nm to 3 000 nm	
		IR-A 780 nm to 1 400 nm	Burn of skin and cornea, burn of retina
Visible	400 nm to 780 nm		
Ultraviolet ^d	10 nm to 400 nm	UV-A 315 nm to 400 nm	Burn of skin and cornea, skin cancer
		UV-B 280 nm to 315 nm	
		UV-C 100 nm to 280 nm	
		EUV 10 nm to 100 nm	
Laser	10 nm to 1 mm (> 300 GHz to 30 PHz)		Burn of skin, cornea and retina
^a Rated processing frequency .			
^b Values of the corresponding free space wavelengths are also given in case of optical radiation.			
^c Direct current type – equipment with no intended change of polarity, but including switch-on and switch-off.			
^d The definition of UV follows IEC 62471:2006; radiation between 380 nm and 400 nm is usually sensed.			

4.2 Classification by voltage

The supply voltage of an installation or equipment is classified as

- extra low voltage (ELV) below 50 V (RMS) at mains frequency or 120 V direct current,
- low voltage (LV) between 50 V (RMS) at mains frequency or 120 V direct current and 1 000 V (RMS) at mains frequency or 1 500 V direct current, and
- high voltage (HV) above 1 000 V (RMS) at mains frequency or 1 500 V direct current.

NOTE The definitions of ELV and voltage band 1, LV and voltage band 2 and HV and voltage band 3 are identical. Voltages below 25 V mains frequency or 60 V direct current are seen as without risk for any **ordinary person** in most circumstances (exception is possible in wet conditions).

This distinction shall be made for the installation and for parts as defined in 4.3.1 and

- depending on the supply and the output voltage, whichever is the higher value (internal voltages inside the **electrical equipment** may be higher), but
- not depending on the process voltage or internal voltage of the installation or equipment.

Different parts of one installation may be classified as ELV, LV or HV.

4.3 Subdivision of installation and equipment

4.3.1 Subdivision into parts

An **EH** or **EPM installation** consists of diverse and specific parts. Figure 1 presents a block diagram of a typical installation for reference. It determines the boundary of installations and equipment. Not all parts are found in every kind of an **EH** or **EPM installation**.

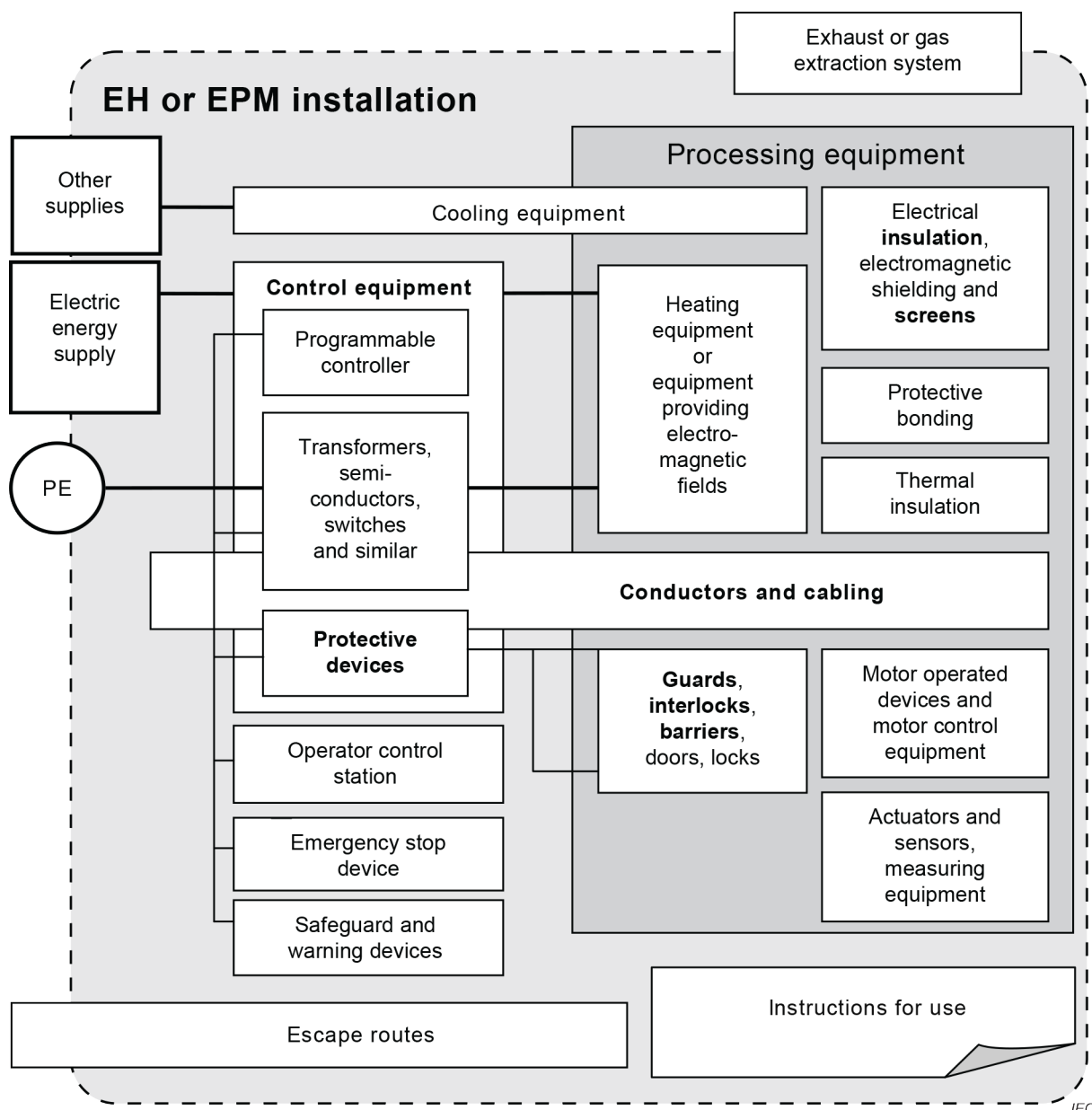


Figure 1 – Block diagram of a typical EH or EPM installation

Table 2 provides references to clauses of this document or to other standards relevant to the parts identified in Figure 1. The requirements for equipment outside the processing equipment are covered by IEC or ISO standards specified in Table 2. The basic sources of safety provisions for **electrical equipment** of **EH** or **EPM installations** and **equipment** are IEC 60204-1 for LV and IEC 60204-11 for HV.

The safety requirements for the processing equipment itself are specific because of its extraordinary environment and of conditions inside or near, where

- a) extreme temperatures can interact with the equipment,

- b) strong electric, magnetic or **electromagnetic fields** can interact with the equipment, and
 c) thermal energy or electromagnetic forces can endanger the structural integrity of the equipment or of **insulation** and of protective means.

Table 2 – Typical EH or EPM installation – Listing of parts and references

Part of installation or equipment – See Figure 1		Condition for which the reference is valid	Reference/source of provisions
Part	Component/item		
Electric energy supply		LV, ≤ 200 Hz	IEC 60364-4-41, IEC 60364-4-42, IEC 60364-4-44, IEC 60364-5-53, IEC 60364-5-54, IEC 60445, IEC 60664-1
Protective earth, PE			
Protective bonding			
Electric energy supply		HV, ≤ 200 Hz	IEC 61936-1, IEC 60071-1
Protective earth, PE			
Protective bonding			
Electric energy supply		all other, ≤ 36 kV	Clause 7
Protective earth, PE			
Protective bonding			
Conductors and cabling at standard environmental conditions		< 40 °C	IEC 60228
Conductors and cabling exposed to non-standard environmental conditions		> 40 °C	6.4.2 and 13.2
Control equipment	Switchgear and controlgear	LV, ≤ 200 Hz	IEC 60204-1
		HV, ≤ 36 kV, ≤ 200 Hz	IEC 60204-11
		> 36 kV, ≤ 200 Hz	Particular requirements
		> 200 Hz	Clause 7
	Programmable controller	all	IEC 61508-1, IEC 62061, ISO 13849-1
	Protective device		
Operator control station (same as switchgear and controlgear)		< 1 000 V, ≤ 200 Hz	IEC 60204-1
		> 1 000 V, ≤ 200 Hz	IEC 60204-11
		all other	Clauses 7 and 8
Emergency stop device (same as switchgear and controlgear)		< 1 000 V, ≤ 200 Hz	IEC 60204-1
		> 1 000 V, ≤ 200 Hz	IEC 60204-11
		all other	ISO 13850
Safeguard and warning devices (same as switchgear and controlgear)		< 1 000 V, ≤ 200 Hz	IEC 60204-1
		> 1 000 V, ≤ 200 Hz	IEC 60204-11
		all other	ISO 13850
Other supplies –for example fluids, compressed air		all	Clause 12; ISO 13577-3
Gaseous or liquid fuels		all	ISO 13577-2
Fluid extraction system		all	Clause 12; ISO 13577-1
Exhaust		all	ISO 13577-1
Escape routes		all	IEC 60364-4-42

Part of installation or equipment – See Figure 1		Condition for which the reference is valid	Reference/source of provisions
Part	Component/item		
Processing equipment	Electroheating equipment	see 6.4	Clauses 7, 8, 9, 10; Particular requirements
	Non-electric heating equipment		ISO 13577-1 ISO 13577-2
	Equipment providing electromagnetic fields		Clauses 7, 8, 9, 10; Particular requirements
	Thermal insulation		Clause 10; ISO 13577-1
	Electrical insulation		Clauses 7, 8, 9, 10
	Electromagnetic shielding		Clauses 7, 8, 9, 10
	Actuators and sensors		IEC 61310-1 IEC 61310-2 IEC 61310-3
	Measuring equipment		IEC 61010-1 Particular requirements
	Motor operated devices and motor control equipment		IEC 60204-1
	Guards, interlocks, barriers, doors, locks		ISO 14119 ISO 14120 Particular requirements
	Cooling		Clauses 10 and 12

4.3.2 Hierarchy and structure of requirements

The following rules are a guideline especially with respect to the requirements on electromagnetic safety, which comprises electric shock, **induced electric shock**, **touch currents** and other effects of **electromagnetic fields**.

- For all parts of an installation that fall under the scope of one of the standards listed in Table 2, that standard shall be used.
- For equipment or parts outside the scope of any of the standards listed in Table 2, Clauses 7 and 8 apply, i.e. for equipment with frequencies above 200 Hz or intended to be used at temperatures higher than 40 °C.
- Equipment exceeding the voltage limit of 36 kV is dealt with in the Particular requirements.
- Further guidance on the references given in Table 2 is provided in the respective clauses of this document.

4.4 Classification of hazards and risks

4.4.1 Classification of hazards

Hazards are differentiated as

- hazards where the harm is immediate – i.e. any accident which directly results in harm, and
- hazards where the harm depends on the **exposure**, accumulation or dose – for example on intensity, a field strength, an **exposure** time.

EXAMPLE 1 Immediate hazards are electric shock, the ejection of objects, explosion, mechanical hazards like cutting or falling, toxic substances of potentially lethal dose.

EXAMPLE 2 **Exposure** related hazards are **exposure** to optical or microwave radiation, **exposure** to electric or magnetic fields, **exposure** to sound or noise, **exposure** to ionizing radiation, toxic or radioactive substances.

NOTE Contact with hot surfaces or hot substances can be dose-related at low temperatures, or immediate, for example direct contact to liquid metals.

Hazards are differentiated as

- c) sensed hazards – i.e. hazards creating adverse body reactions, and
- d) non-sensed hazards or non-perceivable hazards.

EXAMPLE 3 Sensed hazards are temperature of material or of environment, intense visible radiation, fast moving parts, acceleration, vibration or noise.

EXAMPLE 4 Non-sensed or non-perceivable hazards are UV radiation, ionising radiation or radioactive substances, toxic substances, microwave, magnetic or electric fields.

4.4.2 Classification of risks

A specific risk depends on **emission**, duration, intensity of the agent, but also on the exposed bodypart, awareness or sensing of the agent, experience or information about the type of hazard, and behavioural factors such as aversion or withdrawal. Risks are treated through a level categorisation with non-perceivable hazards being categorised as requiring particular protective measures. The **manufacturer** reduces **emissions** of possibly hazardous agents or informs the **user** about residual risks. A classification scheme guides this action. Table 3 summarises the classification of residual **emissions** used in this document.

Table 3 – Safety classification scheme for risks to humans

Risk class		Restrictions and protective measures	Information and training
0	exempt	No restriction or protective measures necessary	No information needed.
1	low risk	Restrictions like limitation of access or protective measures may be indicated depending on the result of a risk assessment done by the user	Information about hazards, risks and secondary effects to be provided by the manufacturer .
2	moderate risk	Special restrictions and protective measures essential	Information about hazards, risks and secondary effects to be provided by the manufacturer . The manufacturer shall indicate to the user , if specific training of the operator is necessary.
3a	high risk	Access possible when protected by personal protective equipment	Information about hazards, risks and secondary effects to be provided by the manufacturer . The manufacturer shall indicate to the user , the necessary specific training of the operator and the personal protective equipment.
3	high risk	No access	Information about hazards, risks and secondary effects to be provided by the manufacturer .

Each spatial position or hazard zone shall be considered individually. **Normal operation** and **single fault condition** shall be taken into account.

5 Risk assessment

This document is based on the risk assessment provided in Annex A.

This risk assessment shall be expanded and specified accordingly throughout the development of the Particular requirements of IEC 60519 (all parts).

The risk assessment in Annex A covers a very broad cluster of equipment and installations, therefore it is quite generic and may not cover specific origins, particular hazardous situations or events, or potential consequences in the details deemed necessary by the **manufacturer**. The **manufacturer** shall then add to this risk assessment the specifics of his technical solution as specified in ISO 12100:2010.

If the **manufacturer** intends to make an equipment or installation not fully under the scope of this document and its risk assessment, or if the Particular requirement is outdated and not referring to this document or no Particular requirement exists, he is advised to reconsider the risk assessment in Annex A. This document then assists with the risk assessment and risk reduction procedure as specified in ISO 12100:2010.

6 General provisions

6.1 Basic considerations

6.1.1 The **EH** or **EPM installation** or **equipment** shall be suitable for its intended use, it shall be designed to be operated, adjusted and maintained without putting persons at risk. Design and construction shall ensure adequate reduction of the risks during **normal operation** or in **single fault condition**, at the state of the art and considering the foreseeable lifetime of the **EH** or **EPM installation** or **equipment**.

Any risk through the **workload** when the **workload** is processed as intended in the **EH** or **EPM installation** and that is foreseeable to the **manufacturer** shall be adequately reduced.

6.1.2 The **EH** or **EPM installation** or **equipment** shall be designed to prevent or to reduce the possibility of misuse or fault condition.

6.1.3 The **EH** or **EPM installation** or **equipment** shall not pose a risk of the immediate or non-perceivable types, unless the intended use is otherwise impossible to achieve. Additional protective measures, warnings and instructions shall be provided in such cases.

6.1.4 The **manufacturer** shall, in the following order,

- a) eliminate risks to achieve an inherent safe installation or equipment,
- b) provide protective measures for those risks that are not eliminated, and
- c) provide all necessary information to the **user** about residual risks, indicate necessary training and personal protective equipment.

6.1.5 Protective measures are a combination of measures incorporated at the design stage and measures being indicated as to be implemented by the **user**. The **manufacturer** shall incorporate all measures identified to be necessary according to Clauses 5 through 17 when applicable.

6.1.6 If a specific hazard is in risk class 1 or 2 as defined in Table 3 and cannot be reduced further by the **manufacturer**, the **manufacturer** shall provide detailed information for the **user**, including

- a) a graphical description or plan of the installation indicating the position and extent of areas belonging to zones with risk class 1 or 2,
- b) information on signalling and warning devices – see 19.3,
- c) necessary marking and written warning – see 19.4,
- d) indication of necessary restrictions and protective measures to be taken by the **user** – see 19.5,

- e) indication of the necessary information for the **operators** – see 19.5, and
- f) indication of working procedures that are safe or reduce the risk.

6.1.7 If a specific hazard is in risk class 3a as defined in Table 3 and cannot be reduced further by the **manufacturer**, the **manufacturer** shall provide detailed information for the **user**, including

- a) a graphical description or plan of the installation indicating the position and extent of areas belonging to zones with risk class 3a,
- b) information on signalling and warning devices – see 19.3,
- c) necessary marking and written warning – see 19.4,
- d) indication of necessary restrictions and protective measures to be taken by the **user** – see 19.5,
- e) indication of the necessary information for the **operators** – see 19.5,
- f) indication of the necessary personal protective equipment to be worn by the **operator** when attending, and
- g) indication of working procedures that are safe or reduce the risk.

6.1.8 If a specific hazard is in risk class 3 as defined in Table 3 and cannot be reduced further by the **manufacturer**, the **manufacturer** shall provide detailed information for the **user**, including

- a) a graphical description or plan of the installation indicating the position and extent of areas belonging to zones with risk class 3,
- b) information on signalling and warning devices – see 19.3,
- c) necessary marking and written warning – see 19.4, and
- d) indication of the necessary information for the **operators** – see 19.5.

6.1.9 Adequate risk reduction shall not be confused with the reduction of **exposure** to levels near **exposure** limits. Adequate risk reduction eliminates a hazard, or if this is impossible, reduces **exposure** to the technical limit. The adequate use of **exposure** limits is the responsibility of the **user**.

6.2 Significant hazards

Provisions for protection against the identified significant hazards defined in Annex A are specified in Clauses 6 to 17. Verification of compliance with the provisions of this document shall be done according to Clause 18.

6.3 Physical environment and operating conditions for the installation as such and electrical equipment outside the processing equipment

6.3.1 The **EH** or **EPM installation** or **equipment** and its **electrical equipment** not placed inside the processing equipment shall be suitable for the physical environment and operating conditions of its intended use.

When special conditions apply or the limits specified in 6.3 are exceeded, an agreement between the **manufacturer** and **user** may be necessary. Subclause 4.1 of IEC 60204-1:2016 is applicable for LV installations and 4.1 of IEC 60204-11:2018 is applicable for HV installations.

6.3.2 The **EH** or **EPM installation** or **equipment** shall not generate electromagnetic disturbances above levels that are appropriate for its intended operating environment.

6.3.3 The **EH** or **EPM installation** or **equipment** shall be capable of operating safely in the intended ambient air temperature. The minimum requirement for all **electrical equipment** is safe operation at air temperatures between 5 °C and 40 °C.

6.3.4 The **EH** or **EPM installation** or **equipment** shall be capable of operating safely when the relative humidity does not exceed 50 % at a maximum temperature of 40 °C. Higher relative humidity is permitted at lower temperatures (e.g. less than 90 % at 20 °C). The **EH** or **EPM installation** or **equipment** shall either be able to operate safely if condensation happens occasionally or the **manufacturer** shall avoid condensation by design or, where necessary, by additional measures (e.g. built-in heaters, air conditioners or drain holes).

6.3.5 The **EH** or **EPM installation** or **equipment** shall be capable of operating safely at air pressure expected at up to 1 000 m altitude and under a wide range of climate and weather conditions. The lower ambient pressure limit shall be 85 % of normal sea-level atmospheric pressure, unless agreed differently between the **manufacturer** and the **user** and specified in the instructions for use.

For equipment intended to be used at higher altitudes or lower air pressure, it is necessary to take into account the reduction of the dielectric strength, the switching capability of the devices and the reduction of the cooling effect of the air caused by reduced density.

6.3.6 The **electrical equipment** of the **EH** or **EPM installation** or **equipment** shall be adequately protected against the ingress of solids and liquids according to 11.3 of IEC 60204-1:2016 for LV equipment. It shall be adequately protected against contaminants (e.g. dust, acids, corrosive gases or salts) that can be present in the physical environment for which it is intended.

6.3.7 When the **EH** or **EPM installation** or **equipment** or parts of it are exposed to radiation (e.g. MW, UV, laser or X-ray), additional measures shall be taken to avoid malfunctioning of the equipment, accelerated deterioration of the **insulation**, metal degradation or corrosion due to radiation induced effects.

6.3.8 Undesirable effects on the **EH** or **EPM installation** or **equipment** caused by vibration, shock and bump (including those generated by the installation and its associated equipment and those created by the physical environment) shall be avoided by the selection of suitable equipment, by mounting it away from the equipment creating the vibration or shock, or by provision of anti-vibration or anti-shock mountings.

6.3.9 When the **EH** or **EPM installation** or **equipment** or parts of it are exposed to plasma, corrosive chemicals or other adverse agents, additional measures shall be taken to avoid malfunctioning, accelerated deterioration of the **insulation**, metal degradation or corrosion due to radiation induced effects.

6.4 Physical environment and operating conditions for electrical equipment caused by operation of the processing equipment

6.4.1 The **electrical equipment** of the **EH** or **EPM installation** or **equipment** placed inside or near the processing equipment shall be suitable for the physical environment and operating conditions of its intended use. Physical conditions inside or near the processing equipment cover a wide range of different environments; it may be necessary for the **manufacturer** and **user** to agree on these conditions.

6.4.2 The **electrical equipment** shall be capable of operating correctly under **normal operation** and **single fault condition**

- a) at the intended temperature levels inside and outside the processing equipment,
- b) at the humidity levels inside and outside the processing equipment (extreme humidity levels or strong condensation can be expected as well as total immersion),
- c) at intended atmospheric conditions inside and outside the processing equipment,
- d) under prevalent electric and magnetic fields inside and outside the processing equipment, and
- e) at intended pressure differences between the outside and inside of the equipment.

6.4.3 Electrical equipment shall be adequately protected against the ingress of solids and liquids, in particular against contaminants (e.g. dust, acids, corrosive gases or salts) that are expected to be present inside and outside the processing equipment.

6.4.4 When **electrical equipment** inside the processing equipment is exposed to radiation (e.g. MW, UV, laser or X-ray), additional measures shall be taken to avoid malfunctioning of the equipment or accelerated deterioration of the **insulation** caused by the radiation.

6.4.5 Undesirable effects on the **EH** or **EPM installation** or **equipment** caused by vibration, shock and bump generated by the processing equipment and those created by the physical environment shall be avoided by selection of suitable **electrical equipment**, by mounting it away from the processing equipment, or by provision of anti-vibration mountings.

6.4.6 When **electrical equipment** inside the processing equipment is exposed to plasma, corrosive chemicals or other adverse agents, additional measures shall be taken to avoid malfunctioning of the equipment, accelerated deterioration of the **insulation**, metal degradation or corrosion due to radiation induced effects. This includes effects from arcing in **vacuum** caused by voltage locally or temporarily exceeding breakthrough voltage.

NOTE Breakthrough can happen over a very broad pressure range and whenever voltage exceeds the minimum breakthrough voltage of the atmosphere inside the equipment. Arcs can become self-sustaining once ignited.

6.5 Power supply

6.5.1 The installation shall be designed to operate correctly under **normal operation** with the conditions of the supply network

- as specified below, or
- as otherwise specified by the **user** and acknowledged by the **manufacturer**, or
- as specified by the **manufacturer** in the case of a special source of supply such as an onboard generator.

For mains frequency supplies, the following, according to IEC 60204-1:2016, applies, unless otherwise explicitly agreed between the **manufacturer** and the **user**:

- a) steady state voltage in the range of 90 % to 110 % of nominal voltage;
- b) frequency in the range of 0,99 to 1,01 of nominal frequency continuously; 0,98 to 1,02 short time (no excessive temperature rise in components due to an abnormal current).

For special supply systems such as onboard generators, the limits given may be exceeded provided that the equipment is designed to operate correctly under those conditions.

6.5.2 In case of failure or fault of the electric supply, the installation or equipment shall

- a) go into a safe mode of operation – it shall not go into **single fault condition**, especially shall not start unexpectedly, shall not be prevented from stopping if the stop command has been given, shall not eject or let fall any part or **workload** unless protection is provided for this case,
- b) not lose the setting of the switchgear, controlgear or programmable controller necessary for safe operation,
- c) be able to keep all **protective devices** fully operational or let them give a stop command, and
- d) be able to cool down without causing a hazard; this can require the prolonged operation of cooling equipment.

6.6 Access

6.6.1 The **EH** or **EPM installation** or **equipment** shall allow safe access to all areas where intervention is necessary during operation or maintenance. The equipment shall be so designed and installed that all devices and components that are intended to be accessible, observed or seen by the **operator** are accessible or visible to the **operator**.

6.6.2 Risks shall be reduced by limiting or preventing the access to any hazard or to any hazard zone. Limitation of access to surfaces or parts that can cause a hazard or of access for entering a hazard zone depends on the hazard itself, its type (immediate or **exposure** dependent) and the strength of the source of the hazard (e.g. the temperature of a surface or the voltage of a **live part**).

6.6.3 The **EH** or **EPM installation** or **equipment** shall provide protection against unintentional access to **hazardous-live parts** or against unintentional entering the **high-voltage hazard zone** in all cases where either there is no **barrier** or **enclosure**, or where **barrier** or **enclosure** are to be removed to gain access to devices requiring manual operation or to components requiring replacement.

The access path to the device and the space needed for its operation shall be such that protection against unintentional contact with **hazardous-live parts** or against unintentionally entering the **high-voltage hazard zone** is provided by an appropriate distance.

Obstacles protecting against unintentional contact shall be provided if the access path or space has less than the appropriate distance from **hazardous-live parts**.

6.6.4 The degree of protection shall be not less than IPXXB (also complied with by IP2X) of IEC 60529:1989, IEC 60529:1989/AMD1:1999 and IEC 60529:1989/AMD2:2013 from the direction of approach to the **hazardous-live part**, and not less than IPXXA (also complied with by IP1X) of IEC 60529:1989, IEC 60529:1989/AMD1:1999 and IEC 60529:1989/AMD2:2013 from other directions.

6.7 Ergonomic aspects

The physical and physiological stress faced by the **operator** during **normal operation** and intended environmental conditions shall be reduced to a possible minimum. In this regard, the main objectives are the following:

- a) avoid a work rate determined by the installation only;
- b) avoid monitoring of the installation or its control unit that demands lengthy concentration;
- c) allow for the variation in the strength, stamina or physical dimensions of different **operators**;
- d) allow for sufficient space for the movements of the **operator**;
- e) adapt the control unit and other interfaces to the foreseeable variation in characteristic of **operators**.

The provisions of ISO 6385:2016 apply.

6.8 Transport and storage

6.8.1 The **EH** or **EPM installation** or **equipment** shall be designed to withstand the effects of transport and storage at temperatures within a range from –25 °C to 55 °C and for short periods not exceeding 24 h at up to 70 °C. Otherwise, suitable precautions shall be taken to protect the **electrical equipment** against such effects. Suitable means shall be provided to prevent damage from humidity, vibration and shock.

6.8.2 The **EH** or **EPM installation** or **equipment** shall be designed for simple removal and refilling of working fluids, if these working fluids may freeze or otherwise harm the equipment during storage or transport. The **manufacturer** shall inform the **user** about procedures for removal and refilling of any working fluids in the instructions for use.

NOTE Equipment susceptible to damage at low temperatures includes PVC insulated cables, certain electrolytic capacitors or equipment using cooling liquids that can freeze.

6.9 Provisions for handling

6.9.1 Any **EH** or **EPM installation** or **equipment** shall be capable of being handled and assembled safely.

6.9.2 Any part of an **EH** or **EPM installation** or **equipment** that cannot be moved by hand shall be enabled for lifting by adequate equipment. The manufacturer shall supply instructions for lifting or handling when applicable.

6.9.3 All parts shall be easily assembled by use of appropriate provisions or lifting gear.

6.10 Consumables and replaceable parts

Consumable or replaceable parts that are intended to be replaced by the **operator** shall be integrated or mounted in a way that replacement is uncomplicated and safe with regard to correct and unambiguous mounting and to electrical connection.

7 Protection against hazards from electric shock

7.1 General

Clause 7 applies for **EH** or **EPM installation** or **equipment** that is not covered by the scope of IEC 60204-1 or IEC 60204-11, i.e.

- a) exceeding 40 °C environmental temperature, or
- b) having an electrical **processing frequency** exceeding 200 Hz.

Clause 7 does neither apply for equipment covered by IEC 60204-1 or IEC 60204-11, nor for installations or equipment with a voltage exceeding 36 kV, which are covered by the Particular requirements.

7.2 Fundamental rule of protection

7.2.1 Hazardous-live parts shall not be accessible and accessible conductive parts shall not be hazardous-live during **normal operation**, or under **electric single fault condition**.

7.2.2 For HV installations or equipment, entering the **high-voltage hazard zone** is considered the same as touching a **hazardous-live part**.

7.2.3 Non-accessible parts are such **hazardous-live parts** or **high-voltage hazard zones** which are beyond the limits of reach – i.e. contact is not possible as defined in ISO 13857:2008 during **normal operation** or in **electric single fault condition**.

7.2.4 Protection during **normal operation** is provided by basic protection (see 7.4), and protection in **electric single fault condition** is provided by fault protection (see 7.5). Protection by enhanced protective provisions as defined in 5.4 of IEC 61140:2016 is not sufficient for any installations or equipment under the scope of this document.

7.3 General provisions

7.3.1 All conductive parts, which are not separated from **hazardous-live parts** by at least **basic insulation**, shall be treated as if they were **hazardous-live parts**. This also applies to conductive parts, which are separated by **basic insulation** but are connected to **hazardous-live parts** through components, which are not designed to sustain the same electric stress as specified for **basic insulation**.

7.3.2 Exposed conductive parts of the installation or equipment shall be connected to the protective bonding terminal. This includes all parts, which are covered only by coatings like paints, varnishes, lacquers and similar products. Not included are conductive parts, which can be touched but are separated from **hazardous-live parts** by protective separation.

7.3.3 If the installation or equipment is not completely covered with conductive parts, the following applies to accessible parts of insulating material. In the following cases, accessible surfaces of parts of insulating material shall be separated from **hazardous-live parts**:

- if they are designed to be gripped; or
- if they are likely to come into contact with conductive surfaces which can distribute hazardous potential; or
- if they can come into significant contact (area more than 50 mm × 50 mm) with a part of the human body; or
- if they are to be used in areas where the pollution is highly conductive.

In this case, they shall be separated from **hazardous-live parts** by

- a) double or reinforced **insulation**, or
- b) **basic insulation** and protective screening, or
- c) a combination of these provisions.

All other accessible surfaces of parts of insulating material shall be separated from **hazardous-live parts** by at least **basic insulation**. For all equipment intended to be part of the installation, the **basic insulation** shall be provided during assembly and installation either by the **manufacturer** or by the **user** as indicated by the **manufacturer** in the information for use.

The requirements are deemed to be complied with if

- a) the accessible parts of insulating material provide the required **insulation** and their temperature does not exceed the limits defined in Clause 10, and
- b) the switchboard is made from metal and driving axles of switches, turn-knobs or similar are effectively brought to earth potential in all positions.

7.3.4 The design of the installation or equipment shall restrict access to **high-voltage hazard zones**. The need for operational and maintenance access by **operators** shall be taken into account. Where safe distances cannot be achieved, permanent protective shielding shall be installed. Access through doors or **obstacles** shall only be possible with the use of a tool.

Applicable warning labels shall be displayed on all access doors, **guards**, **barriers**, and be in compliance with 19.4.

7.3.5 If it is not feasible for operating reasons to prevent the following LV parts being both accessible and hazardous-live, they are permitted to be accessible by an **operator** during **normal operation**:

- a) parts of lamps and lamp sockets after lamp removal;

- b) parts intended to be replaced and which can be hazardous-live during the replacement or other **operator's** action, but only if they are accessible with a tool and have a warning marking – see 19.4.

7.4 Basic protection

7.4.1 All installations or equipment under the scope of this document shall be provided with basic protection.

- a) For LV installations or equipment, in the absence of a specific standard listed in Table 2, all basic protection shall be in compliance with IEC 60364-4-41:2005 and IEC 60364-4-41:2005/AMD1:2017.
- b) For HV installations or equipment, in the absence of a specific standard listed in Table 2, all basic protection shall be in compliance with 7.4.

7.4.2 Basic protection shall consist of one or more provisions that at least during **normal operation** prevent contact with **hazardous-live parts**.

7.4.3 Where solid **basic insulation** is used, it shall prevent contact with **hazardous-live parts**.

In case of HV installations and equipment, a voltage can be present on the surface of solid **insulation** and further precautions may be necessary.

Where **basic insulation** is provided by air, access to **hazardous-live parts** or entering the **high-voltage hazard zone** shall be prevented by **obstacles**, **barriers** or **enclosures** as specified in 7.4.4 and 7.4.5, or by placing them out of arm's reach according to ISO 13857:2008.

Where a conductive **obstacle** is separated from **hazardous-live parts** by **basic insulation** only, it is an exposed conductive part and measures for fault protection shall be applied.

7.4.4 **Barriers** or **enclosures** preventing access to **hazardous-live parts** or entering the **high-voltage hazard zone** shall provide a degree of protection of at least IPXXB (also complied with by IP2X) of IEC 60529:1989, IEC 60529:1989/AMD1:1999 and IEC 60529:1989/AMD2:2013.

Barriers or **enclosures** shall have sufficient mechanical strength, stability and durability to maintain the specified degree of protection, taking account of all relevant influences from the environment and from inside the **enclosure** – ISO 14120:2015 shall be used for their design.

Where the design or construction allows for the removal of **barriers**, the opening of **enclosures** or the removal of parts of **enclosures**, access to **hazardous-live parts** or entering the hazard zone shall only be possible

- with the use of a key or tool, or
- after isolation of **hazardous-live parts** from the supply network where the **enclosure** would no longer provide protection, restoration of the supply being possible only after replacement of **barriers** or parts of **enclosures** or after the closing of doors, or
- where an intermediate **barrier** still maintains the required degree of protection, such **barrier** being removable only by the use of a key or tool, or
- in case no tool or key is required, if an **interlock** according to ISO 14119:2013 that cuts out the hazard immediately is used.

Barriers or **enclosures** shall be designed or made from such material that no hazardous induced currents can be created in them.

7.4.5 In the case of HV installations and equipment, substantial inequalities of electric field strength in or along an insulator or **insulation** shall be reduced to a safe level, or avoided through constructional measures, or through potential grading. This shall prevent the **operator** from hazardous step and **touch voltages**.

NOTE Potential grading is typically used for electrical installations, where high earth currents occur.

7.4.6 At frequencies exceeding 200 Hz, potential grading of the circuit shall be controlled by the following means.

- a) If earthing is necessary for reasons of equipment design, any constructional parts of the installation shall not be relied upon. A separate low reactance conductor forming a direct path between the generator and the processing applicator shall be provided instead.
- b) The voltage drop shall not exceed 5 V RMS over any distance of the installation that can be bridged by a person at once, if the conductor currents exceed 500 A, unless access is hindered to the installation by sufficient **barriers** or **enclosures** (refer to 7.4.4).

NOTE This limitation of the geometric extent is due to electromagnetic waves and their propagation resulting in unreliable earthing continuity at frequencies above approximately 100 kHz.

7.5 Provisions for protection in electric single fault condition

7.5.1 Fault protection shall consist of one or more provisions independent of and additional to those for basic protection. Individual provisions for fault protection are specified in 7.5.2 to 7.5.8.

7.5.2 Electric single fault condition shall be considered, if it can cause

- a) an accessible, non-hazardous-live **part** to become a **hazardous-live part**, or
- b) an accessible conductive part which is not live during **normal operation** to become a **hazardous-live part**, or
- c) a **hazardous-live part** to become accessible.

7.5.3 To meet the fundamental rule under **electric single fault condition**, fault protection shall be achieved by a further protective provision, independent of that for basic protection (7.4). The independent single fault protection shall be provided

- for LV installations or equipment, in the absence of a specific standard listed in Table 2, in compliance with IEC 60364-4-41:2005 and IEC 60364-4-41:2005/AMD1:2017, and
- for HV installations or equipment, in the absence of a specific standard listed in Table 2, in compliance with 7.5.

7.5.4 Each of the two independent protective provisions (fault protection and basic protection) shall be designed so that a failure is unlikely under environmental conditions specified in 6.3 or 6.4 and under **normal operation** or **electric single fault condition**.

The two independent protective provisions shall have no influence on each other.

NOTE Simultaneous failure of the two independent protective provisions is unlikely and is not normally taken into consideration. Reliance is placed on one of the protective provisions remaining effective.

7.5.5 Requirements for protective equipotential bonding are defined in 7.6 and apply independently.

7.5.6 Protective screening shall consist of a conductive **screen** interposed between **hazardous-live parts** of an **EH** or **EPM installation** or **equipment** and the part being protected. The protective **screen** shall be connected to the protective equipotential bonding system of the installation or equipment; it shall itself comply with the requirements for protective equipotential bonding according to 7.6.

7.5.7 Simple separation between a circuit and other circuits or earth shall be achieved by **basic insulation** throughout, rated for the highest voltage present.

If any component is connected between the separated circuits, that component shall withstand the electric stresses specified for the **insulation** which it bridges and its impedance shall limit the prospective current flow through the component to the steady-state **touch current** values indicated in Annex B.

7.5.8 Supplementary **insulation** shall be dimensioned to withstand the same stresses as specified for **basic insulation**.

7.6 Protective equipotential bonding

7.6.1 The protective equipotential bonding system shall consist of one or a suitable combination of two or more of the following elements:

- a) means for protective equipotential bonding in equipment;
- b) earthed protective equipotential bonding in the installation;
- c) protective earthing conductor (PE);
- d) protective earthing conductor being a neutral conductor as well (PEN);
- e) protective screening;
- f) earthed point of the source;
- g) earth electrode (including earth electrodes for potential grading);
- h) earthing conductor.

Specific considerations apply for frequencies well above mains frequency and are given in the Particular requirements.

7.6.2 All parts of the protective bonding circuits shall be so designed that they are able to withstand the highest thermal and mechanical stresses, which can be caused by earth-fault currents, flowing in any part of the protective bonding circuits.

Any structural part of the electrical installation or equipment may be used as part of the protective bonding circuit, in case an earth fault monitoring system is installed.

7.6.3 The equipotential bonding system of an HV installation or equipment shall be connected to earth because of the special risks, which can be present, for example the danger of high **touch** and step **voltage** and of exposed conductive parts becoming live due to an electrical discharge. The impedance to earth of the earthing arrangement shall be rated so that no hazardous **touch current** can occur (refer to Clause 18 in connection with Annex B). Exposed conductive parts, which can become live under fault conditions, shall be connected to the earthing arrangement.

7.6.4 Accessible conductive parts which could acquire a hazardous effective **touch voltage** in the event of a failure of basic protection, i.e. exposed conductive parts and any protective **screen**, shall be connected to the protective equipotential bonding system.

7.6.5 The protective equipotential bonding system shall be of sufficiently low impedance to avoid hazardous potential difference between parts in case of an **insulation** failure and, if necessary, be used in association with a **protective device** operated by the fault current.

This can necessitate consideration of the relative impedance values of the different elements of a protective equipotential bonding system. The difference in potential need not be considered if the impedance of the circuit limits the steady-state **touch current** in the case of an **electric single fault condition** so that it cannot exceed 3,5 mA RMS for frequencies up to 100 Hz or 10 mA for direct current applications when measured in accordance with Clause 18.

In some environments or situations, for example highly conductive locations or wet areas, the limiting values shall be lower.

7.6.6 All parts of the protective equipotential bonding shall be so dimensioned that thermal and dynamic stresses, which are likely to occur due to a fault current, do not impair the characteristics of the protective equipotential bonding system as a consequence of a failure or bridging of **basic insulation**. Some local damage, not impairing safety, for example of a sheet metal part of an **enclosure**, may be accepted at the place where the fault occurs.

7.6.7 All parts of the protective equipotential bonding shall be capable of withstanding all internal and external influences (including mechanical, thermal and corrosive) which can occur during the expected lifetime of the installation.

If parts need to be checked regularly or maintained, the **manufacturer** shall indicate this in the information for use.

Movable conductive connections, for example hinges and slides, shall not be considered to be parts of a protective equipotential bonding system unless compliance with the requirements in 7.6 is maintained.

Where a component of an installation or equipment is intended to be removed, the protective equipotential bonding for any other part of the installation or equipment shall not be interrupted when removing the component unless the electrical supply to the other part is disconnected first.

No element of the protective equipotential bonding shall contain any device which could reasonably be expected to break the electrical continuity or to introduce significant impedance, with the exception of components intended to be removed. This requirement may be dispensed only temporarily for the verification of the continuity of protective conductors or for the measure of the current of the protective conductor – see Clause 18.

7.6.8 Where elements of the protective equipotential bonding can be interrupted by the same coupler or plug-and-socket-outlet device as the relevant supply conductors, the protective equipotential bonding shall not be interrupted earlier than the supply conductors. The protective equipotential bonding shall be re-established not later than when the supply conductors are reconnected. These requirements do not apply when interruption and reconnection are only possible with the equipment in de-energized condition.

7.6.9 In HV installations and equipment, the protective equipotential bonding shall not be interrupted before the main contact has reached an isolating distance which can withstand the equipment rated impulse withstand voltage.

7.6.10 Conductors of the protective equipotential bonding, whether insulated or bare, shall be readily distinguishable by shape, location, marking or colour, except those conductors which cannot be disconnected without destruction, for example in wire-wrap and similar wiring in electronic equipment and tracks on printed wiring boards. If identification by colour is used, it shall be in accordance with IEC 60445:2017.

7.6.11 In LV equipment, the protective conductors or the continuity of the protective bonding system shall be in accordance with 8.2 of IEC 60204-1:2016. This includes the requirements on the exclusion of switching devices, parts that need not be connected, and interruption.

Protective connector connection points, protective bonding in installations with earth **leakage current** exceeding 10 mA, and functional bonding shall be in accordance with 8.2 and 8.4 of IEC 60204-1:2016.

7.6.12 In LV equipment, track rails may be used as a return circuit, provided that under fault conditions, the impedance of the circuit is sufficiently low to limit the step and contact voltages between the rails and the adjacent earth to values not exceeding 25 V RMS or 60 V DC.

7.6.13 The earth, protective conductors, sheaths and structures shall not be used as part of an active circuit, unless specified otherwise in the Particular requirements.

7.6.14 Earthing of secondary circuits shall be avoided unless improving overall safety of the installation. If secondary circuits are earthed, they shall only be accessible if the voltage of the secondary circuit is so low that the **touch current** limits are met – refer to 7.9 for details.

7.6.15 The means of connection, except for plug-and-socket connections, shall be clearly identified either using symbol IEC 60417-5019:2006-08 (see Annex G), or with the letters PE, or by the bicolour combination of green and yellow. The indication shall not be placed on or fixed by screws, washers or other parts, which could be removed when conductors are being connected.

For cord-connected equipment, the protective conductor in the cord shall be the last conductor to be interrupted in the case of failure of the strain-relief mechanism,

7.6.16 All conductively sheathed cables, conduits or pipes passing through those parts of an **enclosure** containing high-voltage circuits in the voltage band 3 shall be earthed at the point where they pass through the **enclosure**.

7.7 Additional provisions for fault protection for frequencies above 200 Hz

7.7.1 Fault protection shall consist of one or more of the measures in 7.7.2 to 7.7.5 independent of and additional to those for basic protection.

7.7.2 Parts of **electrical equipment** operating at higher frequencies than 200 Hz shall be capable of operating correctly in consideration of skin and proximity effects under **normal operation** and **electric single fault condition**.

7.7.3 Any supplementary **insulation** shall be dimensioned to withstand the same stresses as specified for the **basic insulation**. In addition, insulating materials shall have sufficiently low dielectric loss factors at the working temperature and frequency so that the **insulation** is not impaired by dielectric heating of the materials.

7.7.4 All high frequency circuits shall be galvanically separated from the mains frequency earthing system. Failure of the **galvanic separation** between the circuit and the mains frequency earthing system which could result in accessible parts acquiring a hazardous effective **touch voltage** shall be detected by a **protective device** operated by the fault voltage and result in disconnecting and de-energising the circuits.

High frequency earthing may be directly connected to the mains frequency earthing system, if this reduces the associated risks compared with a **galvanic separation**; details are provided in the Particular requirements.

7.7.5 The separated low resistance conductors constituting the main current path from the circuit frequency source to the processing applicator or similar shall comply with the following.

- a) They shall be capable of withstanding all internal and external influences (including mechanical, thermal, corrosive, glow discharge) which can be expected.
- b) They shall comply with the highest occurring voltage under any **electric single fault condition**, if the conductors are accessible during maintenance; their electric **insulation**, and their current-carrying capacity shall be such that they do not overheat during any foreseeable **single fault condition**; if excessive currents can occur with such conductors

under any foreseeable **electric single fault condition** that overheating occurs, a current-sensing device that permanently switches off the equipment before the conductor properties are compromised shall be installed.

- c) They shall not be removable without the use of a tool.
- d) If it is necessary for reasons of equipment design to include a separable disconnection of the main circuit conductor for maintenance, its plug and socket shall be mechanically combined with a safety circuit preventing energising of the main circuit during disconnection and there shall be a latching or similar device incorporated in the plug and socket system, as well as sufficient **insulation** to the exterior for non-hazardous disconnection; these requirements do not apply if separation is needed only during installation and decommissioning and is then only possible with the use of tools.
- e) The connection of the separable circuit conductor shall be re-established not later than when the supply conductors are reconnected; this requirement does not apply when interruption and reconnection are possible only with the equipment in de-energized condition.
- f) The circuit electrical connections at the ends shall be separated and thus not be combined with any other electrical connection or the protective equipotential bonding for any other part of the installation or equipment.

7.8 Currents in protective conductors

7.8.1 Measures shall be taken in the installation or equipment to prevent excessive protective conductor currents impairing safety or **normal operation** of the installation. Compatibility shall be ensured for currents of all frequencies supplied to and produced by the equipment.

7.8.2 The following limits are applicable to equipment supplied at mains frequency:

- a) for plug-in current using equipment fitted with a single or multiphase plug and socket-outlet system rated up to and including 32 A: less than 2 mA for rated current below 4 A, less than 5 mA for rated current exceeding 10 A and 0,5 mA/A in between.
- b) for current-using equipment for permanent connection and current-using stationary equipment, both without special measures for the protective conductor, or plug-in current using equipment fitted with a single phase or multiphase plug and socket-outlet system, rated more than 32 A: less than 3,5 mA for rated current below 7 A, less than 10 mA for rated current exceeding 20 A and 0,5 mA/A in between.

If residual current devices are provided in the installation, the protective conductor current shall be compatible with the protective measures provided.

In **normal operation**, mains frequency equipment shall not generate current with a DC component in the protective conductor which could affect the proper functioning of residual current devices or other equipment, unless a residual current device is chosen, that allows for DC current in the mains circuit.

7.8.3 For current-using equipment intended for permanent connection and having a protective conductor current higher than 10 mA, provision shall be made for a secure and reliable connection with earth such as described in IEC 60364-5-54:2011.

7.9 Touch current and touch voltage

7.9.1 **Touch currents** causing harm shall be avoided. No part or surface that can cause harm when touched shall be accessible. Limits to maximum allowable **touch currents** depending on the frequency of the generating field are provided in Annex B together with applicable risk classes.

7.9.2 If **touch currents** can be perceived either in **normal operation** or **electric single fault condition**, the **manufacturer** shall indicate this to the **user** in the instructions for use.

7.9.3 If parts that can cause non-harmful **touch currents** need to be touched in **normal operation**, the **manufacturer** shall

- a) apply warnings and markings according to Annex G, and
- b) indicate in the information for use specific handling procedures for the **operator** if appropriate; such procedures may include grasping to avoid harm for **touch currents** below the let-go threshold.

7.10 Conductors and insulations at high temperature

7.10.1 The effect of decreasing conductivity with temperature of conductor materials and thus increasing Joule heating of undersized conductors shall be taken into account when dimensioning conductors. IEC 60364-4-42:2010 and IEC 60364-4-42:2010/AMD1:2014 apply.

7.10.2 All conductors shall be able to operate at their maximum expected environmental temperature without overheating. They shall be made from conductive material that does not degrade at the stationary conductor temperature over the intended lifetime. Their **insulation** shall be made from material that does not degrade or disintegrate over the intended lifetime.

The **manufacturer** shall indicate to the **user** if conductors or **insulations** have an intended lifetime less than that of the **EH** or **EPM installation** or equipment and need replacement; he shall indicate inspection and maintenance intervals.

7.10.3 The effect of increasing conductivity with temperature of most insulating materials shall be considered as this can lead to hazardous **leakage currents**.

7.10.4 If the insulating material at the maximum expected temperature does not provide sufficient **insulation**, secondary insulating means shall be introduced.

NOTE Conductivity of all insulating materials increases with temperature.

7.11 Non-electric faults

Such **single fault condition** shall be taken into account where a fault of mechanical or thermal origin leads to parts becoming live – for example the destruction of non-conducting **insulation**, the flow of liquid metals into non-conductive **insulation**, or a dislocated conducting charge connecting conductive elements.

8 Protection against hazards from electric or magnetic fields

8.1 General

8.1.1 Clause 8 specifies provisions for frequencies between 0 Hz and 6 MHz concerning hazards caused by magnetic, electric or **electromagnetic fields**. Provisions for higher frequencies and for propagating fields are provided in the Particular requirements.

8.1.2 The **EH** and **EPM** processing **equipment** shall be designed and operated so as to protect the **operator** and the environment from harmful effects caused by magnetic, electric or **electromagnetic fields**. Secondary phenomena such as the creation of ozone by discharges, induced currents or induced voltages shall also be taken into account.

8.1.3 Annex D provides the relevant risk classes and limits for electric and magnetic fields.

8.2 Magnetic fields

8.2.1 The equipment shall be so designed that the maximum accessible magnetic field level and characteristics do not cause a risk. **Barriers** or **screens** shall hinder **exposure** to hazardous fields and be designed as defined in 8.5.

8.2.2 All hazard zones where risk class 1 conditions exist during **normal operation** or in **electric single fault condition** shall be indicated by the **manufacturer** in the information for use and a warning symbol defined in Annex G shall be provided outside the zone.

8.3 Magnetic fields below 1 Hz

8.3.1 In case of static magnetic fields, the **manufacturer** shall indicate in the information for use safe behaviour for maximum allowed accessible B value level exceeding the limit for risk class 1. This includes specifying slow bodypart movement in and out of the field – time for full entry into the static magnetic field shall exceed a time of 1 s.

8.3.2 Exceptional **exposure** can be allowed for an **operator** not carrying or wearing any metal objects and not having implants of any kind, if the **manufacturer** indicates to the **user**

- a) the need for slow movements in static magnetic fields, especially to slow the bodypart movement into and out of the field to a time being longer than 1 s, if the maximum accessible B value level exceeds 200 mT, and
- b) the necessity to instruct and warn persons carrying any metal objects or having metallic implants of any kind not to enter regions exceeding occupational limits.

8.4 Local electric fields

8.4.1 Clause 7, especially 7.9, applies. **High-voltage hazard zones** shall be non-accessible by any body parts.

8.4.2 The continuity of the earthing of all conductive accessible parts shall be provided in **normal operation** and **electric single fault condition**.

8.4.3 Ionization phenomena, which can occur at high temperatures under high electric fields, shall be taken into account in the design of **insulation** distances along surfaces or in air. Particular care shall be taken in case of metallic vapour **emission**, splashes, pollution, or similar.

8.4.4 Corona discharges at high field intensities can create hazardous ozone concentrations and shall be limited. The **manufacturer** shall indicate to the **user** if relevant ozone is generated in **normal operation** or **single fault condition**.

NOTE At a given field intensity, the corona effect increases with frequency.

8.5 Requirements related to barriers and screens

8.5.1 A non-conductive, non-magnetic **barrier** is not considered as protective measure other than hindering access, like an **obstacle**.

8.5.2 Conductive **screens** guiding or absorbing the field and being protected from direct touch shall have sufficient conductivity and be located in a way that they cannot overheat in **normal operation** or in **electric single fault condition**. They shall neither exceed the temperature limit for touchable surfaces as defined in Clause 10 nor shall their integrity of protection be compromised.

8.5.3 Conductive **screens** which are accessible for direct touch shall have sufficient conductivity and be located in such a manner that they cannot overheat in **normal operation** or in **electric single fault condition**. They shall neither exceed the temperature limit for touchable surfaces as defined in Clause 10 nor shall their integrity of protection be compromised.

8.5.4 All conductive **screens** shall have a material thickness d that exceeds the energy penetration depth by a factor of 3 and thus fulfil the following formula:

$$d = \frac{3}{\sqrt{4\pi \times f \times \sigma(f) \times \mu_0 \times \mu_r}} \quad (1)$$

where

μ_0 = $4\pi \times 10^{-7}$ and is the magnetic constant in $\Omega \text{ s m}^{-1}$;

μ_r is the relative permeability;

f is the frequency in Hz;

$\sigma(f)$ is the material and temperature dependent conductivity in $\Omega^{-1} \text{ m}^{-1}$.

NOTE Some magnetic field leaks through if the plate is thinner. It can be difficult to fulfil the requirement for frequencies below 100 kHz and it is typically impossible below about 10 kHz.

8.5.5 The geometric extent of a conductive **screen** shall be such that no hazardous field extends over its reach.

8.5.6 Other measures for stray field control may be indicated; these can be

- a field filtering **window** for visible access to the working area, or
- an array of well-placed magnetic objects of sufficient permeability.

8.6 Requirements related to objects worn, carried or held by persons

8.6.1 Metallic objects near the processing equipment can be heated by strong induced currents, even if the requirements of 8.4 and 8.5 are complied with. Ferromagnetic materials such as in tools can be strongly heated by the magnetic field.

8.6.2 The hazard of heated up metallic or semiconducting parts shall be considered. Information on relevant fields is provided in Annex D. The **manufacturer** shall indicate hazard zones to the **user** and proper written warning for this region shall be provided in the information for use and proper warning signs shall be provided outside the zone.

8.6.3 Magnetic objects can be exposed to strong mechanical forces and cause a hazard in or near strong magnetic fields and field gradients of static fields or low frequency fields. All zones where such risk can exist during **normal operation** or in **electric single fault condition** shall be indicated by the **manufacturer** in the information for use and proper warning signs shall be provided outside the zone.

8.6.4 Hazards related to implanted active medical devices in strong static or time-variable magnetic fields as well as nuisance related to watches and other electronic equipment such as radios are inevitable. Information on relevant fields is provided in Annex D. The **manufacturer** shall indicate this to the **user** and proper cautions for this region shall be provided in the information for use.

8.6.5 The **manufacturer** shall indicate, in the information for use, with respect to static magnetic fields

- a) if very strong forces are expected when fields are varied, especially when the field is switched on or off,
- b) that **operators** or **ordinary persons** having implants of any kind (for example metallic, semiconducting or medical electronic devices) or wearing any objects made from metal or semiconducting material shall only attend any zone of risk class 1, and
- c) that **operators** or **ordinary persons** carrying any metal objects be instructed about the need of slow movements and that a special optical or audible warning device is in operation indicating the existence of such a field.

8.6.6 The **manufacturer** shall indicate in the information for use with respect to static and alternating magnetic fields

- a) that **operators** carrying any metal objects or having implants of any kind (i.e. metallic or medical electronic devices) or wearing any metal objects shall not attend any zone of risk class 1 or higher – sufficient marking and proper warning signs shall be provided outside the zone, and
- b) that **operators** or **ordinary persons** attending any zone of risk class 2 shall never wear objects like metal necklaces, bracelets, rings, objects that are magnetisable or objects made from silicon, carbon or similar.

9 Protection against hazards from radiation

9.1 General

9.1.1 The **EH** or **EPM installation** or **equipment** shall provide protection against effects of internally generated ultraviolet, ionizing, visible, infrared, and microwave radiation, including radiation from laser sources.

This document does not differentiate between the possible sources of radiation (e.g. emitter, **workload** or furnace lining) with respect to classification or **emission**. Different phases of the life cycle of the **EH** or **EPM installation** or **equipment** can cause different levels of radiation **emission** and shall be treated separately.

9.1.2 The following effects can lead to unintended hazardous **emission** and shall be taken into account:

- **emission** of radiation through openings for entrance and exit of **workload** belonging to continuously operating processing equipment;
- **emission** of radiation through doors of batch processing equipment which are either opened or stay open during the process;
- **emission** of radiation when doors of the processing equipment are opened and the inside of the processing equipment, the **workload**, furnace lining or heating elements have not cooled down in advance;
- **emission** of radiation from a **workload** after leaving the installation;
- **emissions** becoming accessible during maintenance, commissioning or testing;
- **emission** from heating elements that are operated outside the processing equipment;
- reflectors, refractors or reflective walls inside the **EH** or **EPM installation** or **equipment** causing zones of intense irradiation outside.

9.2 Installation or equipment generating ionizing radiation

9.2.1 In the case of **EH** or **EPM installation** or **equipment** not intended to emit ionizing radiation, the effective dose rate of unintended stray radiation at any accessible point 100 mm from the outer surface of the equipment shall not exceed 1 µSv/h unless a national regulation stipulates a different dose.

9.2.2 The **EH** or **EPM installation** or **equipment** shall be so constructed that compartments in which electrons are accelerated by voltages exceeding 5 kV cannot be opened without the use of a tool. Sufficient information for use shall be supplied by the **manufacturer**.

9.2.3 Specific provisions for **EH** or **EPM installation** or **equipment** intended to emit radiation are given in the Particular requirements.

NOTE Equipment that emits ionizing radiation is usually regulated by national authorities. These regulations address both the **emission** of radiation from the equipment and the cumulative dose of radiation that can be received by the **operator** or **ordinary person**.

9.3 Ultraviolet radiation

9.3.1 Annex C provides the applicable restrictions and necessary information to the **user** for hazards to **operators** and bystanders as well as the **emission** risk classes for **EH** or **EPM installation** or **equipment**.

Effects of ultraviolet (UV) radiation include the destruction of biological cells and the degradation of the materials of **enclosures** or **insulations** made from plastic. UV radiation can start chemical reactions and fire. These effects shall be taken into account as well.

9.3.2 All processes where hot reactive gases or surfaces exceeding 2 500 °C are not completely shielded from the outside and all processes involving or employing a plasma being not completely enclosed are defined as intended to emit UV radiation.

9.3.3 Equipment emitting unavoidable stray radiation though not intended to emit UV radiation shall not permit unintentional escape of UV radiation that could cause a hazard.

9.3.4 In the case of equipment intended to emit UV radiation, the **manufacturer** shall reduce the emitted radiation and irradiation to levels that either

- are below the values defined in Annex C, or
- are below the value that can cause a possible **exposure** hazard to **operators**, or
- are below the value that can cause a risk through the degrading of exposed equipment.

The lowest **emission** value applies.

Measures to minimise **emission** include **screens**, **barriers**, locked doors, filtered **windows**.

9.3.5 If **emission** exceeds risk class 0,

- applicable warning and marking shall be applied on the **EH** or **EPM installation** or **equipment**, and
- the **manufacturer** shall indicate to the **user** in the information for use the need for personal protective equipment if hazardous **exposure** is possible.

9.4 Visible and infrared radiation

9.4.1 All **EH** or **EPM installation** or **equipment** shall be so designed and constructed that any **emission** of infrared (IR) or visible (VIS) radiation is limited to the extent necessary for their operation and that their effects on exposed persons are non-existent or reduced to non-hazardous levels.

9.4.2 Annex C provides the applicable restrictions and necessary information to the **user** for hazards to **operators** and bystanders as well as the **emission** risk classes for **EH** or **EPM installation** or **equipment**.

Otherwise, the following effects shall be taken into account:

- effects of intense VIS radiation can cause hazards for the human eye;
- intense VIS radiation can reduce the ability to see and react to signal lights or warning signs;
- effects of intense IR radiation include hazards to the human eye and the hazard of burning of skin;
- intense VIS or IR radiation can ignite flammable materials and fluids;
- surfaces or **windows** acting as optical elements can locally increase the intensity of irradiation outside the equipment.

9.4.3 EH equipment where hot reactive gases or surfaces exceeding 600 °C are not completely shielded from the outside and **EH equipment** employing hot plasma being not completely shielded are defined as intended to emit infrared radiation. Intense visible radiation is usually caused by thermal emitters exceeding 1 500 °C surface temperature, but hazards depend on the size and emissivity of the source.

9.4.4 No exclusive reduction or exclusive filtering of visible radiation shall be done, as a reduction of the visual stimulus of radiation increases risk to persons. Filters shall either be grey or primarily reduce the non-visible parts of the **emission**.

9.5 Laser sources

Installations or equipment including laser sources shall meet the requirements of IEC 60825-1:2014.

10 Protection against hazards from thermal influences

10.1 General

10.1.1 High temperature and thermal energy are relevant hazards to consider during all stages of design and manufacture of **EH** or **EPM installation** or **equipment**. Clause 10 covers direct aspects, whereas indirect aspects of thermal energy are treated throughout this document:

- provisions concerning thermal radiation are given in Clause 9;
- provisions concerning fire hazards are given in Clause 11;
- provisions concerning fluids including hot fluids are given in Clause 12.

10.1.2 EH or **EPM installation** or **equipment** shall be so designed, installed and operated that no hazard due to thermal energy or elevated temperature is likely to occur for the **operator** or the environment, even in case of unattended operation or inadvertent switching.

10.1.3 All materials used shall at least withstand the influence of thermal energy and temperature to which they are exposed during **normal operation** over the designed lifetime of that part. A maintenance cycle shall be part of the information for use indicating the replacement cycle, if the designed lifetime of a part is shorter than the lifetime of the installation or equipment.

10.1.4 All material used shall at least withstand the influence of thermal energy or temperature reasonably expected during **single fault condition** over a reasonable period when safety of the installation or equipment or any part of it depends on its structural integrity. This reasonable time period shall be at least the time necessary for detection and removal of that **single fault condition** and cooling down of the installation. If any materials or parts shall be exchanged after being exposed to thermal energy higher than that foreseen for **normal operation**, this shall be indicated in the information for use.

10.1.5 In case of large accidents, structural parts of the installation and buildings shall at least withstand the influence of thermal energy or temperature for the time necessary to detect the accident and evacuate the installation or building.

10.2 Surface temperature limits for protection against burn

All surfaces intended to be touched for operation of the **EH** or **EPM installation** or **equipment** or which can be touched unintendedly shall not exceed the temperature limits as set in Annex E during **normal operation** or in **single fault condition**. All surfaces exceeding this limit and that are in reach of the **operator** shall be marked accordingly and the risk including possible measures to reduce the risk be indicated in the information for use, or a **barrier** shall be placed to prevent accidental touching.

10.3 Hazards caused by working conditions

The **exposure** of the **operator** to thermal stress, hazard of overheating or dehydration shall be avoided as far as possible. If the **operator** is to be exposed to excessive heat during **normal operation** or **single fault condition**, the **manufacturer**

- a) shall indicate the need for taking this hazard into account in the information for use, and
- b) shall indicate the need for a risk assessment by the **user** based on the working procedures.

10.4 Temperature resistance of components

10.4.1 All structural parts and **enclosures** shall be made from material that is sufficiently temperature resistant at all temperatures they may reach during **normal operation** or prolonged **single fault condition** unless 10.1.5 applies.

10.4.2 **Enclosures** made from plastics or other non-metallic material shall only be used when, during **normal operation** or **single fault condition**, their temperature does not reach

- the limit of flammability,
- the limit of structural deformation, or
- the limit of decomposition.

10.4.3 All **insulation** shall be made from material that is sufficiently heat resistant at all temperatures it can reach during **normal operation** or prolonged **single fault condition**. This includes effects from fault currents inside an insulated conductor.

10.4.4 Clearance distances between conductive parts shall be sufficient for temperatures expected during **normal operation** or **single fault condition**.

10.4.5 Creepage distances between conductive parts shall be made to incorporate any increase of conductivity of insulating materials used due to temperatures expected during **normal operation** or **single fault condition**.

10.4.6 Mechanical stress from thermal expansion shall not cause deformation which could cause a hazard.

NOTE Such mechanical stress is often caused by temperature differences in the equipment structure or by mismatch of the coefficient of thermal expansion of different materials. Both can lead to serious failure.

10.4.7 Any parts or accessories of the processing equipment shall be mounted in such a way that they are not subjected to temperatures exceeding the temperature for which they are designed.

10.4.8 General protective measures against thermal influences on or from the **electrical equipment** shall be provided according to IEC 60364-4-42:2010 and IEC 60364-4-42:2010/AMD1:2014.

10.4.9 In the absence of limits supplied by the **manufacturer** of parts, the maximum increase of temperature as defined in Table 3 of IEC 60335-1:2010 and IEC 60335-1:2010/AMD1:2013 applies to materials and parts or components of the installation.

10.5 Cooling

10.5.1 Where forced cooling of components is employed and lack of cooling can cause a hazard, provisions shall be made for monitoring the cooling action. If the cooling becomes insufficient, an alarm shall be given and the equipment shall be switched into a safe state.

10.5.2 If a liquid cooling agent is used and insufficient cooling due to bubble formation or boiling can cause a hazard,

- a) either the temperature shall be kept sufficiently below the boiling point at applicable pressure or other means shall assure that no bubbles are formed inside the cooling circuit, reducing heat transfer, or
- b) the cooling system shall be designed to operate safely with liquid and gas mixtures.

10.5.3 Release of hot cooling liquid or vapour shall not pose a hazard itself.

10.5.4 Where **live parts** are liquid-cooled, the quality of the coolant, the length of the hoses and the material used for tubes and hoses shall be such that the **touch voltage** resulting from **leakage currents** does not impair safety.

NOTE A closed cooling circuit reduces the risk of environment pollution and loss of coolant.

10.6 Over-temperature protection

10.6.1 In order to ensure the necessary degree of safety in the case of **single fault condition** in the temperature control circuit, appropriate **protective devices** and measures shall be applied as defined in Table 4.

Table 4 – Classification of thermal protective measures

Class	Scope of protection	Extent of protection	Protective device	Protective measure
0	Processing equipment and environment thereof	–	–	Attended operation with non-hazardous workload only Overheating precluded by constructional measures
1		In the case of a fault, no hazard caused by the processing equipment	Thermal cut-out, temperature protector or comparable	Depending on utilization and site of installation
2	Processing equipment, environment thereof and workload	In the case of a fault, no hazard caused by processing equipment or workload	Pre-selected temperature controllers, pre-selected temperature limiters, or comparable	

The **manufacturer** shall, for the case of unattended operation, indicate reasonably limited intervals at which the installation is to be checked by the **user**; the applicable class as defined in Table 4 shall be indicated to the **user**.

If necessary, means shall be provided for the **operator** to check that a temperature **protective device** or system will function in the case of **single fault condition**. The information for use shall specify the method and how often the check is required.

10.6.2 If a **single fault condition** could cause a hazard through overheating of any part of the **EH** or **EPM installation** or **equipment** including the **workload**, a **thermal cut-out** or system meeting the requirements of 14.7 shall de-energize the heating means and any other parts which could cause that hazard.

10.6.3 If an insufficient quantity of heat-transfer liquid – for example cooling water – could cause a hazard, a non-self-resetting liquid-level device shall de-energize the heating means and any other parts which could cause a hazard.

10.6.4 Any hazards arising from overheating of the **workload** or overheating of heat-transfer media (e.g. heating baths) as well as from over-temperature of parts of the processing equipment itself shall be taken into account.

10.6.5 In some cases, a fall in the temperature of a heated medium – for example liquid in a bath or air in an oven or heating cabinet – could cause a hazard. If this can occur as a result of the operation of an over-temperature protection device or a **thermal cut-out** after failure of the temperature control system, an independent temperature control shall be fitted to maintain a safe temperature without the over-temperature device operating.

10.6.6 If no over-temperature protection device is used, a controlled and limited amount of energy supplied to the **workload** can be used to protect against over-temperature.

11 Protection against hazards from fire

11.1 Clause 11 applies for the **EH** or **EPM installation** or **equipment** in general and especially for the processing equipment.

11.2 Annex F defines a basic understanding of fire hazards for thermal processes, as they are the purpose and define **normal operation** of **EH installations** or **equipment**. Basic concepts and methodology of technical fire-prevention and protective measures to be taken at the design and construction phase shall be according to ISO 19353:2019 where applicable.

11.3 Protection against fire hazards for **electrical equipment** shall be according to IEC 60364-4-42:2010 and IEC 60364-4-42:2010/AMD1:2014.

11.4 In case of equipment designed to contain controlled combustion processes, ISO 13577-2:2014 shall apply.

11.5 For equipment designed to contain flammable materials, either for **normal operation** or for heat-transfer, over-temperature protection devices or systems shall ensure that the material cannot exceed in **normal operation** or **single fault condition**

- a) its flash point temperature when being exposed to air, or
- b) a temperature 25 K below the fire point when in contact with any heating element.

11.6 If the **workload** can ignite or cause damage after an emergency stop or in **single fault condition**, measures shall be taken in compliance with 11.6 or as defined in the Particular requirements. The following effects shall be considered:

- a) residual heat stored in the equipment can be released over a long period after switching off;
- b) surface temperature can increase even after switch off due to the release of stored heat.

11.7 Fire-like phenomena can occur and be sustained that are partially supported by electric fields or radiation. Such phenomena require special measures dealt with in the Particular requirements.

12 Protection against hazards from fluids

12.1 General

12.1.1 The **manufacturer** shall take into account protection against hazards from fluids encountered in **normal operation** and **single fault condition**.