



IEC 60519-1

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REDLINE VERSION

INTERNATIONAL STANDARD



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

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Edition 6.0 2020-03
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**Safety in installations for electroheating and electromagnetic processing –
Part 1: General requirements**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

FOREWORD

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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 60519 series, published under the general title *Safety in installations for electroheating and electromagnetic processing*, can be found on the IEC website.

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

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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INTRODUCTION

~~This fifth edition of IEC 60519-1 is a product safety publication and is intended to:~~

- ~~— include all types of installations or equipment that are in the scope of IEC TC 27 dealing with industrial **electroheating (EH)** and **electromagnetic processing of materials (EPM)**;~~
- ~~— cover in these General Requirements all hazards that are relevant for more than one type of equipment or installation individually dealt with in Particular Requirements;~~
- ~~— give requirements on electrical safety, touch currents, electric fields, magnetic fields and radiation, thus mirroring the broad scope of installations covered and their processing frequency;~~
- ~~— give means for verification of the requirements;~~
- ~~— make extensive use of the standards developed by IEC committees with horizontal or group safety functions and of relevant ISO standards by reference, including publications developed by ISO/TC 244 (more information is given in Annex H), in compliance with IEC Guide 104;~~
- ~~— be useable like a type C standard in the sense of ISO 12100;~~
- ~~— include all material, references and requirements suitable for risk assessment and list significant hazards.~~

~~This standard addresses mainly **manufacturers** making made-to-order equipment on a single project base. The **manufacturer** is well aware that it is his responsibility to make equipment safe through adequate risk reduction and it is the responsibility of the **user** to assess exposure of the **operator** in line with applicable health and safety regulations. Looking at projects providing single pieces of equipment or single installations, this clear division of responsibilities tends to blur, caused by inter alia~~

- ~~— development of the process (**normal operation**) through the **manufacturer** and **user**,~~
- ~~— shared definition of working procedures for the **operator** by the **manufacturer** and **user**,~~
- ~~— the scope of delivery often including all protective means,~~
- ~~— individual sales contracts where **users** require an assessment of exposure through the **manufacturer**.~~

~~Thus this standards provides information on exposure hazards and limits where relevant, well aware that this is exceeding the scope of a product standard.~~

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 and object~~

1.1 ~~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.

~~The requirements are applicable to industrial installations or equipment with the possible use as:~~

- ~~— equipment for direct and indirect resistance heating,~~
- ~~— equipment for electric resistance trace heating,~~
- ~~— equipment for induction heating,~~
- ~~— equipment using the effect of electromagnetic forces on materials,~~
- ~~— equipment for arc heating, including submerged arc heating,~~
- ~~— equipment for electroslag remelting,~~
- ~~— equipment for plasma heating and plasma surface treatment,~~
- ~~— equipment for microwave heating,~~
- ~~— equipment for dielectric heating,~~
- ~~— equipment using electron guns,~~
- ~~— equipment for infrared radiation heating,~~
- ~~— equipment for laser heating.~~

~~NOTE The list presents typical examples of equipment and its applications and is not exhaustive.~~

~~The overall safety requirements for the various types of **EH** or **EPM equipment** and **installations** result from the joint application of the General Requirements specified in this standard and Particular Requirements covering specific types of installations or equipment (guidelines are given in Annex G). If no Particular Requirement is covering a specific installation or equipment, the General Requirements are applicable as such.~~

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 ~~or installations~~ 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.

1.2 Object

~~The requirements refer to the complete life cycle of the installation or equipment from design through commissioning, operation, maintenance, inspection, to decommissioning. They cover the safety of persons and protection of the environment during normal operation and under single fault condition.~~

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

~~This standard is intended for verifying that the EH or EPM equipment or installation meets the requirements of this standard through design, site acceptance tests, routine tests or inspection.~~

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 60071-1:2006¹, *Insulation co-ordination – Part 1: Definitions, principles and rules*
IEC 60071-1:2006/AMD1:2010

IEC 60204-1:2005²2016, *Safety of machinery – Electrical equipment of machines – Part 1: General requirements*
~~IEC 60204-1:2005/AMD1:2008~~

IEC 60204-11:2000²2018, *Safety of machinery – Electrical equipment of machines – Part 11: Requirements for HV 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

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

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.

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*

IEC 60398:2015⁷, *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*

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.

⁷ ~~To be published.~~

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 60990:1999/2016, *Methods of measurement of touch current and protective conductor current*

~~IEC 61000-3-3, *Electromagnetic compatibility (EMC) – Part 3-3: Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤ 16 A per phase and not subject to conditional connection*~~

~~IEC TS 61000-3-5, *Electromagnetic compatibility (EMC) – Part 3-5: Limits – Limitation of voltage fluctuations and flicker in low-voltage power supply systems for equipment with rated current greater than 75 A*~~

~~IEC TR 61000-3-6, *Electromagnetic compatibility (EMC) – Part 3-6: Limits – Assessment of emission limits for the connection of distorting installations to MV, HV and EHV power systems*~~

~~IEC 61000-3-11, *Electromagnetic compatibility (EMC) – Part 3-11: Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems – Equipment with rated current ≤ 75 A and subject to conditional connection*~~

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

~~IEC 61000-6-4, *Electromagnetic compatibility (EMC) – Part 6-4: Generic standards – Emission 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*

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~~IEC 61310 (all parts), *Safety of machinery – Indication, marking and actuation*~~

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

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~~intended to perform safety-related functions (functional safety) — General industrial applications~~

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

~~IEC 61508 (all parts), Functional safety of electrical/electronic/programmable electronic safety-related systems~~

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

~~IEC 61672-1, Electroacoustics — Sound level meters — Part 1: Specifications~~

~~IEC 61672-2, Electroacoustics — Sound level meters — Part 2: Pattern evaluation tests~~

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 61786-2:2014⁸, *Measurement of DC magnetic fields, AC magnetic and AC electric fields from 1 Hz to 100 kHz with regard to exposure of human beings – Part 2: Guidance Basic standard for measurements*

IEC 61936-1:2010⁹, *Power installations exceeding 1 kV a.c. – Part 1: Common rules*
IEC 61936-1:2010/AMD1:2014

IEC 62061:2005¹⁰, *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

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CISPR 11:2015¹¹, *Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement*
CISPR 11:2015/AMD1:2016
CISPR 11:2015/AMD2:2019

~~IEC Guide 104, The preparation of safety publications and the use of basic safety publications and group safety publications~~

~~ISO/IEC Guide 51, Safety aspects — Guidelines for their inclusion in standards~~

⁸ ~~To be published.~~

⁹ A consolidated version of this publication exists, comprising IEC 61936-1:2010 and IEC 61936-1:2010/AMD1:2014.

¹⁰ A consolidated version of this publication exists, comprising IEC 62061:2005, IEC 62061:2005/AMD1:2012 and IEC 62061:2005/AMD2:2015.

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

~~ISO 3746, Acoustics – Determination of sound power levels and sound energy levels of noise sources using sound pressure – Survey method using an enveloping measurement surface over a reflecting plane~~

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* — ~~Registered symbols~~ (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*

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 (all parts), Safety of machinery – Safety-related parts of control systems~~

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 terms and definitions given in IEC Guide 104, ISO/IEC Guide 51 and ISO 12100, as well as the following apply.~~

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

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 ~~thermal energy~~ heat for useful purposes

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

~~[SOURCE: IEC 60050-841:2004, 841-21-22, modified — **electroheating** is the preferred term instead of electroheat, new synonym **EH** has been added and the definition has been shortened.]~~

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 ~~or cannot~~ 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: In the context of this standard, **EMF** is caused by a source being part of the installation or equipment.~~

Note ~~2~~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

electromagnetic nearfield

~~non-propagating electromagnetic field~~

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 **agent** authorised representative.

~~Note 2 to entry: From the perspective of the user, the manufacturer is a party responsible for the design, manufacture, supply and commissioning of the equipment or installation.~~

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 ~~able~~ 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

~~[SOURCE: IEC 60050-826:2004, 826-16-01, modified — The word "electrical" is used instead of "electric"; the definition has been editorially improved.]~~

3.2.2

electroheating equipment

EH equipment

DEPRECATED: electroheat equipment

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

~~[SOURCE: IEC 60050-841:2004, 841-22-01, modified — **electroheating equipment** is the preferred term instead of electroheat equipment becoming its synonym, new synonym **EH equipment** has been added, in the definition heat has been replaced by thermal energy]~~

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

~~[SOURCE: IEC 60050-841:2004, 841-22-02, modified — **electroheating installation** is the preferred term instead of electroheat installation becoming its synonym, and a new synonym, **EH installation**, has been added.]~~

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 ~~some~~ 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

~~protective 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 ~~other than a guard or enclosure~~ 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

~~shield, on US~~

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 ~~resettable; temperature protectors are~~ not resettable and are replaced each time they have operated; **temperature protectors** are resettable.

~~**3.3.10**~~

~~**photocoupler**~~

~~**optocoupler**~~

~~optoelectronic device designed for the transfer of electrical signals by utilizing optical radiation to provide coupling while the output is isolated from the input~~

~~Note 1 to entry: This device can provide immunity against electromagnetic influences as well as independence of the distance of two voltage system levels.~~

~~[SOURCE: IEC 60050-521:2002, 521-04-45, modified – The note has been added.]~~

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

HV hazard zone

area 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**

~~DEPRECATED: earth 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: The electric field is usually induced by an **electromagnetic nearfield** and does not necessitate contact to a conductor.~~

~~Note 2 to entry: The effects of **induced electric shock** are essentially the same as those of electric shock caused through contact to a conductor, for example burn or nerve reaction. Conditions for ventricular fibrillation are in practice excluded.~~

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.

3.4.7**emergency switching-off**

~~operation intended to switch off any electric power from an electrical installation to avert or alleviate a hazardous situation~~

~~Note 1 to entry: Some power can remain in function if that provides a less hazardous outcome than a complete switching-off.~~

~~[SOURCE: IEC 60050-826:2004, 826-17-03, modified — The words "opening operation of a switching device intended to remove electric power" have been replaced by "operation intended to switch off any electric power" and a note has been added.]~~

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 ~~a photocoupler~~ 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

~~EMF electromagnetic field~~

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**, ~~i.e. the frequency of the voltage, current or electromagnetic field used for the process~~. 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 ^a range defining equipment type	Frequency range ^b used for safety limits	EMF-relevant frequency range	Hazards associated with the frequency range
direct current ^e or stationary field	0 Hz	0 Hz or no change in polarity		electric shock, neural stimulus
low frequency	>0 Hz to <60 Hz		0,1 Hz to 200 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 200 Hz		
		>200 Hz to 100 kHz		
high frequency	>100 kHz to 0,3 GHz	>100 kHz to 6 MHz	>100 kHz to 0,3 GHz	burn, bodypart heating
		>6 MHz to 0,3 GHz		bodypart heating
microwave		>0,3 GHz to 300 GHz		
infrared	(>300 GHz to 400 THz) 1 mm to 780 nm	1 mm to 3 000 nm	not applicable	burn of skin and cornea
		3 000 nm to 1 400 nm		
		1 400 nm to 780 nm		burn of skin and cornea, retina
visible	(>400 THz to 790 THz), 780 nm to 380 nm			
ultraviolet	(>790 THz to 30 PHz), 380 nm to 10 nm			burn of skin and cornea, skin cancer
laser	(>300 GHz to 30 PHz), 1 mm to 10 nm			burn of skin and cornea, retina

^a— Rated process frequency.

^b— Values of the corresponding free space wavelengths are also given in case of optical radiation.

^e— Direct current type — equipment with no intended change of polarity, but including switch-on and switch-off.

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	
Visible	400 nm to 780 nm		Burn of skin and cornea, burn of retina
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
<p>^a Rated processing frequency.</p> <p>^b Values of the corresponding free space wavelengths are also given in case of optical radiation.</p> <p>^c Direct current type – equipment with no intended change of polarity, but including switch-on and switch-off.</p> <p>^d The definition of UV follows IEC 62471:2006; radiation between 380 nm and 400 nm is usually sensed.</p>			

4.2 Classification by voltage

~~Throughout all electrical equipment for industrial applications a division between~~

The supply voltage of an installation or equipment is classified as

- extra low voltage (ELV) ~~and low voltage (LV) is made at~~ 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) ~~is made at~~ 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

- a) depending on the supply and the output voltage, whichever is the higher value (internal voltages inside the **electrical equipment** may be higher), ~~but~~
- b) ~~independently of~~ 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**.

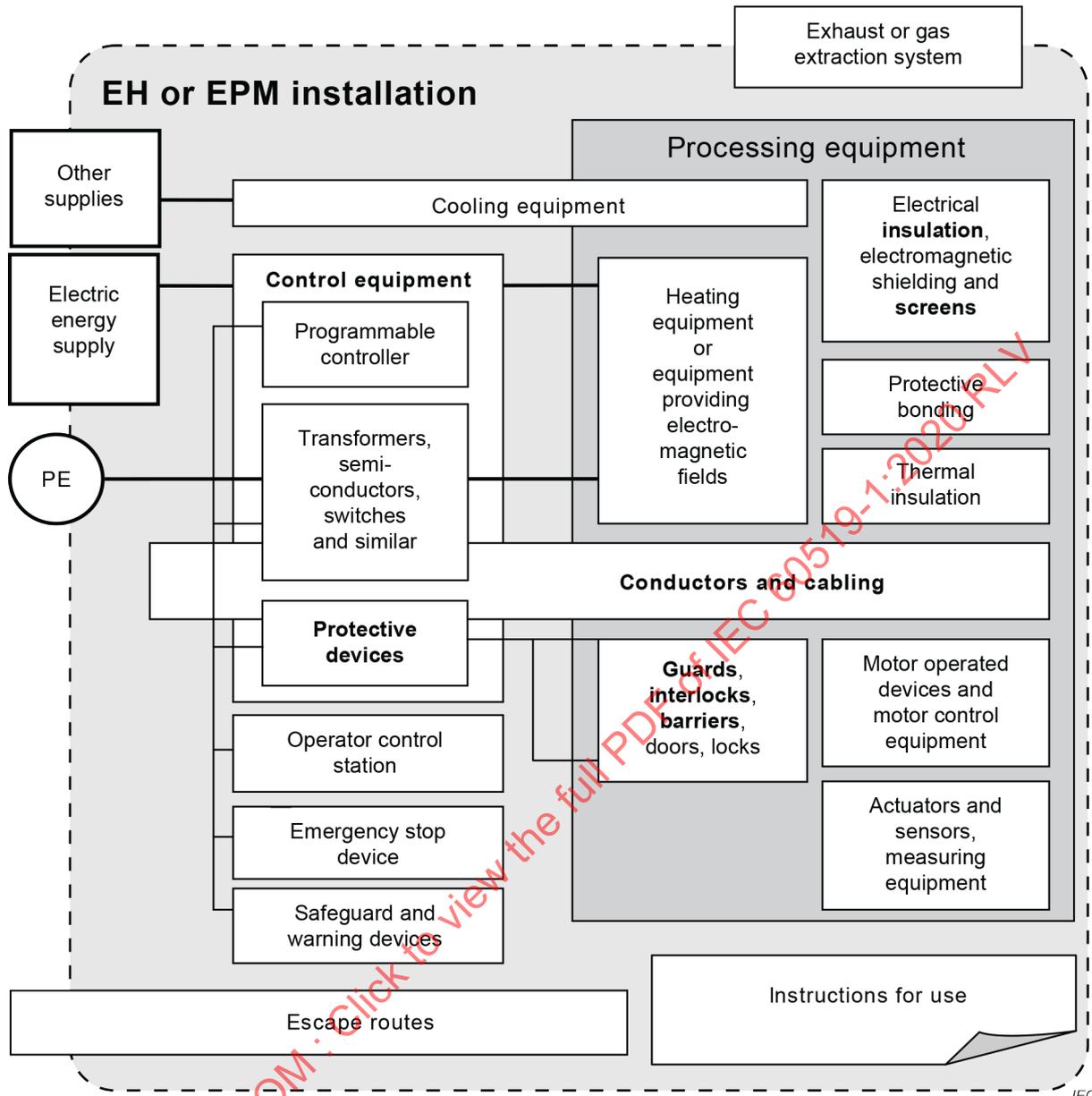


Figure 1 – Block diagram of a typical EH or EPM installation

Table 2 provides references to clauses of this document or to other standards relevant to the parts identified in Figure 1. The requirements for ~~electrical~~ 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 60204-1:2005 and IEC 60204-1:2005/AMD1:2008 for LV and IEC 60204-11:2000 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 ~~electrical~~ the equipment,
- b) strong electric, magnetic or **electromagnetic fields** can interact with the ~~electrical~~ 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			
conductors and cabling at standard environment			
Electric energy supply		HV, ≤ 200 Hz	IEC 61936-1, IEC 60071-1
Protective earth, PE			
Protective bonding			
conductors and cabling at standard environment			
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 13.32
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 series IEC 61508-1, IEC 62061, ISO 13849 series 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, fuel, 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

Part of installation or equipment – See Figure 1		Condition for which the reference is valid	Reference/source of provisions
Part	Component/item		
Escape routes		all	IEC 60364-4-42
Processing equipment	electrical heating equipment, usually 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 series 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 ~~according to the following criteria~~ 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

- a) sensed hazards – i.e. hazards creating adverse body reactions, and
- b) 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

~~Risks depending~~ A specific risk depends on ~~exposure level~~ **emission**, duration, intensity of the agent, but also ~~depending~~ 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 ~~of the risk~~, 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 ~~this as a general approach~~ the classification of residual **emissions** used in this document.

Table 3 – Safety classification scheme for ~~exposure~~ risks to humans

Risk Group 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 deemed necessary by the manufacturer, he shall indicate this.
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. ~~Annex B and Annex C provide examples of risk group classifications.~~

4.4.3 Limits

~~Limits for significant hazards dealt with in this standard concern the following:~~

- ~~— electric, magnetic and **electromagnetic fields** including touch currents — information on hazards and applicable limits is provided in Annex B;~~
- ~~— optical radiation in the infrared, visible and ultraviolet — information on internationally recognised limits is provided in Annex C;~~
- ~~— acoustic fields — information on limits is provided in Annex D;~~
- ~~— hot ambient environment and objects — limits are given in ISO 13732-1, which corresponds to IEC Guide 117 (see also Clause 10).~~

~~It is in the responsibility of the **manufacturer** or **user**, as relevant, to take into account limit values specified by national regulations, if such exist. If not, the limits defined in this standard can be used.~~

5 Risk assessment

~~The risks associated with hazards relevant to the installation shall be assessed. This determines the adequate reduction of identified risks and the necessary protective measures, while still maintaining an appropriate performance of the installation.~~

~~This standard, in combination with the applicable Particular Requirements, assists the **manufacturer** during the process of risk assessment and risk reduction. This standard addresses the hazards specific and typical for **EH** and **EPM installations**. Annex A provides a list of significant hazards considered in this standard.~~

~~Implementation and methods of risk assessment and risk reduction are specified in ISO 12100 and apply.~~

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 ~~Any~~ 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 ~~during **normal operation** or **single fault condition**~~. 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 ~~for~~ considering the foreseeable lifetime of the **EH** or **EPM installation** or **equipment**.

~~It shall not cause~~ 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 ~~Any~~ The **EH** or **EPM installation** or **equipment** shall be designed to prevent or to reduce the possibility of ~~any~~ misuse or fault condition.

6.1.3 ~~Any~~ 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.

~~Even though an inherently safe design seems out of reach for most EH or EPM installations or equipment, the manufacturer shall attempt to achieve this where possible.~~

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 ~~group~~ 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 ~~group~~ 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 ~~group~~ 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 ~~group~~ 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 ~~various types of~~ the identified significant hazards defined in Annex A are specified in Clauses 6 to 17. ~~Annex A provides a list of significant hazards relevant for the application of this standard.~~

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. ~~In this case, 4.1 and Annex B of IEC 60204-1:2005 and IEC 60204-1:2005/AMD1:2008 are applicable for LV installations and 4.1 and Annex B of IEC 60204-11:2000 are applicable for HV installations.~~ 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. ~~In addition, the equipment shall have a level of immunity to electromagnetic disturbances so that it can operate in its intended environment. Requirements are identified in Annex E.~~

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 ~~of the equipment~~ 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 60204-1:2005/2016 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** ~~is~~ 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 ~~inside~~ 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 ~~an extremely~~ 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 ~~or near~~ and outside the processing equipment,
- b) at the humidity levels inside ~~or near~~ and outside the processing equipment (extreme humidity levels or strong condensation can be expected as well as total immersion),
- c) at intended atmospheric conditions ~~and pressures~~ inside ~~or near~~ and outside the processing equipment,
- d) under prevalent electric and magnetic fields inside ~~or near~~ 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 ~~or near~~ 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 ~~and~~ 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 ~~on by~~ 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; ~~according to IEC 60204-1~~, 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) ~~shall not go into unsafe~~ a safe mode of operation ~~or~~ – 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) ~~shall~~ not lose the setting of the switchgear, controlgear or programmable controller necessary for safe operation,
- c) ~~shall~~ be able to keep all **protective devices** fully operational or let them give a stop command, and
- d) ~~shall~~ 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 ~~the~~ any hazard or to ~~the~~ 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** ~~shall be provided~~ 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.

6.6.4 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 ~~device or component~~ **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 **Electrical** 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 **Electrical** Equipment susceptible to damage at low temperatures includes PVC insulated cables, certain electrolytic capacitors or equipment using cooling-~~water~~ 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 ~~fitted with attachments~~ 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) for the processing equipment, if this is not covered by the scope and the environmental limits of the IEC 60204 series, i.e. exceeding 40 °C and~~

~~b) for equipment of **EH** or **EPM installations** with an electrical frequency exceeding 200 Hz.~~

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 ~~the IEC 60204 series~~ IEC 60204-1 or IEC 60204-11, nor for installations or equipment with a voltage exceeding 36 kV, which ~~is~~ are covered by the Particular requirements.

~~NOTE – Electrical hazards are associated with electric charges and currents between frequencies of 0 Hz and up to about 100 kHz. Conventional electric shock phenomena gradually change or disappear at the upper limit; protective means like equipotential bonding cease to operate reliably.~~

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 ~~either~~ during **normal operation**, or under **electric single fault condition**.

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

7.2.3 Non-accessible parts are ~~all~~ 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 5.34 of IEC 61140:2004/2016 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 ~~which~~ 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 ~~HV~~ **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.

~~If any of the parts mentioned in a) and b) receive a charge from an internal capacitor, they shall not be hazardous-live 10 s after interruption of the supply.~~

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 14119 and~~ 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 ~~shall become~~ 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 **touched** 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 ~~protection~~ 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 7.5.78.

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 (7.3.4). 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. ~~For the assessment of short circuit currents IEC 60909-0 shall be used, for effects of short circuit currents IEC 60865-1 is applicable.~~

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-voltage 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.

~~NOTE—IEC TS 60479-1 can provide relevant data on impedance.~~

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 60204-1:2005/2016. 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 60204-1:2005/2016.

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 duration 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 ~~Protective conductor currents~~ **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 current hazards are caused by currents flowing through the human body (this current is not necessarily equal to the current flowing through a protective conductor). The effect of electric current on a human body is causing some distinct responses which need to be considered. These are~~

- ~~a) perception of a current or a spark up to pain;~~
- ~~b) a physical reaction caused by the perception or pain, this physical reaction can be uncontrolled;~~
- ~~c) hindering of let-go;~~
- ~~d) electric burn, either small scale at the touch point or large scale due to overheating of bodyparts of high resistivity.~~

~~Each of these body responses has a unique threshold level and there are significant differences in the manner in which some of these thresholds vary with frequency.~~

7.9.1 Touch currents causing harm shall be avoided. No part or surface that can cause harm when touched shall be ~~within arm's reach. Annex B informs about limits for touch currents and touch voltages~~ 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.

~~NOTE IEC TS 60479-1 and IEC TS 60479-2 provide additional information for risk assessment as well as Annex A of EN 50445:2008.~~

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 AnnexG, 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 ~~caused by~~ from electric or magnetic ~~nearfields~~ 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 ~~nearfields~~ 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 ~~of~~ caused by magnetic ~~or~~, electric ~~nearfields and from~~ **EMF** 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** Direct contact between the hand or fingers and live conductors shall be hindered, as for protection against electric shock in Clause 7.~~

~~**8.1.4** Access by hands, arms, head and torso to regions with field intensities exceeding the limits or characteristics resulting in efficient induction of electric fields shall be prevented by the same geometric restrictions as for live parts – refer to Clause 7.~~

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 ~~group~~ 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 ~~group~~ 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 ~~optical or audible warning devices are in place and the following requirement is met~~ the **manufacturer shall indicate** indicates to the **user if applicable**

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, ~~according to IEC 60664-1.~~

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 Limits of maximum ozone concentrations over time can be found in national regulations.~~

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

~~**8.3.5** If fires or explosions can result from ignition of flammable materials by sparks caused by induced fields, contact currents, or spark discharges, Clause 11 applies.~~

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 ~~under these conditions~~ neither ~~cause a hazard due to excessive heat~~ exceed the temperature limit for touchable surfaces as defined in Clause 10 nor shall their integrity of protection be compromised. ~~If heating exceeding the limits for safe touch is expected, Clause 10 applies.~~

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 ~~under these conditions~~ 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 B 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 ~~static~~ magnetic fields and field gradients of **static fields or low frequency fields**. ~~Annex B provides information for static 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 ~~pacemakers~~ **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 B D. The **manufacturer** shall indicate this ~~problem~~ 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 carrying any metal objects or having implants of any kind (i.e. metallic or medical electronic devices) or wearing any metal objects shall only attend any zone of risk group 1, if they are instructed about the need of slow movements and if a special optical or audible warning device is in operation indicating the existence of such a field.~~

- 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 or ordinary persons~~ 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 ~~group 2~~ 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 ~~group 1 or higher~~ 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 ~~different~~ the possible sources of radiation (e.g. emitter, **workload** or ~~wall~~ 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 ~~shall be taken into account as they~~ can lead to unintended hazardous ~~exposure~~ **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 ~~by a very hot~~ from a **workload** after leaving the installation;
- **emissions** becoming accessible during ~~access for~~ maintenance, commissioning or testing;
- **if emission** from heating elements that are operated outside the processing equipment;
- **if** reflectors, refractors or reflective walls inside the **EH** or **EPM installation** ~~cause~~ or **equipment** causing zones of intense irradiation outside ~~the installation~~;
- ~~if hot walls inside the processing equipment cause zones of intense irradiation outside the installation.~~

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 ~~in most countries~~ usually regulated by national authorities. These regulations ~~usually~~ 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**. ~~Examples of regional or national regulations are Directive 96/29/EURATOM for the European Union and document 29 CFR 1910.1096 for the USA.~~

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** The assessment of UV hazards for lamps is detailed in IEC 62471, but that approach shall be used for any UV radiation source without limiting its validity.~~

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 ~~designed~~ intended to ~~provide external UV illumination~~ 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 radiation and irradiation levels to safe levels that either cause a possible exposure hazard to **operators**, or cause equipment not suited to exposure to intense UV radiation to levels that can destroy such equipment preliminary. Measures can include **screens, barriers**, locked doors, filtered **windows** and warning markings. The **manufacturer** shall indicate to the **user** in the information for use the need for personal protective equipment if hazardous exposure is possible.~~

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** ~~or installations under the scope of this standard~~ 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 ~~The assessment of visible light and infrared hazards for lamps is detailed in IEC 62471, but that approach shall be used for any visible or infrared radiation source without limiting its validity.~~ **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, ~~refer to Annex C~~. Filters shall either be grey or primarily reduce the non-visible parts of the **emission**.

9.5 Laser sources

~~Equipment employing~~ 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 ~~Aside from electrical hazards,~~ High temperature and thermal energy are ~~the most important~~ relevant hazards to consider during all stages of design and manufacture of **EH** ~~and~~ or **EPM installation** or **equipment**. Clause 10 covers direct aspects, whereas indirect aspects of thermal energy are treated throughout this document:

- provisions concerning ~~hazards caused by~~ thermal radiation are given in Clause 9 ~~as bodies at elevated temperature cause radiation~~;
- 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 ~~The general rule for normal operation is that~~

- ~~a) all materials used shall at least withstand the influence of thermal energy exposed to during normal operation over the designed lifetime of that part;~~
- ~~b) if the designed lifetime of a part is shorter than the lifetime of the installation or equipment a maintenance cycle shall be part of the information for use indicating replacement cycle.~~

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 ~~The general rule for single fault condition is that~~

- ~~a) all material used shall at least withstand the influence of thermal energy 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;~~
- ~~b) 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;~~
- ~~c) if any materials or parts are exchanged after being exposed to thermal energy higher than that foreseen for normal operation, this shall be indicated in the information for use.~~

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 unintentionally shall not exceed the temperature limits as set in **ISO 13732-1 Annex E** during **normal operation** or in **single fault condition** ~~unless national regulations provide other limits.~~

All ~~other~~ surfaces exceeding this limit and that are in reach of the **operator**

- ~~a) shall either not exceed the limits as set in ISO 13732-1, or~~
- ~~b) a barrier shall be placed to prevent accidental touching, or~~
- ~~c) 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, ~~e.g. following ISO 15265.~~

10.4 Heat Temperature resistance of components

10.4.1 All structural parts and **enclosures** shall be made from material that is sufficiently **heat** temperature resistant at all temperatures they ~~are exposed to~~ 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 ~~never reaches~~ **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 ~~is exposed to~~ 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 ~~of~~ 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 ~~Released~~ **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	Processing equipment and environment thereof	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 ~~attended~~ **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** ~~in a temperature control system, heater, cooling means, circulating pump or fan, agitator, or other part~~ **condition** could cause a hazard through overheating of any part of the **EH** or **EPM installation** or **equipment** ~~or of including the workload, a non-self-resetting thermal cut-out~~ or system meeting the requirements of 14.7 shall de-energize the heating means and any other parts which could cause ~~a~~ 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 ~~In EH and EPM equipment or installations~~ 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, ~~a second an independent temperature control system~~ 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

~~This Clause 11 applies for the installation in general and the processing equipment. Protection against fire hazards for **electrical equipment** shall be according to the relevant standards identified in Table 2.~~

~~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.~~

~~NOTE 1 Hot surfaces, intense optical radiation, arcs, plasmas, hot gases or liquids are to be expected near or inside **EH installations**. Plasma or static electrical discharges can occur in **EPM installations**.~~

~~NOTE 2 Plasmas, discharges and other electric phenomenon can provide extra energy thus lowering the flame point or lead to ignition.~~

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 ~~liquid~~ material cannot exceed in **normal operation** or **single fault condition**

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

~~**10.6.7** 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.~~

11.6 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**.

12.1.2 ISO 13577-2:2014 applies for combustion and fuel handling systems; ISO 13577-3:2016 applies for protective and reactive atmospheres if applicable. For all other fluid systems, the provisions 12.1.3 through 12.1.9 apply.

12.1.3 If, in **normal operation** or **single fault condition**, fluid is likely to be spilt into the **EH** or **EPM installation** or **equipment**,

- a) ~~the equipment~~ it shall be designed so that no hazard is possible – for example as a result of the wetting of **insulation** or of internal **hazardous-live parts**,
- b) no corrosion leading to a hazard ~~is~~ shall be possible – for example as a result of the contact of potentially aggressive substances with parts ~~of the equipment~~ likely to be damaged, and
- c) suitable means ~~below the equipment~~ able to collect or divert the spill shall be positioned.

NOTE Fluids or spills can be regulated with respect to environmental hazards; this can affect the means taken.

If in **normal operation** or **single fault condition**, potentially aggressive substances (such as corrosive, toxic or flammable liquids) are likely to be spilt on parts of the **EH** or **EPM installation** or **equipment**, the possibly affected surfaces shall be made from material not affected by the aggressive substance.

12.1.4 The maximum pressure to which a part of the **EH** or **EPM installation** or **equipment** can be subjected in **normal operation** or **single fault condition** shall not exceed the rated maximum working pressure for the part. The maximum pressure shall be considered to be the highest of the following:

- a) the rated maximum supply pressure specified for an external source;
- b) the pressure setting of an overpressure safety device provided as part of the assembly;
- c) the maximum pressure that can be developed by a pressure generating device that is part of the assembly, unless the pressure is limited by an overpressure safety device.

12.1.5 Fluid-containing parts shall not cause a hazard through rupture or leakage. No **intended** leakage is allowed from fluid-containing parts intended for toxic, flammable, or otherwise hazardous substances.

12.1.6 Fluid-containing parts of refrigeration systems shall meet the relevant pressure-related requirements of IEC 60335-2-24 or IEC 60335-2-89 as applicable.

12.1.7 Leakage from or into fluid-containing parts at pressures lower than ambient shall not cause a hazard.

12.1.8 Liquid overflowing from any container in the equipment which can be overfilled shall not cause a hazard during **normal operation**, for example as a result of the wetting of **insulation** or of internal parts that are hazardous-live.

Equipment likely to be moved while a container is full of liquid shall be protected against liquid surging out of the container.

12.1.9 Any cleaning, decontamination or disinfection process indicated by the **manufacturer** shall not cause degradation of the equipment or any foreseeable hazard.

12.2 Poisonous and injurious ~~gases and substances~~ fluids

12.2.1 The **EH** or **EPM installation** or **equipment** shall not liberate ~~dangerous~~ hazardous amounts of poisonous or injurious ~~gases or substances~~ fluids in **normal operation**, or create a hazard in **single fault condition**.

12.2.2 If such ~~gases or substances~~ fluids are likely to be liberated, they shall be drawn into an extraction system.

12.2.3 If ~~released gases~~ a flow of fluids or particulate matter can pose a hazard due to their temperature or impulse ~~they~~, it shall be diverted from the installation and from the **operator**.

12.2.4 Hazard zones shall be marked and a **barrier** or **obstacle** shall limit accessibility.

12.2.5 **EH** or **EPM installation** or **equipment** drawing in air for any purposes shall not draw in exhaust gas unless necessary for the process or for energy ~~recuperation~~ efficiency needs.

12.2.6 The **manufacturer** shall indicate necessary personal protective equipment for such substances or gases that can be liberated during **normal operation** or **single fault condition**.

12.3 Explosion and implosion of pressurised parts or vacuum equipment

12.3.1 Pressurised parts of the **EH** or **EPM installation** or **equipment** including **vacuum** equipment shall be designed to **sustain normal operation** and **single fault conditions** over the intended lifetime.

NOTE ISO 16528-1:2007 can be used unless different national or regional regulations apply.

12.3.2 Components liable to burst, implode or explode if overheated ~~or~~, overcharged, or in other **single fault condition** shall be provided with a pressure release device.

12.3.3 Protection of **operators** by **enclosures** shall be incorporated in the **EH** or **EPM installation** or **equipment** to protect them from debris or expelled parts.

12.3.4 The effect of sudden boiling of liquids at pressure loss and resulting hazards, like spill, explosion, burn and scald shall be taken into account.

13 Specific requirements for components and subassemblies

13.1 General

All components and devices of the **EH** or **EPM installation** or **equipment**

- a) shall be suitable for their intended use,
- b) shall conform to relevant IEC or ISO standards where such exist, and
- c) shall be applied in accordance with their information for use.

13.2 Electrical equipment and conductors

13.2.1 The **electrical equipment** of the **EH** or **EPM installation** or **equipment** shall satisfy the safety requirements identified by the **manufacturer**.

Depending upon the **EH** or **EPM installation** or **equipment**, its intended use and its **electrical equipment**, the designer may select parts of the **electrical equipment** of the installation that are for LV in compliance with relevant parts of the IEC 61439 series and for HV parts in compliance with relevant parts of the IEC 62271 series – see also Annex **EF** of IEC 60204-1:2005/2016 ~~and IEC 60204-1:2005/AMD1:2008~~.

NOTE IEC 61439 (all parts) specifies requirements for equipment covering a wide range of possible applications of LV switchgear and controlgear assemblies. IEC 62271 (all parts) specifies requirements for equipment covering a wide range of possible applications of HV switchgear and controlgear assemblies.

13.2.2 The dimensioning of electrical conductors depending on maximum current and temperature shall follow IEC 60228:2004 for intended temperatures of the conductors up to 40 °C. Clause 11 of IEC 60335-1:2010 and IEC 60335-1:2010/AMD1:2013 provides calculation methods and tests for assessing the maximum temperature of electric conductors at a temperature exceeding 40 °C and shall be used when applicable.

13.2.3 The proximity and the skin effect shall be taken into account when dimensioning conductors for higher frequencies, ~~as the penetration depth of the current decreases with increasing frequency. This affects cross sectional area of the conductor and surface to volume ratio.~~

NOTE The penetration depth of the current decreases with increasing frequency. This affects the cross sectional area of the conductor and surface to volume ratio. Thus tables of cable current-carrying values relevant for mains frequency (50 Hz/60 Hz) are generally not applicable for installations working at higher frequencies.

13.3 Connection to the electrical supply network and internal connections

13.3.1 The connection to the electrical supply network depends on the type and the voltage of the supply system according to 312 of IEC 60364-1:2005. The conductors shall be in accordance with Clause 12 of IEC 60204-1:2005/2016 for LV and in accordance with Clause ~~12~~13 of IEC 60204-11:2000/2018 for HV. The conductors shall be identified according to IEC 60445.

13.3.2 The incoming supply conductor shall be in accordance with 5.1 of IEC 60204-1:2005/2016 for LV ~~and~~ connection or in accordance with 5.1 of IEC 60204-11:2000/2018 for HV connection.

13.3.3 Interconnecting conductors shall be designed and arranged so that ~~in normal operation~~ they do not undergo abnormal mechanical stresses in **normal operation**, for example due to bending, tension, flexing, torsion, friction or vibration, or effects of radiation, heat, moisture or vapours liable to damage them. **Single fault condition** shall be considered as well.

13.3.4 Enclosures of conductors shall ensure

- protection of **insulation** of conductors against abrasion and laceration, and
- protection of conductors against tension and torsion.

Enclosures and devices adopted to avoid tensile stress in fixed electrical connections shall not be hazardous-live. They shall also be so designed that any damage of the conductor to be protected from abnormal tensile stresses is prevented.

13.3.5 EH or EPM installation or equipment, or parts of it, which ~~is~~ are not permanently connected to the supply network shall meet the following requirements:

- a) it shall have a permanent fixed flexible connecting conductor which can only be removed with the use of a tool;
- b) connections using a sliding contact shall be inaccessible, ~~both~~ when connected and when disconnected but live;
- c) **live parts** of plug-and-socket devices shall be inaccessible when connected ~~or~~ and when disconnected but live;
- d) removable connecting lines shall contain the necessary active and protective conductors clearly identified and laid-up together;
- e) when several plugs are used, an erroneous connection shall be prevented by shape or distinct marking of the plugs.

13.3.6 All flexible wiring shall meet the following requirements:

- a) it shall be provided with protective sheaths; measures taken to ensure protection against tensile stress and torsion shall be readily recognizable;
- b) it shall be protected against excessive flexing at the points of entry; protective sheathing shall be sufficiently long to avoid any damage through bending;
- c) it shall be fixed securely or other means shall avoid any hazard through their position in or near the installation.

13.3.7 All conductors internally or externally cooled with a liquid coolant, and where the coolant circuit is part of the conductor, shall

- a) at least meet the requirements of Clause 12 with respect to the coolant circuit, and
- b) be designed such that **leakage currents** do not cause a hazard.

NOTE Some coolants, like water, are conductive or can become conductive; their use can lead to **leakage currents**.

13.4 Isolation and switching

13.4.1 Isolation, switching-off for maintenance, ~~emergency switching-off~~, and functional switching shall be provided and be in accordance with the ~~relevant~~ applicable standards, IEC 60204-1 for LV and IEC 60204-11 for HV respectively, or IEC 60364-4-41 and IEC 60364-5-53, when applicable.

13.4.2 Examples of control and auxiliary circuits which, depending on the application, need not to be switched off, are:

- a) lighting and socket-outlet circuits for the connection of repair and maintenance tools, for example lamps or drills (irrespective of their voltage);
- b) circuits supplying under-voltage trips and circuit-breaker closing and tripping devices which are operated at mains voltage, but are not used for control purposes;
- c) auxiliary circuits with ELV;
- d) other auxiliary circuits supplying essential components, for example pumps, fans and drives, as well as cooling equipment, which shall not be switched off during the period of interruption of the mains supply;
- e) uninterruptable power supply circuits providing power to equipment for safety control, computer, human machine interfaces, or closed control TV.

In the case of LV or HV, the circuits mentioned in a) to e) above shall employ cables or insulated conductors segregated from those following the supply disconnecting switch. They shall be connected via separate specially enclosed terminals and shall be provided with a separate disconnecting switch.

In the case specified under item b), this disconnecting switch may not be applied. The circuits, which are not disconnected by the supply-disconnecting switch, shall be clearly indicated in the technical documentation and may be indicated on the equipment.

13.4.3 Switching of direct current or mains frequency currents at HV through the use of circuit breakers is permissible for supply, disconnection and isolation, providing the following conditions exist:

- a) an isolating distance is provided and visible – for example a disconnecting switch or a withdrawn circuit-breaker;
- b) facilities are provided to prevent closing of the isolating switches and providing connection to earth of the outgoing cables or busbars.

13.5 Sensors and actuators safeguarding moving parts

ISO 13855 ~~and ISO 13857 apply~~ applies.

13.6 Motors

Clauses 14 and 18 of IEC 60204-1:20052016 for LV and ~~Clause 14~~ Clauses 15 and 19 of IEC 60204-11:20002018 for HV installations or equipment apply.

13.7 Non electric-heating means

Combustion based heating means shall conform to ISO 13577-2, ~~if applicable~~.

13.8 Lighting

13.8.1 If the ambient lighting is not sufficient to prevent risks – for example areas of shadow or dazzle exist – the **EH or EPM installation or equipment** shall be designed with integrated lighting. Parts requiring frequent maintenance, inspection or adjustment and not illuminated sufficiently by the ambient light shall be provided with integrated lighting.

13.8.2 The **EH or EPM installation or equipment** shall be designed and constructed so that there is no area of shadow likely to cause nuisance, that there is no irritating dazzle and that there are no dangerous stroboscopic effects ~~on moving parts~~ due to the lighting or moving parts.

13.9 Structural parts and stability

13.9.1 The **EH or EPM installation or equipment** and all its parts shall be sufficiently stable to avoid break-up or collapse during **normal operation** or **single fault condition**.

13.9.2 The **EH or EPM installation or equipment** shall be sufficiently designed or anchored to avoid tripping, overturning, falling or any uncontrolled movements during **normal operation** or **single fault condition**.

13.9.3 Design of the structural parts or foundations of the **EH or EPM installation or equipment** shall not generate hazards, for example through the possibility of trapping of the **operator** in **normal operation** or **single fault condition**. This includes hazards from spilled fluids.

13.10 Doors, windows and other openings

13.10.1 Subclauses 11.4 and 11.5 of IEC 60204-1:20052016 apply ~~for LV installations or equipment~~.

13.10.2 **Means of access** shall be secured by an **interlock**, where the **interlock** eliminates the hazard immediately. Hazards that are not eliminated immediately shall only be accessible by the use of a tool.

Means of access shall be fitted with marking and warning as defined in Annex G.

13.11 Transformers, inductors, capacitors

13.11.1 Refer to 13.1. Subclause 7.2.7 of IEC 60204-1:2016 and 7.2.4 of 60204-11:2018 apply. A **thermal cut-out** shall operate, if over-currents in the secondary circuit of transformers can cause overheating of the winding.

13.11.2 Energy stored in capacitors and inductive components shall be released or discharged safely in **normal operation** or **single fault condition**.

13.11.3 Safe working procedures, methods to safely discharge prior to maintenance or in case of emergency as well as any residual hazards shall be indicated to the **user** of the equipment.

13.12 Handheld applicators

13.12.1 The start of **normal operation** of a **handheld applicator** shall be through the sequential activation of a start switch and an operation switch. The switches shall be located at such a distance from each other that simultaneous activation by a single hand is not possible.

Both switches shall be biased-off switches, i.e. switches that automatically return to the off position when their actuating member is released. The start switch enables the operation switch and the operation switch enables **normal operation**.

The **handheld applicator** shall indicate its operation to the **operator** through a signal lamp or comparable means.

13.12.2 In case operation of the **handheld applicator** generates a hazardous field when lifted off a **workload** surface, it shall have an **interlock** that deactivates operation when it is removed from the **workload**.

13.12.3 **Screens** or **barriers** shall prevent the placement of hands or other bodyparts near the active part of the **handheld applicator** if it emits hazardous fields.

Such **screens** or **barriers** shall only be removable with a tool; their mechanical stability shall be sufficient in consideration of their expected handling by the **operator**.

13.12.4 An applicable warning as defined in Annex G for the type of field shall be affixed and visible near the active part of the **handheld applicator**.

13.13 Vacuum system

Arcing inside a **vacuum** system shall not create a hazard.

13.14 Protective and reactive gas generator

In case the **EH** or **EPM installation** or equipment includes a generator for protective or reactive gases, Clause 11 of this document and ISO 13577-3:2016 apply.

14 Control of the installation or equipment

14.1 General

The need for **operator** intervention shall be limited. If intervention is necessary, it shall be conducted ~~easily and~~ safely and with ease.

Subclauses 14.2 through 14.7 define requirements based on this general concept.

NOTE The decision to use functional safety concepts is beyond the scope of this document. ISO 13577-4:2014 provides an illustration, when the application of IEC 61508-1:2010 or ISO 13849-1:2015 becomes necessary.

14.2 Operator control unit

14.2.1 Any operator control unit shall be

- a) clearly visible and identifiable, using ~~pictograms~~ standardised symbols where appropriate,
- b) positioned in such a way as to be safely operated without hesitation or loss of time and without ambiguity,
- c) located outside a hazard zone – the sole exception being emergency stops, and
- d) positioned in such a way that the operation cannot cause additional risks.

14.2.2 Any operator control unit or the control system with EH or EPM installations or equipment with defined hazard zones shall

- a) be positioned in a way that enables the operator to ensure that no one is inside a hazard zone,
- ~~b) assure that starting is prevented while someone is in the hazard zones,~~
- ~~e) give acoustic, visual or a combination of both warnings before the installation is started; exposed persons shall have sufficient time to leave the hazard zone or prevent starting, and~~
- c) assist the operator to assure that starting is prevented while someone is inside a hazard zone.

Persons inside a hazard zone or otherwise potentially being exposed to any hazard shall have sufficient time to leave the hazard zone or prevent starting.

NOTE In large installations the operator may not be able to see all hazard zones.

14.2.3 The provisions of Clause 10 of IEC 60204-1:2005/2016 for LV and those of Clause 10 of IEC 60204-11:2000/2018 for HV installations or equipment for operator control units and operator-machine interfaces apply.

14.2.4 If there is more than one operator control unit, the control system shall assure that the use of one of them precludes the use of the others, except for ~~stop controls and~~ emergency stops; ~~the use of stop controls may be kept.~~ Each operator control unit shall be provided with all the required control devices without the operators hindering or putting each other into a hazardous situation. For details, refer to ~~9.2.5.4~~ 9.2.3 of IEC 60204-1:2005/2016 ~~for LV installations or equipment.~~ Each unit shall be provided with controls to stop some or all of the functions of the equipment or installation, depending on the ~~existing~~ relevant hazards, so that safety is ensured during and after the stop.

14.2.5 Any operator control unit shall be designed or protected in such a way that the desired effect, where a hazard is involved,

- a) can only be achieved by a deliberate action, and
 - b) is manufactured to withstand foreseeable forces.
- e) Particular attention shall be paid to emergency stop devices as these are liable to be subjected to considerable forces in case of an emergency.

14.3 Emergency stop

~~The design of the emergency stop shall be according to ISO 13850. All emergency stop devices shall be clearly identifiable, clearly visible and quickly accessible. Once the active operation of the emergency stop has ceased following a stop command, that command shall be sustained by engagement of the emergency stop device until that engagement is specifically overridden. It shall not be possible to engage the device without triggering a stop command. It shall be possible to disengage the device only by an appropriate operation, and disengaging the device shall not restart the equipment but only permit restarting. Emergency~~

~~stop devices shall be in accordance with 10.8 of IEC 60204-1:2005 for LV installations or equipment.~~

14.3.1 Emergency stop devices shall be in accordance with 10.7 of IEC 60204-1:2016.

14.3.2 All emergency stop devices shall be clearly identifiable, clearly visible and quickly accessible.

14.3.3 Once the active operation of an emergency stop has ceased following a stop or switching off command, the effect of this command shall be sustained until it is reset. This reset shall be possible only by a manual action at the device where the command has been initiated. The reset of the command shall not restart the equipment but only permit restarting.

14.3.4 The emergency stop signal shall stop the hazardous process as quickly as possible, without creating additional risks. It can trigger or permit the triggering of safeguarding actions. The emergency stop function shall be available and operational at all times, regardless of the operating mode. Emergency stop devices shall be a back-up to other safeguarding measures; they shall not be a substitute for them.

14.3.5 The sequence of emergency stopping operations (e.g. fan and conveyor motors in relation to main processing circuits) shall be taken into account by the **manufacturer** during design and shall be specified in the information for use.

14.4 Control systems and their safety functions

14.4.1 Control systems shall be designed and constructed in such a way as to minimise the occurrence of hazardous situations with the aim of achieving adequate reduction of risks, or prevent hazardous situations. In particular, they shall be designed and constructed in such a way that

- they can withstand the intended operating stresses and external influences,
- a fault in the hardware or the software of the control system does not lead to hazardous situations,
- errors in the control system logic do not lead to hazardous situations, and
- reasonably foreseeable human error during operation does not lead to hazardous situations.

It is not always possible to fully avoid all hazards; in this case, an adequate reduction of risks shall be reached and documented by the **manufacturer**.

NOTE Adequate risk reduction can ~~This may~~ be reached through suitable functional safety as defined in IEC 61508-1:2010 or ISO 13849-1:2015.

14.4.2 Start functions shall be initiated by a start button. Start functions shall initiate the energizing of the relevant circuit. Start shall not be automatic if this can create a hazard. In case push buttons are used, separate push-buttons for "Start" and "Stop" shall be provided.

14.4.3 **Interlocks** shall be provided to secure correct sequential starting.

14.4.4 Stop functions shall override related start functions. The installation shall not be prevented from stopping if ~~the~~ a stop signal has been given. Where more than one control station is provided, the stop command from any control station shall be effective.

14.4.5 For operating modes, 9.2.3 of IEC 60204-1:2005/2016 applies with the addition that "motion" shall include "heating" and "processing".

14.4.6 For suspension of safety functions or protective measures, ~~9.2.4 of IEC 60204-1:2005 applies with the addition, that “motion” shall include “heating” or “processing”~~ 9.3.6 of IEC 60204-1:2016 applies.

14.4.7 For cableless control system, ~~9.2.7 of IEC 60204-1:2005~~ 9.2.4 of IEC 60204-1:2016 applies.

14.4.8 For emergency operations, ~~9.2.5.4~~ 9.2.3.4 of IEC 60204-1:2005/2016 applies.

14.4.9 For control functions in the event of failure, 9.4 of IEC 60204-1:2005/2016 ~~and IEC 60204-1:200/AMD1:2008~~ applies.

14.5 Controlgear

14.5.1 Sensors ~~of any physical quantity~~ and actuators shall be selected and mounted taking into account all conditions during **normal operation** and **foreseeable single fault condition** – for example temperature, mechanical action or electromagnetic phenomena.

14.5.2 ~~Push-buttons~~ Actuators shall be in accordance with 10.2 of IEC 60204-1:2005/2016.

14.5.3 Indicator lights and displays shall be in accordance with 10.3 of IEC 60204-1:2005/2016.

14.5.4 Control circuits shall comply with 9.1 of IEC 60204-1:2005/2016.

~~14.5.5 Control circuits can be supplied from a network of type TN or TT – refer to 312.2 of IEC 60364-1:2005.~~

~~14.5.6 In control circuits supplied via a transformer~~

- ~~a) with one end of the secondary winding connected to the earth, short circuit protection shall be provided in the unearthed conductor of the secondary side. Such protection is not required if short circuit protection elements on the primary side ensure equivalent safety;~~
- ~~b) with earthed centre tap of the secondary winding, protection against short circuits shall be provided in both poles of the secondary side of the control circuits.~~

14.5.5 When photocouplers are used as a means of **galvanic separation**, for example in semi-conductor converters, clearance and creepage distances shall be specified as minimum values, ~~based on the principles~~ according to

- IEC 60071-1:2006 and IEC 60071-1:2006/AMD1:2010 for the upstream or power network side, and
- IEC 60664-1:2007 for the downstream or converter side.

14.5.6 An earth fault on any control circuit operating below 200 Hz shall neither cause inadvertent switching on nor prevent switching off ~~the EH or EPM installation or a part of it.~~

- a) In order to fulfil this requirement, it is recommended that one side of the control transformer(s) be earthed and coils and contacts be connected accordingly. Unearthed control circuits fed from the transformer shall be provided with an **insulation-monitoring** device, which either indicates an earth fault or interrupts the circuit automatically after an earth fault. The direct current internal resistance of the **insulation-monitoring** device shall be at least ~~15~~ 50 kΩ. For certain electronic devices, much higher values of this resistance may be necessary.
- b) In the case of control transformers with an earthed centre tap, a differential current circuit-breaker shall be used.
- c) For control circuits in which single-pole earthing is required for operational reasons, the **manufacturer** shall provide for earthing. Such operational reasons can be, for example

the use of electromagnetic clutches having an internal earth or of control circuits with electronic components. In this case, separate control transformers or one control transformer with several isolated secondary windings shall be used.

~~14.5.7 In case of earthed control circuit supplies, the common conductor is connected to the protective bonding circuit at the point of supply. All contacts, solid state elements and other parts, which are intended to operate an electromagnetic or other device (for example, a relay or indicator light) are inserted between one side, the switched conductor of the control circuit supply and one terminal of the coil or device. The other terminal of the coil or device (preferably always having the same marking) is connected directly to the common conductor of the control circuit supply without any switching elements – refer to Figure 3 of IEC 60204-1:2005.~~

~~The following exceptions to this rule are allowed:~~

- ~~a) contacts of protective relays, for example overload relays, may be connected between the side connected to the protective circuit and the coils, if the conductors between such contacts and the coils of the control devices, on which the relay contacts operate, are inside the same control enclosure;~~
- ~~b) in special cases, where a different arrangement of the contacts leads to a simplification of the external control accessories (e.g. trolleys, cable winders, multiple plugs), if the requirements of the first paragraph of 9.4.3.1 of IEC 60204-1:2005 are met. In this case, a very careful design is required, to avoid a hazard in case of an earth fault – refer to 9.4.3.1 of IEC 60204-1:2005.~~

In case of earthed control circuit supplies, refer to Figure 7 and 9.4.3.1 of IEC 60204-1:2016.

14.6 Protective devices

~~14.6.1 Protective devices including interlocks used to protect operators from hazards shall prevent~~ protecting an **operator** from a hazard shall prevent the **operator** from being exposed to the hazard before the hazard is removed. It shall meet the following requirements specified in 14.6.2 to 14.6.7.

~~14.6.2 Protective devices shall not obstruct the normal operation~~ or the view onto the **EH** or **EPM installation** or **equipment** as being necessary for safe operation.

~~14.6.3 Only after the action has been reversed or cancelled, which caused the protective device to give a stop command, shall the protective device and thus the EH or EPM installation or equipment be reactivated by use of a tool~~ means of an intentional action.

~~14.6.4 Protective devices for the protection of an operator shall ensure~~ be designed such that a ~~single fault condition in the protective device is either unlikely to occur during the expected life of the equipment, or~~ cannot cause a hazard – i.e. any fault of the **protective device** is a fault to safety. In most cases, this implies that any **protective device** shall give a stop command if it is not fully effective.

~~14.6.5 Protective devices shall not easily be bypassed or made non-operational.~~

NOTE "Easily" implies without the use of a tool.

~~14.6.6 Protective devices shall be adjustable only by means of an intentional action.~~

~~14.6.6 Protective devices reacting in case of any short-circuit shall be adequately sized for the switching elements in the control circuits.~~

~~14.6.7 Adjustable protective devices and systems shall be adjustable only with the use of a tool or be protected by a password.~~

14.6.8 Normal operation includes the correct setting of any adjustable **protective device**. Incorrect setting of a **protective device** is a **single fault condition**.

14.7 Over-temperature ~~protective device~~ protection devices and systems

14.7.1 Over-temperature **protective devices** and systems designed to operate in **single fault condition** shall be

- a) designed and tested to ensure reliable function, and
- ~~b) rated to interrupt the maximum voltage and current of the circuit in which they are employed;~~
- ~~c) rated so that components or materials whose temperatures are intended to be limited by the device do not exceed the relevant temperature limits of Clause 10 or other defined limits.~~

~~**14.7.2** If necessary, means shall be provided for the operator to check that a 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.~~

- ~~a) For adjustable devices or systems the check can normally be made by setting the over-temperature device to a lower temperature than that of the temperature control system.~~
- ~~b) For non-adjustable devices or systems it may be necessary to provide a self-resetting means to override the temperature control system temporarily.~~

14.7.3 Over-temperature **protective devices** shall be separated from any temperature control system. This applies not only to the temperature sensing means but also to all disconnecting devices in the circuits to be de-energised.

~~**14.7.4** Adjustable over-temperature and liquid level devices and systems shall be adjustable only with the use of a tool.~~

~~**14.7.5** **Normal operation** includes the correct setting of any adjustable over-temperature device. Incorrect setting of a device by the use of a tool is a single fault condition.~~

~~**14.7.6** Liquid level devices used to protect against over-temperature shall meet the same requirements as over-temperature **protective devices** and systems.~~

14.8 Overpressure safety device

An overpressure safety device shall not ~~operate~~ react or release in **normal operation**. It shall conform to the following requirements.

- a) It shall be connected as close as possible to the fluid-containing parts of the system that it is intended to protect.
- b) It shall be installed so as to provide easy access for inspection, maintenance and repair.
- c) It shall not be capable of being adjusted without the use of a tool.
- d) It shall be located so that a discharge does not cause hazard to **operators**; especially it shall have its discharge opening so located and directed that the released material is not directed towards the **operator**.
- e) The **EH** or **EPM installation** or **equipment** shall be designed such that no pressure release device is obstructed.
- f) It shall have its discharge opening located and any discharge directed so that operation of the device does not deposit material on parts, if that could cause a hazard.
- g) It shall have adequate discharge capacity to ensure that the pressure cannot exceed the rated maximum working pressure of the system.
- h) There shall be no shut-off valve between an overpressure safety device and the parts that it is intended to protect.

15 Protection against mechanical hazards

15.1 With respect to mechanical hazards, the **manufacturer** shall refer to ISO 13577-1:2016, if applicable. In all other cases, the requirements 15.2 through 15.11 apply.

15.2 No accessible part of the **EH** or **EPM installation** or **equipment** shall have rough surfaces, sharp edges or angles posing a hazard.

15.3 Any moving part that poses a hazard shall be prevented from becoming a risk through **guards** or **protective devices**. ISO 14120:2015 applies for design and construction, assuring the mechanical stability of **guards**.

15.4 Sufficient precautions shall be implemented to prevent any hazardous situation from expelled parts, fluids (Clause 12) or **workload**.

15.5 It shall either be impossible that an **operator** gets trapped inside any part of an installation or equipment or, if this is impossible to achieve, means to summon help shall be installed.

~~**15.6** If an **operator** can be trapped inside the installation, sufficient means for escape or an emergency stop from the inside shall be installed.~~

~~**15.6** Zones where a human body or bodyparts can be exposed to trapping, crushing, shearing, impact, cutting, entanglement, drawing in, stabbing or abrasion shall be inaccessible or, if this is impossible for normal operation, one of the following or other measures shall prevent the risk: Such a hazard zone is considered not to present a mechanical hazard if~~

- a) the gaps of the zone comply with the dimensions specified in Tables 13 and 14 of IEC 61010-1:2010,
- b) the distances separating the **operator** from the hazard zone exceed the values specified in ISO 13857:2008, and
- c) **guards** and protective measures prevent access.

If this is impossible for **normal operation**, other measures shall adequately reduce the risk.

~~**15.8** Protective measures shall be designed and incorporated into the control system so that~~

- a) ~~moving parts cannot start to move while they are in the reach of operators;~~
- b) ~~once the equipment has started to move, the hazard zone cannot be reached, or, if this hazard zone is reached, system movement shall stop. No hazard or damage shall result from the system stop;~~
- c) ~~if in single fault condition of the protective measure, an unacceptable risk could arise, one or more emergency stopping devices in the equipment shall be provided;~~
- d) ~~the absence or failure of one of their components prevents starting or stops the moving parts.~~

~~Protective measures include **protective devices** for mechanical hazards.~~

15.7 The speed of movement of any part of the equipment that can come into contact with the **operator**, and where contact of the **operator** with the equipment can result in a hazardous situation, shall be limited so that the **operator** can adequately react to the moving part without resulting in an unacceptable risk.

15.8 Controls elements shall be so positioned, recessed, or protected by other means that they cannot be accidentally actuated, resulting in unacceptable risk.

15.9 The risk due to over-travel (travel past the range limits) of equipment parts shall be reduced to an acceptable level. End stops or other stopping means shall be provided to act as the ultimate travel limiting measure in both **normal operation** and in **single fault condition**. Such means shall have the mechanical strength to withstand the intended loading. The over-travel (stopping distance) of such movement, occurring after operation of a control to stop the movement, shall not result in an unacceptable risk.

15.10 When a part of the equipment has been stopped, any drift away from the stopping position, for whatever reason other than **intended action** ~~on~~ through the control devices, shall be prevented or shall be such that it does not cause a hazard.

15.11 If the **operator** is supposed to move about or stand on the installation or equipment, sufficient means to prevent slipping, tripping or falling shall be implemented.

16 Protection against hazards resulting from use

16.1 Particular hazards in processing of food, feed, cosmetics and similar intended for human or animal consumption

16.1.1 Hygiene hazards differ from other hazards because they are **hazardous** hazards for consumers of the **workload** being processed. ~~This does~~ They usually do not pose a hazard for the **operator**. Hygiene risks are associated with the ability of the equipment to be freed from product debris and micro-organisms, and thus preventing product contamination.

16.1.2 Particular hygienic and contamination hazards exist in the processing of **workload** like food, beverages, animal feed, pharmaceuticals and cosmetics and shall be considered. The equipment shall in that case fulfil the relevant requirements of ISO 14159:2002 and applicable national regulations. Furthermore, such **workload** shall not be contaminated during pasteurization, sterilization or other processing, resulting in hazardous products.

16.1.3 Interaction of cleaning or disinfection agents or their residuals with the processing equipment shall be considered. The **manufacturer** shall include information on safe to use agents in the information for use. The **manufacturer** shall indicate cleaning or disinfection agents that are not safe to use.

~~16.2 Radio frequency interference~~

~~CISPR 11 shall be adhered to, if applicable.~~

~~16.3 Particular hazards in electroheating and electromagnetic processing~~

~~Other particular hazards unique to specific installation sites or equipment use are to be covered by the Particular Requirements and may be agreed between the **manufacturer** and **user** – for example, external conditions such as earthquakes.~~

16.2 Combination equipment

If the equipment is intended to be used in combination with other equipment, any hazard due to the combination shall be considered.

~~17 Protection against other hazards~~

~~17.1 General~~

~~Complementary to the potential hazards addressed in previous clauses, hazards according to ISO 13577-1 and Annex B of ISO 12100:2010 shall be evaluated by the **manufacturer** at the design stage, and the relevant requirements of these standards shall be fulfilled, if applicable. Furthermore, the specific hazards addressed in 17.2 shall be considered.~~

~~17.2 Sonic, infra- and ultra-sonic pressure~~

~~The equipment or installation shall not cause a hazard from sonic, infra- and ultra-sonic pressure.~~

~~Installation instructions shall specify how the user can ensure that the sound pressure level from equipment, at its point of use after installation, does not reach a value which could cause a hazard. These instructions shall identify readily available and practicable protective materials or measures which can be used, including the fitting of noise-reducing baffles or hoods.~~

17 EMC

17.1 Radio frequency interference

17.1.1 With respect to the **processing frequency** of the **EH** or **EPM installation** or **equipment**, Clause 4 of CISPR 11:2015 applies.

17.1.2 With respect to limits of electromagnetic disturbances caused by the **EH** or **EPM installation** or **equipment**, Clause 6 of CISPR 11:2015, CISPR 11:2015/AMD1:2016 and CISPR 11:2015/AMD2:2019 applies.

17.2 Immunity

The **EH** or **EPM installation** or **equipment** shall be able to work properly under the electromagnetic disturbances being expected at its intended position. IEC 61000-6-2:2016 applies in general and IEC 61000-6-7:2014 applies for all equipment intended to provide safety functions.

18 Verification and testing

18.1 General

Compliance of the **EH** or **EPM installation** or **equipment** with the applicable safety requirements ~~or~~ of this document including protective measures shall be verified by one or a combination of the following methods;

- a) examination of drawings or calculations;
- b) visual inspection;
- c) measurement;
- d) **functional test**;
- e) numerical modelling.

Table 5 lists ~~the recommended~~ methods of verification with respect to the specific requirements of this document. The applied method and result of the verification shall be ~~reported~~ documented.

Table 5 – Methods for the verification of requirements

Sub-clause	Requirement or measure relating to	Verification done by				
		examination	visual inspection	measurement	functional test	numerical modelling
		18.4	18.5	18.6	18.7	18.8
6.4	Physical environment and operating conditions for electrical equipment inside the processing equipment	✓	✓	✓		
6.5	Power supply	✓	✓			
6.6	Access	✓	✓			
6.7	Ergonomic aspects	✓	✓			
6.8	Transport and storage	✓	✓			
6.9	Provisions for handling	✓	✓			
6.10	Consumables and replaceable parts	✓	✓			
7.3	General provisions		✓	✓	✓	
7.4	Basic protection	✓	✓			
7.5	Provisions for single fault protection	✓	✓			
7.6	Protective equipotential bonding	✓	✓			
7.7	Additional provisions for fault protection for frequencies above 200 Hz	✓	✓			
7.8	Protective conductor currents	✓	✓			
7.9	Touch current and touch voltage	✓	✓	✓	✓	✓
7.10	Conductors and insulations at high temperature	✓	✓	✓		
7.11	Non-electric faults	✓	✓			
8.2	Magnetic fields	✓	✓	✓	✓	✓
8.3	Local electric fields	✓	✓	✓	✓	✓
8.4	Requirements related to barriers and screens	✓	✓			
8.5	Requirements related to objects worn, carried or held by persons	✓	✓			
9.2	Installation or equipment generating ionizing radiation	✓	✓	✓		
9.3	Ultraviolet radiation	✓	✓	✓	✓	✓
9.4	Visible and infrared radiation	✓	✓	✓	✓	✓
9.5	Laser sources	✓	✓	✓	✓	✓
10.2	Surface temperature limits for protection against burn	✓	✓	✓		
10.3	Hazards caused by working conditions		✓			✓
10.4	Heat resistance of components	✓	✓			
10.5	Cooling	✓	✓			
10.6	Over-temperature protection	✓	✓			
11	Protection against hazards from fire	✓	✓			
12.2	Protection against hazards from fluids — Poisonous and injurious gases and substances	✓	✓			
12.3	Protection against hazards from fluids — Explosion and implosion of pressurised parts	✓	✓			
13.2	Electrical equipment and conductors	✓	✓	✓	✓	

Sub-clause	Requirement or measure relating to	Verification done by				
		examination	visual inspection	measurement	functional test	numerical modelling
		18.4	18.5	18.6	18.7	18.8
13.3	Connection to the electrical supply network and internal connections	✓	✓		✓	
13.4	Isolation and switching	✓	✓		✓	
13.5	Sensors and actuators safeguarding moving parts	✓	✓	✓		
13.6	Motors	✓	✓			
13.7	Non electric heating means	refer to ISO 13577-1				
13.8	Lighting	✓	✓			
13.9	Structural parts and stability	✓				
13.10	Doors, windows and other openings	✓	✓			
14	Control of the installation or equipment		✓		✓	
15	Protection against mechanical hazards	✓	✓	✓		
16.1	Particular hazards in processing of food, feed, cosmetics and similar intended for human or animal consumption	✓	✓	✓		
16.2	Radio frequency interference			✓	✓	
17.2	Sonic, infra- and ultra-sonic pressure			✓	✓	

Sub-clause	Requirement or measure relating to	Verification done by				
		examination	visual inspection	measurement	functional test	numerical modelling
		18.4	18.5	18.6	18.7	18.8
6.4	Physical environment and operating conditions for electrical equipment caused by operation of the processing equipment	✓	✓	(✓)		(✓)
6.5	Power supply	✓	✓	(✓)	✓	
6.6	Access	✓	✓		✓	
6.7	Ergonomic aspects	✓	✓			
6.8	Transport and storage	✓	✓			
6.9	Provisions for handling	✓	✓			
6.10	Consumables and replaceable parts	✓	✓			
7	Protection against hazards from electric shock	refer to ISO 14120:2015				
7.3	General provisions	✓	✓			
7.4	Basic protection	✓	✓			
7.4.6	At frequencies exceeding 200 Hz, potential grading of the circuit shall be controlled by the following means.	✓	✓	✓		
7.5	Provisions for protection in electric single fault condition	✓	✓			
7.6	Protective equipotential bonding	✓	✓	✓		

Sub-clause	Requirement or measure relating to	Verification done by				
		examination	visual inspection	measurement	functional test	numerical modelling
		18.4	18.5	18.6	18.7	18.8
7.7	Additional provisions for fault protection for frequencies above 200 Hz	✓	✓			
7.8	Currents in protective conductors	✓	✓	✓	✓	(✓)
7.9	Touch current and touch voltage	✓	✓	✓		(✓)
7.10	Conductors and insulations at high temperature	✓	✓	(✓)		(✓)
7.11	Non-electric faults	✓	✓			
8.2	Magnetic fields	✓	✓	✓		(✓)
8.3	Magnetic fields below 1 Hz	✓	✓	✓		(✓)
8.4	Local electric fields	✓	✓	✓		(✓)
8.5	Requirements related to barriers and screens		✓			
8.6	Requirements related to objects worn, carried or held by persons	✓	✓			
9.2	Installation or equipment generating ionizing radiation	✓	✓	✓		(✓)
9.3	Ultraviolet radiation	✓	✓	✓		(✓)
9.4	Visible and infrared radiation	✓	✓	✓		(✓)
9.5	Laser sources	refer to IEC 60825-1				
10.2	Surface temperature limits for protection against burn	✓	✓	✓		
10.3	Hazards caused by working conditions		✓			(✓)
10.4	Temperature resistance of components	✓	✓			
10.5	Cooling	✓	✓	✓		
10.6	Over-temperature protection	✓	✓			
11	Protection against hazards from fire	✓	✓			
12.2	Poisonous and injurious fluids	✓	✓	✓		

Sub-clause	Requirement or measure relating to	Verification done by				
		examination	visual inspection	measurement	functional test	numerical modelling
		18.4	18.5	18.6	18.7	18.8
12.3	Explosion and implosion of pressurised parts or vacuum equipment	✓	✓			
13.2	Electrical equipment and conductors	✓	✓	✓	✓	
13.3	Connection to the electrical supply network and internal connections	✓	✓			
13.4	Isolation and switching	✓	✓		✓	
13.5	Sensors and actuators safeguarding moving parts	refer to ISO 13855:2010				
13.6	Motors	✓	✓			
13.7	Non electric-heating means	refer to ISO 13577-2:2014				
13.8	Lighting	✓	✓			
13.9	Structural parts and stability	✓	✓			
13.10	Doors, windows and other openings	✓	✓			
13.11	Transformers, inductors, capacitors	✓	✓			
13.12	Handheld applicators	✓	✓		✓	
13.13	Vacuum system	✓	✓			
13.14	Protective and reactive gas generator	refer to ISO 13577-3:2016				
14	Control of the installation or equipment	✓	✓		✓	
15	Protection against mechanical hazards	✓	✓	✓		
16.1	Particular hazards in processing of food, feed, cosmetics and similar intended for human or animal consumption	✓	✓	✓		
16.2	Combination equipment	✓		✓		
17	EMC			✓	✓	
19	Information for use	✓				
Key						
✓ mandatory when applicable						
(✓) non mandatory, but preferred						

18.2 Performing measurements and tests

18.2.1 Accuracy of measuring equipment and measurement methods shall conform to IEC 60398:~~12~~:2015, as relevant.

18.2.2 This document defines some tests at cold state and other tests under **normal operation** conditions. The test conditions of **normal operation** shall be the most unfavourable conditions causing the maximum expected stress to the installation and the highest probability or strength of hazards in the range of **normal operation** specified by the **manufacturer**.

18.2.3 This document does not define tests under **single fault condition** as these can result in serious damage to the installation.

NOTE IEC 61010-1:2010 can be used in combination with this document to develop verification means for **single fault condition** or for type testing.

~~18.2.4 For all installations under the scope of ISO 13577-1, that standard applies with respect to verification with the exception of electrical, magnetic and radiation hazards and requirements, for which Clauses 7 through 10 of this standard are applicable.~~

18.3 Verification of ~~conformity with limits for electric or magnetic fields~~ requirements from references

~~If the measured or calculated value exceeds reference levels or comparable values set in a national regulation, it does not necessarily follow that the applicable basic restriction is exceeded and that an operator can be exposed to hazardous levels of electric or magnetic fields. However, whenever a reference level is exceeded, it is an indication of a possible hazard and it becomes necessary to verify compliance with the applicable basic restriction. This can be done through improved screening where possible or through using one of the following methods:~~

- ~~a) assessment of human exposure to magnetic or electric fields (for example according to IEC 62311 or EN 50413 covering the range from 0 Hz to 300 GHz);~~
- ~~b) assessment of human exposure to magnetic or electric fields according to the IEEE C95 series;~~
- ~~c) use of the numerical calculation of the electric or magnetic fields according to the IEC 62226 series for low and intermediate frequency range;~~
- ~~d) numerical assessment of the interaction between the processing equipment and exposed persons;~~
- ~~e) or by use of any other method, that will provide with comparable accuracy, if the basic restrictions are met.~~

This document references to other standards, where applicable. Such reference includes requirements and the verification of these requirements when given in those standards.

18.4 Examination of drawings or calculations

The examination of drawings and calculations ~~is~~ shall be done to verify if all parts of the **EH or EPM installation or equipment** comply with the applicable requirements of this document.

18.5 Visual inspection

~~18.5.1~~ Visual inspection of the **EH or EPM installation or equipment** shall be done ~~after mounting and during commissioning prior to any hot state tests~~, to compare the erected installation with the drawings. This visual inspection shall ensure the following:

- a) the installation has been erected as defined in the drawings;
- b) all markings and warnings have been affixed;
- c) all **barriers, obstacles, guards** and similar protective means are in place;
- d) all **barriers, guards** and similar protective means intended to be removed with a tool are only removable with the use of a tool;
- e) all protective measures are adequate and exist and all earthing provisions and equipotential connections are in accordance with the drawings.
- f) all **insulations** are in place, clean and in intended state.

~~18.5.2~~ A first cold state visual inspection is usually done after mounting and prior to any hot state tests. Further visual inspection ~~shall~~ can be carried out after finishing all hot state tests of commissioning. This second visual inspection ~~shall ensure~~ ensures that the parts of the **EH**

or **EPM installation** or **equipment** subject to heat, ~~EMF electromagnetic fields~~, intense radiation or to other influences causing wear are still in their intended state. ~~Especially~~ Linings, heating elements, thermal **insulation** and refractories, **barriers**, doors, gates, **windows**, lips, systems for transporting or positioning the **workload** ~~shall be~~ are inspected with the focus on drop-out, crack, distortion, unusual abrasion, burn-through, oxidization and ~~creepage~~ creep.

18.6 Measurements

18.6.1 Environment and operating conditions inside the processing equipment

This measurement verifies if the assumed conditions used for the design are met. It can be impossible to measure all relevant values.

18.6.2 Impedance of protective bonding

The measurement defined in 6.5.2.4 of IEC 61010-1:2010 applies for plug connected equipment.

The measurement defined in 6.5.2.5 of IEC 61010-1:2010 applies for permanently connected equipment.

18.6.3 Insulation resistance measurement ~~up to 200 Hz~~

~~For the insulation resistance measurement up to 200 Hz, 18.3 of IEC 60204-1:2005 applies with the addition that the tests shall be performed in the cold state.~~

The measurement defined in 18.3 of IEC 60204-1:2016 applies for **insulation** resistance measurement at LV; the measurement defined in 19.3 of IEC 60204-11:2018 applies for **insulation** resistance measurement at HV and up to 200 Hz. In addition to the requirements from the references the tests shall be performed in the cold state.

Measurements above 200 Hz are under consideration.

18.6.4 Measurement of electric or magnetic fields

IEC 61786-2¹³:2014 applies for measurements of electric or magnetic fields ~~and IEC 61786-1 for measuring equipment for frequencies up to 100 kHz~~ in the range of frequencies between 1 Hz and 100 kHz, and IEC 61786-1:2013 applies for measurement instruments.

Measurements above 100 kHz are under consideration.

18.6.5 Touch current measurement

~~The measurement of touch currents shall adhere to IEC 60990 with the exception of the use of the circuit for high frequencies.~~

~~The high frequency test method in IEC 60990 is recommended here only with the following alterations: to determine the frequency variation of skin capacitances with increasing frequency — skin being a significant part of the current circuit and being most sensitive due to its small volume and cross section for burns — the capacitance shall instead be applied in series and set to $A \cdot 0,01 \mu\text{F}$, where A is the skin area in cm^2 . For normal gripping and 10 kHz to 10 MHz a series capacitance of $0,45 \mu\text{F}$ and a skin impedance of $A \cdot f^{-1} \cdot 3 \cdot 10^6 \Omega$ is recommended, where f is the frequency in Hz.~~

¹³To be published.

~~NOTE 1— In Figure 3 of IEC 60990:1999, R_s represents the skin and C_s the skin capacitance where C_s is probably by a factor of 10 too large.~~

~~NOTE 2— The recommended gripping contact area represented in IEC 60990 is 200 cm². This surface area is unusually large and commonly 50 cm² are used instead.~~

The measurement of **touch currents** shall adhere to IEC 60990:2016 between 0 Hz and 1 kHz. The provided method can be used above that frequency for large contact area situations.

18.6.6 Measurement of ionising radiation ~~measurement~~

Conformity is checked by measuring the amount of radiation emitted in the most unfavourable conditions, when maximum ionising radiation occurs; equipment containing X-ray sources is set to produce the maximum possible level of radiation. The method of determining the amount of radiation shall be effective over the range of possible radiation energies. ~~Equipment containing cathode ray tubes is tested while displaying a pattern from each beam not exceeding 30 mm × 30 mm or the smallest possible display, whichever is larger. Equipment containing X-ray sources is set to produce the maximum possible level of radiation. Displays are positioned so as to produce maximum radiation.~~

18.6.7 Measurement of non-coherent optical irradiation

18.6.7.1 For the measurement of non-coherent optical radiation, Clause 5 of IEC 62471:2006 applies with ~~the following amendments~~, the clarifications in 18.6.7.2 to 18.6.7.8 and including requirements given in Annex C.

18.6.7.2 Separated locations of the installation, like separate doors or **windows** are separate sources of radiation, as defined in 9.1.2 and can belong to different risk classes. They shall be assessed and verified separately.

18.6.7.3 Usually no controlled environment is possible to achieve. Thus the measurement conditions and an assessment of the influence of measurement conditions on the quality of the measured data shall be part of the measurement report. Measurement conditions shall be reported as part of the evaluation and the assignment of risk classification.

18.6.7.4 To maintain stable output during the measurement process and provide reproducible results, the **EH** or **EPM installation** or **equipment** shall be seasoned for an appropriate period of time prior to measurement. During the initial period of operation, the output characteristic will change as components oxidise, age, or come otherwise to a state of near equilibrium. If measurements are taken with unseasoned installations, the variations within the measurement period and between measurements can be significant. The necessary ageing period depends on the specific installation and the environment. It varies with different types of installations and it can be impossible to reach sufficient ageing for assessment during commissioning. In this case, measurement shall be done again at a later stage of equipment lifetime.

18.6.7.5 Careful checks shall ensure that other sources of radiation like nearby equipment or ovens, hot **workload**, hot ~~shields~~ **screens**, or reflections do not add significantly to the measured signal.

18.6.7.6 All measuring equipment for non-spectrally resolved measurement of irradiance or radiance shall be of class 3.0 or better. For thermal or broad-band radiation the measuring equipment shall have a flat or constant spectral response between 400 nm and 10 μm, a flat response between 200 nm and 20 μm is preferred. For non-thermal radiation, the measuring equipment shall have a flat or constant spectral response over the complete wavelength-range of the source. The measuring equipment shall be sufficiently stabilised to avoid any drift exceeding the limits.

NOTE 1 This can be a thermally stabilised pyroelectric detector for thermal radiation.

NOTE 2 Non thermal sources include LEDs and many types of UV emitter.

18.6.7.7 Annex B of IEC 62471:2006 applies for spectrally resolved measurements. The accuracy of the measurement results shall be calculated and stated. Measurement inaccuracy should not exceed 30 % of the lowest classification limit in absolute values.

18.6.7.8 Usually large areas need to be assessed; therefore a scanning procedure over the surface contributing to the **emission** from one source shall be used, assuring that more than 90 % of the emitted power is inside the scanned area.

18.6.8 Measurement of coherent optical radiation ~~including emission from LEDs~~

All measurements of radiation from laser ~~or LED~~ sources shall adhere to IEC 60825-1:2014.

18.6.9 Surface temperature measurement

Verification of accessible surfaces shall be done according to 5.4. of ISO 13732-1:2006.

~~**18.6.8 Sound level measurement**~~

~~Conformity is checked by measuring the maximum A-weighted sound pressure level at the **operator** position and if necessary, calculating the maximum A-weighted sound power level produced by the equipment, as specified in ISO 3746. Measurement is performed during **normal operation** and with the combination of **workload** and other operating conditions (for example, pressure, flow or temperature) which create the maximum sound pressure level.~~

~~Sound level meters used in the measurement shall conform either to class 1 of IEC 61672-1 or, if an integrating sound level meter, to class 1 of IEC 61672-2.~~

18.6.10 Temperature of structural components subject to heat

For measurement equipment, methods and requirements, 6.5 of IEC 60398:2015 applies. The assessment shall provide the temperatures under the worst case conditions in **normal operation** or other condition specific to the installation or equipment. Measurement positions shall provide information about critical parts or positions, i.e. parts or positions exposed to maximum heat stress or temperature.

18.7 Functional tests

18.7.1 Protection by automatic disconnection of supply

Subclause 18.2 of ~~IEC 60204-1:2005 and IEC 60204-1:2005/AMD1:2008~~ applies IEC 60204-1:2016 applies for LV and 19.2 of IEC 60204-11:2018 for HV.

18.7.2 Voltage test

For LV installations or equipment, the test of 18.4 of IEC 60204-1:2005/2016 applies, for HV installations the test from 19.4 of IEC 60204-11:2018.

18.7.3 Dielectric test

The test given in Clause 13 of IEC 60335-1:2010, IEC 60335-1:2010/AMD1:2013 and IEC 60335-1:2010/~~AMD1:2013~~AMD2:2016 applies, when applicable.

18.7.4 Accessibility of live parts

18.7.4.1 Inaccessibility of any **live parts** for LV shall be checked by tests defined according to IEC 60529:1989, 12.3.1.

18.7.4.2 Inaccessibility of any **live parts** for HV shall be checked by tests defined according to IEC 60529:1989, 12.3.2.

18.7.4.3 Verification of inaccessibility defined through use of ISO 13857:2008 is done according to that standard through examination and visual inspection.

18.7.5 Protective devices and systems

Protective systems are tested by applying the signal expected from the **protective device** in a fault to the electric circuit that should react.

18.8 Numerical calculations and modelling

18.8.1 General

The accuracy of any calculation shall at least be sufficient for the problem to be solved or comparable to the achievable accuracy of measurements. This defines the needed accuracy of the implemented geometrical setup and minimum grid resolution or number of cells, surface elements, time resolution, bands or rays used as well as the used physical or thermochemical data.

The use of calculated data instead of measurements shall be stated in the technical documentation.

The documentation of the calculation shall include

- a) the geometrical setup used,
- b) all relevant modelling data and a description of the models used,
- c) the software and version used,
- d) the set parameters of the software that influence the result,
- e) the method used for verification of the accuracy of the used models and the calculation itself, and
- f) all results used for classification.

It shall be possible, from the ~~data stored~~ documentation, to implement the models again and to make the calculation again on another system or with another software.

~~Relevant data of the measurements~~ The documentation of the calculation shall be kept at the **manufacturer** of the equipment. It shall be kept either over the expected lifetime of the equipment or over a time defined by national regulations.

18.8.2 Numerical assessment of short circuit currents

For the assessment of short circuit currents, IEC 60909-0:2016 shall be used; for the effects of short circuit currents, IEC 60865-1:2011 is applicable.

18.8.3 Numerical assessment of electric or magnetic ~~fields~~ emission

A numerical assessment of the interaction between the ~~processing~~ **EH or EPM installation or equipment** and exposed persons ~~regarding~~ with respect to electric or magnetic fields and induced electric fields in bodyparts may be used to assess the induced currents in bodyparts of exposed persons in case of complex geometries or for such applications where the underlying assumptions for calculating a reference level are not sound (the **near-field region**) and if the calculation reaches a sufficient accuracy.

The use of computational electrodynamics for assessing external fields, internal electric field, specific absorption rate (SAR) or contact current is a numerical experiment and accuracy depends inter alia on

- the model of the source, the model of the installation and the model of the human body,
- the calculation method used, and
- the spatial and temporal resolution.

The documentation of the calculation shall include in addition to the list of 18.8.1

- a) the ~~geometry~~ geometries and electromagnetic properties of all conductors and ~~all bodies~~ objects relevant to the calculation, and
- b) the grid and resolution or mesh and voxel data.

For **accessible emission** caused by strongly curved magnetic nearfields in the range between 1 Hz and 6 MHz, the methods in IEC TS 62997:2017 of employing source geometry and current can be applied.

For **accessible emission** caused by electric fields in the range between 1 kHz and 6 MHz interacting with specified bodyparts and other objects in specified onerous positions and thus resulting in an inhomogeneous field, the methods in IEC TS 62996:2017 can be applied.

NOTE IEEE 1597 (all parts) provides a method and guide for the validation of numeric models for electromagnetics and can be used.

18.8.4 Numerical assessment of optical radiation emission

The assessment of ~~exposure~~ **emission** and subsequent classification can be based on ray tracing calculation of irradiance and radiance at all positions relevant for risk assessment instead of measurements and if a comparable accuracy is reached by the calculation.

As ray tracing is a numerical experiment, the demands on position and orientation of virtual detectors are the same as for physical detectors during measurements.

The calculation of radiance or irradiance, depending on the defined spatial angles or angular subtenses shall follow the same procedure as for measurements defined in 18.6.57 or 18.6.68.

The documentation of the calculation shall include in addition to the list of 18.8.1

- a) all relevant modelling data and a description of the models used for involved surfaces, their scattering behaviour, diffuse or specular reflection,
- b) the set parameters of the software that influence the result, like splitting of rays, maximum number of split rays followed, minimum amount of energy in a single ray, randomisation method, and
- c) number of rays used, energy lost due to numerical effects.

19 Information for use

19.1 General requirements

19.1.1 The **manufacturer** of the **EH** or **EPM Installation** or **equipment** shall provide information for use of the equipment consisting of communication links such as texts, words, signs, signals, symbols or diagrams, used separately or in combination to convey information to the **user**.

Information about the intended use of the **EH** or **EPM Installation** or **equipment** shall be provided, taking into account its operating modes, measures required to ensure its intended and correct use ~~of the equipment~~, in particular information on residual risks.

~~The information shall include:~~

- ~~a) details of the required training;~~
- ~~b) personal protective equipment requirements;~~
- ~~c) additional details of the **guards** or **protective devices**.~~

19.1.2 The information for use shall cover separately or in combination transport, assembly and installation, commissioning, use (including operations like setting, teaching, programming ~~or~~, process changeover, operation, cleaning, fault finding and maintenance) of the **EH** or **EPM installation** or **equipment**, and if applicable de-commissioning, dismantling and disposal.

19.2 Location and nature of the information for use

The **manufacturer** shall decide whether the information for use or parts of it are given

- a) in or on the ~~installation~~ **EH** or **EPM Installation** or **equipment** itself,
- b) in accompanying documents,
- c) on the packaging, or
- d) by other means such as signals and warnings outside the **EH** or **EPM installation** or **equipment**.

This decision shall be based on the risk, the time when the information is needed and the design of the installation.

19.3 Signalling and warning devices

Visual signals (e.g. flashing lights) or acoustic signals (e.g. sirens) shall be used to warn **operators** or **ordinary persons** of an impending hazardous event (for example start-up of the ~~equipment~~ **EH** or **EPM installation** or over-temperature). The following requirements shall be met:

- a) signals shall be emitted before the occurrence of the hazardous event;
- b) signals shall be unambiguous and shall be clearly recognized by the **operator**;
- c) signals shall be clearly perceived and differentiated from all other signals used.

If warning devices are used, they shall be designed and located such that checking for proper operation is easy. The information for use shall determine procedures for verifying proper operation of warning devices.

The **manufacturer** shall consider the risk of "sensorial saturation" when designing the warning devices. This risk results from too many visual or acoustic signals, which can lead to ignoring or defeating the warning devices by the **operator**.

19.4 Markings, pictograms, written warnings

19.4.1 The **EH** or **EPM installation** ~~and its~~ or **equipment** shall be marked on nameplate(s) at least with the following data in a visible and legible manner:

- a) serial number, if any, or name of the **EH** or **EPM installation** or **equipment**;
- b) name and address of the **manufacturer** or **authorised representative**;
- c) year of construction;
- d) year of modification, if applicable;
- e) number of phases and rated input voltage; when the **EH** or **EPM installation** or **equipment** is intended to be used at different rated supply voltages, the association of the particular voltage and corresponding supply terminals as well as the type of connection shall be indicated on the nameplate;
- f) type and value of rated input current;
- g) rated input power; in case of ~~installations~~ **EH** or **EPM installation** or **equipment** for several voltage ranges, the maximum values for the power input pertaining to the voltage ranges shall be stated;
- h) input frequency and rated **processing frequency** or range of **processing frequencies**, where appropriate, shall be stated;
- i) class and group of the **EH** or **EPM installation** or **equipment** according to CISPR 11:2015 and CISPR 11:2015/AMD1:2016, if applicable.

19.4.2 The **EH** or **EPM installation** or **equipment** shall be marked with all information that is necessary for its safe use, for example

- the maximum **workload** or output to be processed,
- the maximum operation temperature,
- the atmosphere to be used (e.g. non-flammable, explosive, toxic, **pressure range**), if specific,
- the necessity to wear personal protective equipment, and
- **guard** or **barrier** adjustment data.

19.4.3 Appropriate warnings shall be displayed, in particular against hazards, which cannot be immediately perceived, such as **caused by HV**, ionizing radiation, non-ionizing radiation or **electromagnetic fields**.

19.4.4 IEC 60204-1:2005/2016, 16.2 ~~shall be used~~, applies for the marking of electrical features.

Letters, words or symbols shall identify control and signalling devices ~~shall be identified by letters, words or symbols~~.

Identification of conductors shall be in accordance with 13.2 of IEC 60204-1:2005/2016.

The electrical components and their references to the circuit diagram in the documentation shall be durably marked. The designation shall comply with the indications on the circuit diagram.

19.4.5 The **EH** or **EPM installation** or **equipment** shall bear all markings which are necessary to indicate its compliance with ~~relevant~~ applicable requirements.

19.4.6 Information printed directly on the **EH** or **EPM installation** or **equipment** shall be permanent and remain legible throughout the expected life of the equipment.

Markings shall be durable, legible and clearly visible. Markings shall be in the language of the country in which the equipment is to be installed, unless agreed differently. Written warnings shall be drawn up in the language(s) of the country in which the equipment will be used for the first time and, on request, in the language(s) understood by **operators**.

Markings, symbols, signs and written warnings shall be readily understandable and unambiguous, especially as regards the part of the function(s) of the equipment to which they are related. Readily understandable pictograms should be used in preference to written warnings. Graphical symbols shall conform to IEC 60417 and ISO 7000. Signs, labels or signboards shall be designed according to ISO 3864-1:2011. Annex G provides examples of relevant symbols and safety signs.

~~Graphical symbols shall conform to IEC 60417 or ISO 7000, if applicable. Signs, labels or signboards shall be designed according to ISO 3864-1. Annex F provides examples of relevant symbols and safety signs.~~

19.5 Instruction handbook(s) / installation, commissioning, operation, maintenance, and decommissioning manual(s)

19.5.1 ~~The instruction handbook and technical documentation shall be provided in paper form; it may be accompanied by electronic data.~~ The instruction handbook, including technical documentation and manuals for installation, commissioning, operation, maintenance, and decommissioning, shall be provided in paper form and can be accompanied by electronic data, unless local law allows for electronic data only.

19.5.2 The instruction handbook ~~or other written instructions~~ shall conform with IEC 82079-1:2012 and shall contain at least the following information relating to transport, handling and storage of the installation or equipment, including but not limited to:

- a) storage condition for the **EH** or **EPM installation** or **equipment** or parts of it;
- b) dimension, mass ~~value(s)~~, position of the centre ~~(s)~~ of gravity;
- c) indication for handling – for example, drawings indicating application points for lifting equipment.

19.5.3 The instruction handbook ~~or other written instructions~~ shall contain at least the following information relating to installing and commissioning of the **EH** or **EPM installation** or **equipment**, including but not limited to:

- a) fixing/anchoring and vibration dampening requirements, or foundation if necessary;
- b) mandatory earth terminals in the vicinity of parts of the **EH** or **EPM installation** or **equipment** where it is necessary for maintenance and inspection that conductors and bare conductive parts are earthed after switching off the supply;
- c) if the **EH** or **EPM installation** or **equipment** is ~~not sent assembled~~ unassembled to the **user**, specific instructions on unpacking of the equipment, checklist of parts, plan of the configuration, plan for installation of all parts and a connection schedule of parts – IEC 61082-1:2014 applies;
- d) ~~instructions for connecting the installation or equipment to water, hydraulic liquids, pressurized air, including permissible pressures~~ instructions for connecting the **EH** or **EPM installation** or **equipment** to sources for working fluids, including their permissible pressures (this includes water, hydraulic liquids, pressurized air, protective and reactive gases and other working fluids);
- e) instructions for connecting the **EH** or **EPM installation** or **equipment** to the power supply, especially tolerable voltage and frequency fluctuations, and including protection against electrical overloading;
- f) test plan including all tests performed prior to connecting or operating the **EH** or **EPM installation** or **equipment**;
- g) assembly and mounting conditions;

- h) space needed for use and maintenance of the **EH or EPM installation or equipment**;
- i) permissible conditions of the environment – for example temperature, moisture, vibration, **electromagnetic radiation**, intended atmosphere and atmospheric pressure;
- j) recommendation about process waste removal or disposal, if applicable;
- k) recommendation for the implementation of protective measures, safety distances, safety signs and signals by the **user**.

19.5.4 The instruction handbook ~~or other written instructions~~ shall contain information relating to the **EH or EPM installation or equipment** itself, such as the following:

- a) detailed description of the equipment, its fittings, **guards** and other **protective devices**;
- b) the comprehensive range of applications for which the **EH or EPM installation or equipment** is intended, including prohibited usages;
- c) diagrams, especially schematic representation of safety functions in conformity with Clause 17 of IEC 60204-1:2005/2016;
- d) ~~data on noise and vibration generated by the equipment~~, data on radiation, gases, vapours and dust emitted by ~~it~~ the **EH or EPM installation or equipment**, including if applicable ~~including~~ reference to the measurement methods used;
- e) technical documentation of the **electrical equipment** in conformity with Clause 17 of IEC 60204-1:2005/2016;
- f) documents attesting that the **EH or EPM installation or equipment** complies with mandatory and regulatory requirements;
- g) explicit warning, if **emission** from the ~~emitted radiation~~ **EH or EPM installation or equipment** can cause a hazard;
- h) explicit warning, if making the **EH or EPM installation or equipment** electrically live for the purpose of measurement and inspection causes excessive stress to electrical **insulation**, including if applicable instructions for such tests and the maximum voltage to be applied.

19.5.5 The instruction handbook ~~or other written instructions~~ shall contain information relating to the use of the **EH or EPM installation or equipment**, such as that related to or describing the following:

- a) intended use;
- b) manual controls (actuators);
- c) setting, adjustment and the list of setting values and adjusting values of the **EH or EPM Installation or equipment** at the completion of the commissioning test;
- d) modes and means for start-up, operation and stopping (for example emergency stop);
- e) residual risks;
- f) particular risks which can be generated by certain applications, by the use of certain fittings, and about specific safeguards necessary for such applications;
- g) reasonably foreseeable misuse and prohibited applications;
- h) procedure for fault identification, location and for repair;
- i) safe procedure ~~(s)~~ for restarting after an intervention or after a fault;
- j) personal protective equipment to be used;
- k) required training.

19.5.6 The instruction handbook ~~or other written instructions~~ shall contain information for maintenance, such as the following:

- a) nature and frequency of inspection for safety functions;
- b) specification of the spare parts to be used, when these can affect the health and safety of the **operator**;

- c) instruction relating to maintenance operations which require a definite technical knowledge or particular skills and hence need to be carried out exclusively by a **skilled person**;
- d) instruction relating to maintenance actions, like replacement of parts, which do not require specific skills and hence can be carried out by the **operator**;
- e) drawings and diagrams enabling the **operator** to carry out his task, especially during maintenance or fault finding;
- f) maintenance items which can only be conducted by the equipment **manufacturer** or its designated representative;
- g) instructions, drawings and diagrams related to maintenance;
- h) necessary consumables, such as cleaning and disinfection agents or lubricants;
- i) type and specific characteristics of fuses.

19.5.7 The instruction handbook or other written instructions shall contain information for maintenance of **electrical equipment** of the **EH or EPM installation or equipment**, such as the following:

- a) necessary testing of the resistance of earth circuits during maintenance;
- b) mandatory testing of equipotential bonding and **insulation** resistance values of the conductors to earth and to each other during maintenance;
- c) procedure for discharging capacitors and checking the absence of voltage on capacitors, if applicable;
- d) instructions on escape routes during maintenance;
- e) procedures for maintenance work with equipment live – the voltage shall not exceed the LV limits;
- f) preparation of the **EH or EPM installation or equipment** for maintenance through switch off, connection to earth and short-circuiting;
- g) instructions for maintenance in potentially flammable environments – no live circuit or the replacement of a lamp or fuse is usually tolerable under such conditions – or procedure for removing flammable atmospheres from the **EH or EPM installation or equipment**;
- h) instructions for maintenance in areas liable to contain toxic gases, or procedures for removing the toxic gases prior to work.

19.5.8 The instruction handbook or other written instructions shall contain information for de-commissioning, dismantling or disposal.

19.5.9 The instruction handbook or other written instructions shall contain information for emergency situations, such as

- a) the operating procedure to be followed in the event of an accident or breakdown,
- b) the type of fire-fighting equipment to be used,
- c) warning of possible **emission** or leakage of hazardous substance(s) and, if possible, an indication of means for fighting their effects, and
- d) instructions on the application of first aid to the victims of accidents of electrical origin.

19.5.10 If the instruction handbook or other written instructions contain maintenance instructions provided for **skilled persons** and maintenance instructions provided for **instructed persons**, they shall appear clearly separated from each other.

~~**19.5.11** The instruction handbook or other written instructions shall contain relevant information regarding EMC.~~

19.5.11 The instruction handbook or other written instructions shall contain relevant information concerning hazards to specific groups of persons – for example pregnant women or people wearing **implanted active medical devices**.

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Annex A (informative)

List of significant hazards

Table A.1 lists hazards that are significant for at least some types of installations covered by this standard. This list is intended for the use in risk assessment. Particular attention should be paid to the fact that this list

- lists mainly those hazards dealt with in this standard,
- does not list many hazards beyond the scope of this standard, as they are listed in Annex B of ISO 12100:2010, ISO 13577-1 or in other documents,
- is not exhaustive for specific installations or equipment for risk assessment purposes.

Table A.1 gives examples of hazardous situations or events that can occur.

Table A.1 – List of hazards dealt with in this standard

Hazard			Clause/subclause of this standard or reference
Origin	Hazardous situation/event	Potential consequence	
1 — Mechanical			ISO 13577-1, ISO 12100
high pressure gases and liquids	bursting of vessel, ejection of (hot) gases, falling or ejection of objects, ejection of (hot) liquids	suffocation, impact, explosion, being thrown, crushing, slipping or tripping,	12-3
movable parts	getting caught by part, getting crunched between parts	shear, crunching,	15
vacuum	implosion of vessel, bursting of window	impact, injection or ejection	12-3
2 — Electrical			
short-circuit arc live parts parts which have become live under fault conditions		electric shock, burn, shock, electrocution, falling or being thrown	7 and 8
		fire, chemical reaction, explosion, projection of molten particles	7, 10, 11
insufficient distance to live parts under HV — people/equipment	entering the HV hazard zone	electrical shock, fire, explosion	7, 10, 11
leakage current caused by hot insulation or through water or contamination	static electricity builds up on surface and ignites material	electric shock	7, 10, 12
prospective circuit breaker not fast enough		shock, any other (for example, mechanical, electrical) as a consequence of equipment failure or overheating	7, 14

Origin	Hazard		Clause/subclause of this standard or reference
	Hazardous situation/event	Potential consequence	
prospective short circuit current		fire, any other (for example, mechanical, electrical) as a consequence of equipment failure or overheating	7, 10, 11
inrush current cause relays to weld and stick in 'on'		any other (for example, mechanical, electrical) as a consequence of equipment failure or overheating	7, 14
discharge into electric control or measuring equipment		any other (for example, mechanical, electrical) as a consequence of equipment failure or overheating	7, 14
onboard electrical source frequency variation		destruction of power source	6, 7, 14
overload	workload contacts heating means, foam formation	eruption or ejection of workload	10
undervoltage		any other (for example, mechanical, electrical) as a consequence of equipment failure	6.5
overvoltage	overheating of electric connections, melting of insulation	any other (for example, mechanical, electrical) as a consequence of equipment failure or overheating	6.5
magnetic field		projection or ejection of workload or other metallic parts, effects on medical implants, body heating, neural stimulus, any other (for example, mechanical, electrical) as a consequence of equipment failure or overheating	8
electromagnetic force		ejection of workload or projection of metallic parts, effects on medical implants, body heating, any other (for example, mechanical, electrical) as a consequence of equipment failure or overheating	8
electric field		ejection of workload or projection of metallic parts, effects on medical implants, body heating, any other (for example, mechanical, electrical) as a consequence of equipment failure or overheating	8
arc or plasma generating ozone		breathing harm, destruction of insulations	8
arc or plasma generating UV light		destruction of insulations	9
electrostatic phenomena causing arcs		electric shock, any other (for example, mechanical, electrical) as a consequence of equipment failure or overheating	7, 8

Hazard			Clause/subclause of this standard or reference
Origin	Hazardous situation/event	Potential consequence	
3 Thermal			
hot environment	prolonged stay near processing equipment	burn, dehydration, discomfort, dizziness, any other (for example, mechanical, electrical) as a consequence of a human error	9, 10, 11
flame			ISO 13577-2
explosion of gas, dust, aerosols	falling or ejection of objects, ejection of (hot) gases	any other (for example, mechanical, electrical) as a consequence of equipment failure	11, IEC 60079 series
projection or sudden eruption of material	falling or ejection of objects ejection of (hot) gases, ejection of (hot) liquids, thermal energy stored in workload projects hazard	burn, scald, impact, being thrown, crushing, slipping or tripping, explosion, any other (for example, mechanical, electrical) as a consequence of equipment failure	8, 10, 11, 15
failure of liquid cooling enclosure in contact with liquid workload		burn, scald, impact, being thrown, crushing, slipping or tripping, explosion, any other (for example, mechanical, electrical) as a consequence of equipment failure	12, ISO 13577-1
objects or materials with a high temperature	non-sufficient thermal strength of parts of the installation leads to break-up during operation	burn, ignition, explosion, radiation	10
hot liquids, hot liquid flowing out of a vessel, hot liquid flowing into water	falling or ejection of objects, ejection of hot liquids, liquid metal causes sudden steam eruption	burn, scald, poisoning, slipping or tripping, explosion, ejection, any other (for example, mechanical, electrical) as a consequence of equipment failure	11, 15
superheated hot liquids		burn, scald, poisoning, impact, being thrown, crushing, slipping or tripping, explosion, any other (for example, mechanical, electrical) as a consequence of equipment failure	10, 12
hot high pressure gases		scald, burn	10, 12
hot high pressure liquids		scald, burn	10, 12
radiation from heat sources		see infrared radiation	9
4 Noise			17.2 ISO 12100
5 Vibration			ISO 13577-1 ISO 12100

Hazard			Clause/subclause of this standard or reference
Origin	Hazardous situation/event	Potential consequence	
6 — Electromagnetic fields below 300 GHz			
electric field		burn, dizziness, body heating.	8
magnetic field	Magnetic field interacts with installation and leads to break-up	any other (for example, mechanical, electrical) as a consequence of equipment failure or overheating	8
7 — Radiation — electromagnetic fields above 300 GHz			
ionising radiation		effects on reproductive capability, mutation, cancer, burn, severe illness or death, any other (for example, mechanical, electrical) as a consequence of equipment failure	9.2
ultraviolet radiation		damage to eyes and skin, mutation, cancer of skin	9.3
visible radiation		damage to eyes and skin, burn	9.4
infrared radiation		burn, damage to eyes, any other (for example, mechanical, electrical) as a consequence of equipment failure or overheating	9.4
ignition of flammable substance by radiation		burn, explosion, noxious gases	9, 10, 11 IEC 60079 series
laser radiation		damage to eyes and tissue	9.5
8 — Material or substance related			
aerosol, combustible, dust, explosive, fibre, flammable, fluid, fume, gas, mist, oxidizer		breathing difficulties, suffocation, cancer, corrosion, explosion, fire	ISO 12100, ISO 13577-1
9 — Ergonomic			
access	moving into hazard zone	any as a consequence of a human being in the wrong place	6.7, 8, 9, 10, 12, 13, 14, 15
design or location of indicators and visual display units		any other (for example, mechanical, electrical) as a consequence of a human error	19.3
design, location or identification of control devices		any other (for example, mechanical, electrical) as a consequence of a human error	14, 19

Hazard			Clause/subclause of this standard or reference
Origin	Hazardous situation/event	Potential consequence	
flicker, dazzling, shadow, stroboscopic effect by the installation		discomfort, fatigue, stress, any other (for example, mechanical, electrical) as a consequence of a human error	13.8, 14
lighting in installation	tripping due to dim lighting not perceiving warning due to glare	any other (for example, mechanical, electrical) as a consequence of a human error	13.8
work process design	excessive effort, human errors, human misbehaviour (unintentional or deliberately induced by the design), Loss of direct visibility of the working area, Painful and tiring postures, Repetitive handling at high frequency	any other (for example, mechanical, electrical) as a consequence of a human error	14, 15
10 — Associated with the environment in which the installation is used			
General			ISO 12100
electromagnetic disturbance	malfunction of the controls	any other as a consequence of the effect caused by the sources of the hazards on the equipment or parts of the equipment	Annex E
insufficient lighting	tripping due to dim lighting, not perceiving warning due to glare	any other (for example, mechanical, electrical) as a consequence of a human error	13.8, 19.2, 19.3, 19.5
flicker, dazzling, shadow, stroboscopic effect by other installations		discomfort, fatigue, stress, any other (for example, mechanical, electrical) as a consequence of a human error	19
11 — Combination of hazards			
repetitive activity + effort + high environmental temperature		dehydration, loss of awareness, heat stroke	

Annex B **(informative)**

Electric and magnetic fields, touch currents – limits of exposure hazards

B.1 Overview and motivation

B.1.1 General

This Annex B informs about limits for exposure to electric and magnetic fields as well as for touch currents and voltages. Meeting exposure limits is not to be confused with adequate risk reduction. The limits can be used if no applicable national regulations exist.

B.1.2 Basic concepts

Exposure limits are based on the physical quantity or quantities directly related to the established health effects and are termed basic restrictions, their values are for example defined in ICNIRP:2010 or in IEEE C95.1.

The induced electric field strength in exposed body parts is the physical quantity used by those sources and adhered to in this Annex B in the frequency range between 1 Hz and 100 kHz. It is this field that affects nerve cells and other electrically sensitive cells and causes an immediate reaction.

Reference levels are measurable values that are derived from the basic restrictions. Their calculation is usually based on very general worst case scenarios and includes generous safety margins. The implicit safety margin differs quite markedly between ICNIRP:1999, ICNIRP:2010 and IEEE C95.1. They can exaggerate the hazard by orders of magnitude. Meeting a reference level during verification shows that a position is safe; exceeding a reference level does not necessarily indicate that the same position is unsafe.

Values for the general public are kept in this Annex B as these are needed for the classification with respect to 4.4.

B.1.3 Hazard sources and hazard effects

This Annex B is concerned with hazards caused by

- a) static magnetic fields and magnetic fields with a frequency below 1 Hz;
- b) live conductors and charges on non-conducting surfaces causing touch currents including arcing;
- c) electric or magnetic nearfields causing electric fields in body parts.

The basic physical quantity used for specifying electric, magnetic and current limiting values on electric shock effects is the internal tissue electric field strength in all cases where local bodypart heating is not the determining hazard, otherwise it is the localised specific absorption rate (SAR).

Painful local heating or burn caused by touch currents are considered as electric shock effects. Such heating effects can also be internal and caused by the product of the electric field and the current it causes in the tissue. There are no limiting values specified by international organisations or local authorities based on a quantification of the various factors to be considered. Thus skin heating effects are not included in this Annex B.

~~External wave propagation phenomena complicate the exposure scenario above some MHz as involved fields are no longer only nearfields. Effects that limit the energy penetration into the body occur above some MHz frequencies. A value of 6 MHz is set as the upper limit considered in this standard. Higher frequencies are dealt with in the applicable Particular Requirements.~~

~~All fields dealt with in this Annex B are quasistatic and non-propagating.~~

~~B.1.4 — Frequency dependence~~

~~The assessment of hazards becomes more complicated for frequencies higher than 200 Hz due to~~

- ~~a) electric and propagating fields becoming significant to the human body with increasing frequency, as the induced electric field strength increases with the frequency;~~
- ~~b) any coupling between external magnetic fields and a bodypart causing an induced electric field, depends on the geometry and location of the bodypart in relation to the direction, curvature and strength;~~
- ~~c) strength of displacement currents, e.g. caused by touching an insulated conductor, increases with the frequency;~~
- ~~d) circuits do not remain as reliable as at low frequencies, due to skin and proximity effects;~~
- ~~e) conventional **electric shock** phenomena of nerve and muscle reflex reactions diminish with increasing frequency, skin burns and internal bodypart heating become significant instead.~~

~~Exposure to strong magnetic fields induces local electric fields in human bodyparts, and by that also currents and local heating of bodyparts. The electric field causes electric shock type effects which, however, diminish in the frequency range between 100 kHz and 6 MHz.~~

~~B.2 — Static magnetic fields~~

~~Table B.1 provides the exposure limits to static magnetic fields according to~~

- ~~a) ICNIRP:2009 where static is defined as having a frequency of less than 1 Hz; the spatial peak limits are for people without medical implants made from ferromagnetic materials or including electronic equipment;~~
- ~~b) IEEE C95.6:2002 where static is defined as having a frequency of less than 0,153 Hz; these levels are derived from restrictions on induced internal electrical fields.~~

~~**Table B.1 — ICNIRP and IEEE limits of exposure to static magnetic fields**~~

Exposure characteristics	Magnetic flux density, spatial peak exposure and rms					
	general public		occupational		exceptional occupational	
	ICNIRP	IEEE	ICNIRP	IEEE	ICNIRP ^a	IEEE
Exposure of head and of trunk	0,4 T	0,118 T	2 T	0,353 T	8 T	n.a.
Exposure of limbs	0,4 T	0,353 T	8 T	0,353 T	8 T	n.a.
^a For specific work applications, exposure up to 8 T can be justified, if the environment is controlled and appropriate work practices are implemented to control movement-induced effects.						

~~Limits to safeguard personnel against the hazard of objects being accelerated in an inhomogeneous field are lower than the safety limits for the exposure of people, the variation of the magnetic field strength is usually limited to 0,3 T m⁻¹ for any direction. For persons having medical electronic implants or devices in or on the body, the corresponding maximum~~

value is usually 0,5 mT unless these devices are certified to withstand and operate reliably at higher values.

B.3 Time varying magnetic, electric and electromagnetic fields

B.3.1 Basic restrictions between 1 Hz and 100 kHz

Table B.2 summarises the ICNIRP basic restrictions on induced time-varying electric fields in body tissues over the frequency range from 1 Hz to 10 MHz; Table B.3 summarises the basic restrictions on induced time-varying electric fields in body tissues over the frequency range from 0,153 Hz to 3 GHz according to IEEE C95.1:2005 and IEEE C95.6:2002. From these values other limits and reference levels are derived.

Table B.2 – ICNIRP basic restrictions for internal electric fields in human tissue in the frequency range between 1 Hz and 10 MHz

Exposure characteristic	Frequency range	Internal electric field in $V \cdot m^{-1}$	
		general public	Occupational
Central nervous system (CNS) tissue of the head	1 – 10 Hz	$0,1 \times f^{-1}$	$0,5 \times f^{-1}$
	10 Hz – 25 Hz	0,04	0,05
	25 Hz – 400 Hz	$0,4 \cdot 10^{-3} \times f$	$2 \cdot 10^{-3} \times f$
	400 Hz – 3 kHz	0,4	0,8
	3 kHz – 10 MHz	$1,35 \cdot 10^{-4} \times f$	$2,7 \cdot 10^{-4} \times f$
All tissues of head and body	1 Hz – 3 kHz	0,4	0,8
	3 kHz – 10 MHz	$1,35 \cdot 10^{-4} \times f$	$2,7 \cdot 10^{-4} \times f$

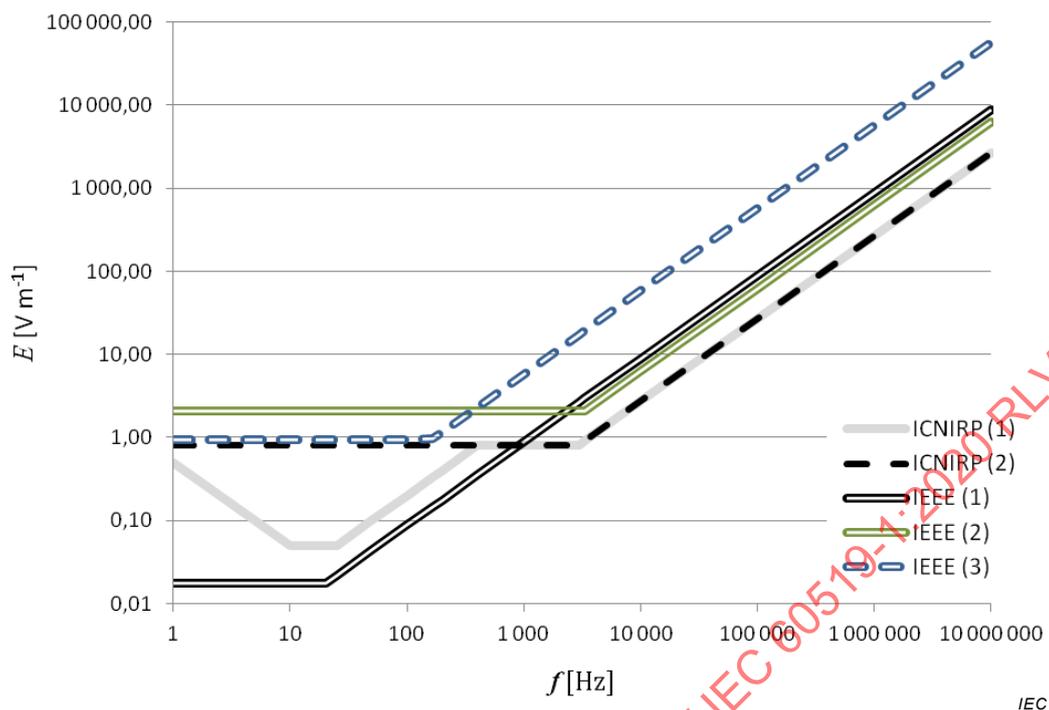
NOTE – f is the frequency in Hz; all values are rms.

Table B.3 – IEEE basic restrictions for internal electric fields in human tissue in the frequency range between 0,153 Hz and 3 GHz

Exposure characteristic	Frequency range	Internal electric field in $V \cdot m^{-1}$	
		general public	occupational
Brain	< 20 Hz	0,005-89	0,017-7
	20 Hz – 3 GHz	$2,95 \cdot 10^{-4} \times f$	$8,85 \cdot 10^{-4} \times f$
Heart	< 167 Hz	0,943	0,943
	167 Hz – 3 GHz	$5,76 \cdot 10^{-3} \times f$	$5,76 \cdot 10^{-3} \times f$
Hands, wrists, feet and ankles	< 3-350 Hz	2,1	2,1
	3-350 Hz – 3 GHz	$6,27 \cdot 10^{-4} \times f$	$6,27 \cdot 10^{-4} \times f$
other tissue	< 3-350 Hz	0,704	2,1
	3-350 Hz – 3 GHz	$2,09 \cdot 10^{-4} \times f$	$6,27 \cdot 10^{-4} \times f$

NOTE – f is the frequency in Hz; all values are rms.

The data is illustrated in Figure B.1.

**Key**

(1) — = central nervous system or brain tissue

(2) — = all other tissue

(3) — = heart tissue

 f — = frequency E — = induced internal electric field**Figure B.1 — Illustration of the basic restrictions from Tables B.3 and B.4****B.3.2 — Basic restrictions between 100 kHz and 300 MHz**

Table B.4 summarises the basic restrictions on SAR values and power flux densities due to exposure to time-varying electric, magnetic or **electromagnetic fields** in the frequency range between 100 kHz and 300 MHz according to ICNIRP:2010 and IEEE C95.1:2002.

Table B.4 — Specific absorption rate (SAR) and power flux density basic restrictions between 100 kHz and 300 MHz

	Frequency range	Whole-body average SAR ^a in W·kg ⁻²		Localized SAR ^b (head and trunk) in W·kg ⁻²		Localized SAR (limbs) in W·kg ⁻²		Power flux density in W·m ⁻²	
		ICNIRP	IEEE	ICNIRP	IEEE	ICNIRP	IEEE	20 cm ² average	1 cm ² average
								ICNIRP	ICNIRP
general public	100 kHz – 3 GHz	0,08	0,08	2	2	4	4	10	200
	3 GHz – 10 GHz		n.a.		n.a.		n.a.		
	10 GHz – 300 GHz	n.a.							
occupational	100 kHz – 3 GHz	0,4	0,4	10	10	20	20	50	1 000
	3 GHz – 10 GHz		n.a.		n.a.		n.a.		
	10 GHz – 300 GHz	n.a.							

^a—All SAR values are to be averaged over any 6-min period.

^b—Localized SAR averaging mass is any 10 g of continuous tissue; the maximum SAR so obtained should be the value used for the estimation of exposure.

B.3.3 — Heated worn objects

Some objects worn in an electric or magnetic field can cause a risk; this includes ring-shaped objects like necklaces, bracelets, rings as well as magnetisable objects or objects made from material of comparably poor conductivity, like carbon or silicon. No clear limits can be given.

B.4 — Touch currents

Table B.5 summarises the ICNIRP:2010 reference levels for exposure to touch currents; one can instead derive sufficient safe levels from the basic restrictions for specific cases.

Table B.5 — ICNIRP reference levels for time-varying touch currents

Frequency range	Maximum contact current (mA)	
	general public	occupational
1 Hz – 2,5 kHz	0,5	1,0
2,5 kHz – 100 kHz	0,2 <i>f</i>	0,4 <i>f</i>
100 kHz – 10 MHz	20	40
NOTE <i>f</i> is the frequency in kHz.		

B.5 — Touch voltages

B.5.1 — Extra-low voltage (ELV) below 100 Hz

The following values define ELV circuits which can be touched without restrictions:

- A touch voltage of up to 120 V is accepted at 0 Hz.
- A touch voltage of up to 50 V rms value is accepted between 10 Hz and 100 Hz.
- For a composite of 0 Hz and alternating components up to 100 Hz, a peak value not exceeding 120 V and rms ripple not exceeding 12 V are accepted.

B.5.2 — Extra-low voltage (ELV) above 100 Hz

Limits for **touch voltages** for higher frequencies would be determined from the touch current, for the actual configuration of the accessible live conductor and the touching part of the body.

IEC TR 60479-5 and IEC TS 61201 provide information on limitations at mains frequency. Limits at other frequencies are under consideration.

IEEE C95.1:2005 suggests 140 V as the upper limit to prevent arc formation between equipment and an exposed person in the frequency range 100 kHz to 100 MHz.

B.6 — Classification of exposure

B.6.1 — General

Following the approach of 4.4, the following risk groups are defined. A risk group describes the risk of exposure to a hazard for a specific spatial position or hazard zone. The classification applies for **normal operation** and single-fault condition.

B.6.2 — Exempt group

Any equipment that does not pose any hazard caused by electric, magnetic or **electromagnetic field** is classified in the exempt group. This requirement is met by any **EH** or **EPM equipment** that does

- not pose a hazard to an **ordinary person**;
- not cause a static magnetic field exceeding the limit for the general public as defined in Table B.1,
- not cause an internal electrical field exceeding the limit for the general public as defined in Table B.2,
- not cause SAR exceeding the limit for the general public as defined in Table B.4;
- not cause a touch current exceeding the reference level defined for the general public as defined in ICNIRP.

This complies with equipment that either has been assessed using methods defined in Clause 18 or that does not cause an electric field strength, magnetic field strength, magnetic flux density or equivalent plane wave power density exceeding the reference level as defined in ICNIRP:2010, IEEE C95.1:2002 or IEEE C95.6:2005 for general public.

B.6.3 — Risk group 1 (low risk)

Any equipment that does not pose a hazard for occupational exposure is classified in the low risk group. This requirement is met by any equipment that exceeds the limits for the exempt group but that does

- not pose a hazard for **operators**;
- not cause a static magnetic field exceeding the occupational limit as defined in Table B.1,
- not cause an internal electrical field exceeding the occupational limit as defined in Table B.2,
- not cause a SAR exceeding the occupational limits as defined in Table B.3,
- not cause a touch current exceeding the reference level defined for occupational use as defined in Table B.4.

This complies with equipment that either has been assessed using methods defined in Clause 18 or that does not cause an electric field strength, magnetic field strength, magnetic flux density or equivalent plane wave power density exceeding the reference level as defined in ICNIRP:2010, IEEE C95.1:2002 or IEEE C95.6:2005 for occupational exposure.

~~B.6.4 — Risk group 2 (moderate risk)~~

~~Any equipment, that does not pose a hazard for short exposure duration is classified in the moderate risk group. This requirement is met by any kind of equipment that exceeds the limits for risk group 1 (low risk), but that does not cause~~

- ~~— a static magnetic field exceeding the occupational limit as defined in Table B.1 for specific work applications where the environment is controlled and appropriate work practices are implemented to control movement-induced effects;~~
- ~~— a touch current exceeding the level causing harm over a short time.~~

~~B.6.5 — Risk group 3 (high risk)~~

~~Any equipment that can pose a hazard even for momentary or brief exposure, or which exceeds the limits for risk group 2 (moderate risk), is classified in risk group 3 (high risk).~~

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Annex C (informative)

Optical radiation — limits of exposure hazards

C.1 Non-coherent radiation limits

This Annex C informs about limits for exposure to non-ionising radiation. Meeting exposure limits is not to be confused with adequate risk reduction. The limits can be used if no applicable national regulations exist. Non-ionising radiation includes hazards from ultraviolet, from visible and from infrared radiation. The limits provided in Table C.1 and

Table C.2 comply with IEC 62471.

Table C.1 — Exposure limits in the ultraviolet, visible and infrared, irradiance based values

Hazard	Formula ^a	Wavelength range	Exposure duration	Limiting aperture	Exposure limit in terms of constant irradiance ^b
Actinic UV skin and eye	$E_S = \sum E_\lambda \cdot S(\lambda) \cdot \Delta\lambda$	200 nm — 400 nm	< 30 000 s	1,4 rad / 80°	30/t W·m ⁻²
Eye UV-A	$E_S = \sum E_\lambda \cdot S(\lambda) \cdot \Delta\lambda$	200 nm — 400 nm	< 30 000 s	1,4 rad / 80°	30/t W·m ⁻²
Eye infrared	$E_{IR} = \sum E_\lambda \cdot \Delta\lambda$	780 nm — 3 000 nm	≤ 1 000 s	1,4 rad / 80°	18 000/t ^{0,75} W·m ⁻²
Eye infrared	$E_{IR} = \sum E_\lambda \cdot \Delta\lambda$	780 nm — 3 000 nm	> 1 000 s	1,4 rad / 80°	100 W·m ⁻²
Skin thermal	$E_H = \sum E_\lambda \cdot \Delta\lambda$	380 nm — 3 000 nm	< 10 s	2π rad	20 000/t ^{0,75} J·m ⁻²

NOTE The exposure limit for the skin thermal hazard is a dose and not a power, thus it is stated in Joules (J) per area.

^a E is the spectral irradiance;
 λ is the wavelength;
^b t is the exposure time.

Table C.2 — Exposure limits in the infrared, radiance based values

Hazard	Formula ^a	Wavelength range	Exposure duration	Limiting aperture	Exposure limit in terms of constant irradiance
Blue light	$L_B = \sum L_\lambda \cdot B(\lambda) \cdot \Delta\lambda$	300 nm — 700 nm	0,25 s — 10 s		
Retinal thermal	$L_R = \sum L_\lambda \cdot R(\lambda) \cdot \Delta\lambda$	380 nm — 1 400 nm	< 0,25 s	0,0017 rad	50 000/(α·t ^{0,25}) W·m ⁻²
Retinal thermal	$L_R = \sum L_\lambda \cdot R(\lambda) \cdot \Delta\lambda$	380 nm — 1 400 nm	0,25 s — 10 s	0,011√t/10 rad	50 000/(α·t ^{0,25}) W·m ⁻²
Retinal thermal, weak ^b vis. stim.	$L_{IR} = \sum L_\lambda \cdot R(\lambda) \cdot \Delta\lambda$	780 nm — 1 400 nm	> 10 s	0,011 rad	6 000/α W·m ⁻²

NOTE The functions $B(\lambda)$ and $R(\lambda)$ are defined in IEC 62471:2006.

^a L is the spectral irradiance;
^b where a weak visual stimulus is inadequate to activate the aversion response.

~~In the case of danger of burn caused by infrared radiation, the limit is defined as a dose, not by a specific irradiation. Operators can be exposed to a safe dose repeatedly, as the doses do not accumulate—in contrast to e.g. exposure to UV radiation.~~

~~For infrared radiation exceeding 3 000 nm, no limits are usually set, ICNIRP:2006 provides the necessary information.~~

C.2—Radiation from laser sources and LEDs

~~Coherent non-ionising radiation is emitted from sources like lasers and LEDs. Table C.3 summarises the classification of equipment according to IEC 60825-1 and connects it with the classification conform to IEC 62471 and used in Clause 0.~~

Table C.3—Risk group classification of equipment by emission of optical radiation

Class	Laser radiation Highest class IEC 60825-1	Non-coherent optical radiation Highest risk group
0	1, 1M	Exempt group—see C.3.2 Risk group 1 (low risk)—see C.3.3
1	2, 2M	Risk group 2 (moderate risk)—see C.3.4
2	3R, 3B, 4	Risk group 3 (high risk)—see C.3.5

C.3—Non-coherent optical radiation—risk groups

C.3.1—General

~~The classification as illustrated in Table C.3 depends for each single location on the highest single risk, summarised over all positions and all emission bands. A detailed description of risk groups for optical radiation is given in IEC 62471.~~

~~Risk groups simplify the task of assessment of exposure. They mirror specific aspects of behaviour or tasks of operators. They are derived from the exposure limits as given in Table C.1 and Table C.2.~~

~~As radiation hazards are depending on the radiation itself, not on the cause or source, it is advisable to include all radiation from all sources of the installation into this classification.~~

C.3.2—Exempt group

~~Any equipment that does not pose any photobiological hazard is classified in the exempt group. This requirement is met by any **EH** or **EPM equipment** that~~

- ~~—does not pose an actinic ultraviolet hazard within 8 h of exposure;~~
- ~~—does not pose a near-UV hazard within 1 000 s;~~
- ~~—does not pose a retinal blue-light hazard within 10 000 s;~~
- ~~—does not pose a retinal thermal hazard within 10 s;~~
- ~~—does not pose an infrared radiation hazard for the eye within 1 000 s;~~
- ~~—emits infrared radiation without a strong visual stimulus (i.e. less than 10 cd·m⁻²) and does not pose an IR-A retinal hazard within 1 000 s.~~

C.3.3 — Risk group 1 (low risk)

Any equipment that does not pose a hazard due to normal behavioural limitations on exposure is classified in the low risk group. This requirement is met by any equipment that exceeds the limits for the exempt group but

- does not pose an actinic ultraviolet hazard within 10 000 s;
- does not pose a near ultraviolet hazard within 300 s;
- does not pose a retinal blue-light hazard within 100 s;
- does not pose a retinal thermal hazard within 10 s;
- does not pose an infrared radiation hazard for the eye within 100 s;
- emits infrared radiation without a strong visual stimulus (i.e. less than $10 \text{ cd}\cdot\text{m}^{-2}$) and does not pose an IR-A retinal hazard, within 100 s.

C.3.4 — Risk group 2 (moderate risk)

Any equipment, that does not pose a hazard due to the aversion response to very bright light sources or due to thermal discomfort is classified in the moderate risk group. This requirement is met by any kind of equipment that exceeds the limits for risk group 1 (low risk), but that

- does not pose an actinic ultraviolet hazard within 1 000 s exposure;
- does not pose a near ultraviolet hazard within 100 s;
- does not pose a retinal blue-light hazard within 0,25 s (aversion response);
- does not pose a retinal thermal hazard within 0,25 s (aversion response);
- does not pose an infrared radiation hazard for the eye within 10 s;
- emits infrared radiation without a strong visual stimulus (i.e. less than $10 \text{ cd}\cdot\text{m}^{-2}$) and does not pose an IR-A retinal hazard within 10 s.

C.3.5 — Risk group 3 (high risk)

Any equipment that can pose a hazard even for momentary or brief exposure, or which exceeds the limits for risk group 2 (moderate risk), is classified in risk group 3 (high risk).

C.3.6 — Pulsed equipment

For the definition of risk groups for pulsed sources covered by this standard, 6.2 of IEC 62471:2006 applies.

Annex D (informative)

Limits for exposure hazards – noise and vibration

D.1 General

This Annex D informs about limits for exposure to noise and vibration. Meeting exposure limits is not to be confused with adequate risk reduction. The limits can be used if no applicable national regulations exist.

D.2 Sonic noise

The physical parameters used as risk predictors are defined as follows:

- a) peak sound pressure (p_{peak}): maximum value of the 'C' frequency weighted instantaneous noise pressure;
- b) daily noise exposure level ($L_{\text{EX},8\text{h}}$) (dB(A) re. 20 μPa): time weighted average of the noise exposure levels for a nominal eight hour working day as defined by ISO 1999:2013, 3.6. It covers all noises present at work, including impulsive noise;
- c) weekly noise exposure level ($L_{\text{EX},8\text{h}}$): time weighted average of the daily noise exposure levels for a nominal week of five eight hour working days.

The exposure limit values and exposure action values in respect of the daily noise exposure levels and peak sound pressures should not exceed:

- exposure limit values: $L_{\text{EX},8\text{h}} = 87$ dB(A) and $p_{\text{peak}} = 200$ Pa (140 dB (C) in relation to 20 μPa) respectively;
- upper exposure action values: $L_{\text{EX},8\text{h}} = 85$ dB(A) and $p_{\text{peak}} = 140$ Pa (137 dB (C) in relation to 20 μPa) respectively;
- lower exposure action values: $L_{\text{EX},8\text{h}} = 80$ dB(A) and $p_{\text{peak}} = 112$ Pa (135 dB (C) in relation to 20 μPa) respectively.

When applying the exposure limit values, the determination of the operator's effective exposure should take account of the attenuation provided by the individual hearing protectors worn by operators. The exposure action values should not take account of the effect of any such protectors.

NOTE These limits are derived from Directive 2003/10/EC.

D.3 Ultrasonic pressure

Limit for exposure to ultrasonic pressure is 110 dB above the reference pressure value of 20 μPa , for frequencies between 20 kHz and 100 kHz.

D.4 Infrasonic

Currently, there are no national regulations or international standards defining permissible exposure limits to infrasound. However, proposed limits with respect to the safety and preservation of the auditory system were provided by von Gierke and Nixon in "*Effects of Intense Infrasonic on Man*" (1976): for 8 h of exposure the limit ranges from 136 dB at a low frequency of 1 Hz to 123 dB at the upper end of the infrasonic range at 20 Hz. The limits can be approximately adjusted for shorter or longer duration exposures using a 3 dB exchange rate, i.e. if the duration is halved, the level can be increased by 3 dB.

D.5 ~~Vibration~~

~~Limiting values standardised to an eight-hour reference period and for hand-arm vibration are, where the values and assessment method are defined in ISO 5349-1:~~

- ~~a) the daily exposure limit value is 5 m/s²;~~
- ~~b) the daily exposure action value is 2,5 m/s².~~

~~Limit values for whole-body vibration are, where the values and assessment method are defined in ISO 2631-1:~~

- ~~c) the daily exposure limit value is 1,15 m/s² or a vibration dose value of 21 m/s^{1,75};~~
- ~~d) the daily exposure action value is 0,5 m/s² or a vibration dose value of 9,1 m/s^{1,75}.~~

~~NOTE These limits are derived from Directive 2002/44/EC.~~

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Annex E **(normative)**

Provisions concerning EMC

E.1 General

~~Even as EMC is not inside the scope of this standard per se, EMC can cause serious risks concerned with control or safety circuits.~~

~~The equipment shall be designed for functional safety with regard to EMC, in accordance with IEC 61326-3-1. The methodology in IEC TS 61000-1-2 can be used for guidance.~~

~~Flicker and harmonics shall be taken into account, especially shall the short-circuit capacity of the supply system be taken into account in the evaluation of flicker and of harmonics.~~

E.2 Requirements

~~The requirements on maximum voltage fluctuation and flicker for equipment with a rated input current~~

~~— less or equal to 16 A given in IEC 61000-3-3,~~

~~— for greater than 16 A in IEC TS 61000-3-5 and~~

~~— less than or equal to 75 A in IEC 61000-3-11~~

~~shall be applied.~~

~~Guidelines on limits of fluctuating loads in medium-voltage and high-voltage power systems are provided in IEC TR 61000-3-7. Specific provisions of the local utility may apply.~~

~~The fluctuation and flicker are also related to the short-circuit capacity of the supply system. That in turn also influences the level of the possible hazard.~~

~~Electromagnetic disturbances created by **EH** and **EPM installations** or **equipment** shall be within the limits given in CISPR 11, as far as it applies.~~

~~Effects of harmonic currents shall be taken into account. The characteristics of the supply system shall then be taken into account for the evaluation of the type and levels of harmonics.~~

~~Requirements on emission shall comply with IEC 61000-6-4.~~

~~Guidelines on limitations of distorting loads in medium-voltage and high-voltage power systems are provided in IEC TR 61000-3-6 and apply.~~

~~Immunity to **electromagnetic fields** shall be taken into account, if necessary. Requirements on immunity for industrial equipment given in IEC 61000-6-2 apply.~~

Annex F (normative)

Marking and warning

F.1 — EMF hazard zones

All areas where exposure to hazardous electric or magnetic fields is expected shall be marked when they are class 1 or class 2 as defined in Annex B or national regulations indicate. This refers to risk group 2 (moderate risk) and risk group 3 (high risk). Examples of marking presented in Figure F.1 consist of graphical symbols registered in IEC 60417 (see Table F.4) and text labels, which state the kind of field, the class and the reference (this standard or a national regulation).

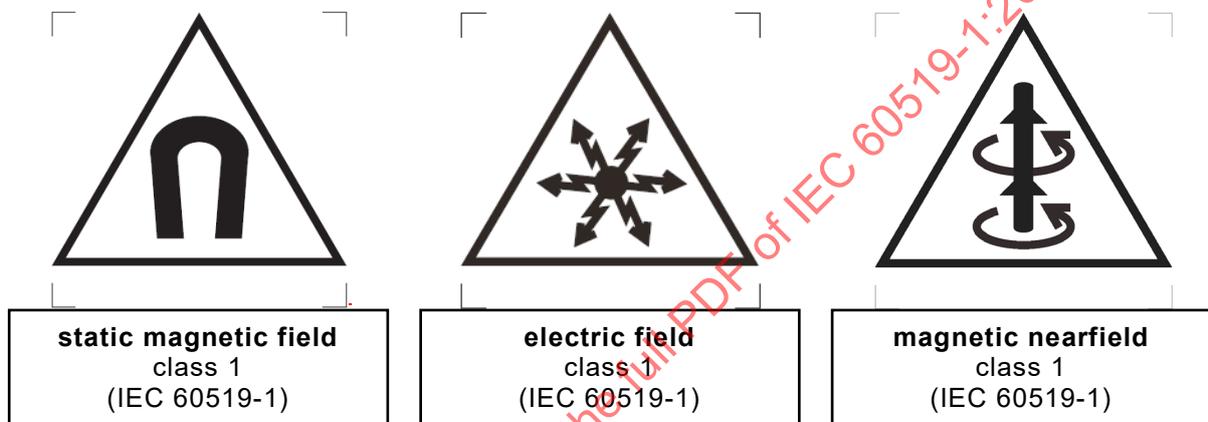


Figure F.1 — Examples of marking for magnetic and electric fields

F.2 — Touch currents and surfaces

All surfaces where exposure to touch currents is expected shall be marked, when they are class 1 or class 2 as defined in Annex B or national regulations indicate. This refers to the risk group 2 (moderate risk) and risk group 3 (high risk). Examples of marking given in Figure F.2 consist of graphical symbols registered in IEC 60417 (see Table F.4) and text labels, which state the kind of hazard, the class and the reference (this standard or a national regulation).

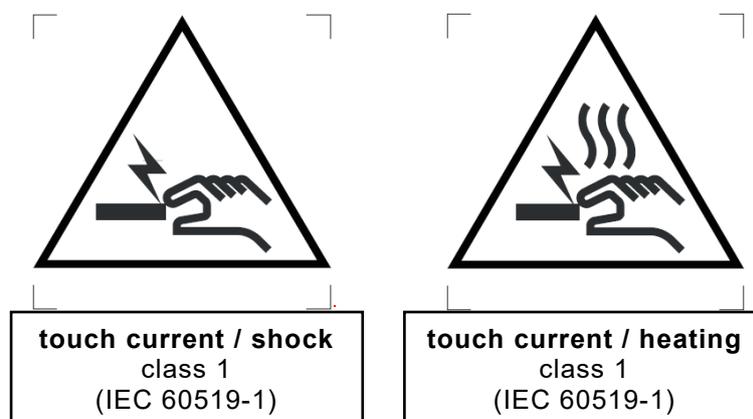


Figure F.2 — Examples of marking for touch current

F.3 ~~Optical radiation hazards~~

~~All openings or areas where exposure to radiation is expected shall be marked, when they are class 1 or class 2 as defined in Annex C or indicated in national regulations. This refers to the risk group 2 (moderate risk) and risk group 3 (high risk). The example of marking given in Figure F.3 consists of a graphical symbol IEC 60417-6151 (2012-02) and a text label, which states the kind of radiation, the class and the reference (this standard or a national regulation).~~

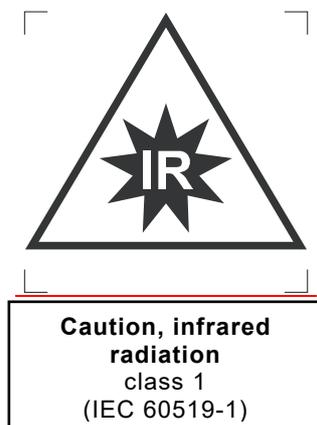


Figure F.3 – Example of marking for infrared radiation

~~Laser radiation under the scope of IEC 60825-1 should be marked as defined in that standard.~~

F.4 ~~Symbols and signs used for markings and warnings~~

~~In case of application of symbols in warning signs the rules according to ISO 3864-1 are recommended. Relevant symbols and signs registered in IEC 60417, ISO 7000 or ISO 7010 should be used, if applicable — some examples are given in Table F.4. Supplementary text signs or labels should be used to increase comprehension.~~

~~Relevant safety or warning signs and labels should be specified in the information for use according to 19.4.~~

Table F.4 – Examples of symbols and signs for use in EH or EPM installations

Symbol / sign	Reference	Description	Clause
	IEC 60417-5036 (2002-10)	Dangerous voltage	7
	IEC 60417-6042 (2010-11)	Caution, risk of electric shock	7
	IEC 60417-5019 (2006-08)	Protective earth; protective ground	7
	IEC 60417-6204 (2013-07)	Caution, static magnetic field hazard	8
	IEC 60417-6205 (2014-08)	Caution, alternating magnetic nearfield hazard	8
	IEC 60417-6206 (2013-07)	Caution, electric field hazard	8
	IEC 60417-6207 (2013-07)	Caution, touch current that can cause burns	8
	IEC 60417-6208 (2013-07)	Caution, touch current or voltage	8
	ISO 7010:2011—P007	No access for people with active implanted cardiac devices	8
	ISO 7010:2011—P014	No access for people with metallic implants	8
	ISO 7010:2011—P008	No metallic articles or watches	8
	IEC 60417-6166 (2012-07)	Caution, non-ionizing electromagnetic radiation ; Caution, microwave radiation	8, 9
	IEC 60417-5152 (2002-10)	Radiation of laser apparatus	9
	IEC 60417-6151 (2012-02)	Caution, infrared radiation	9
	IEC 60417-5041 (2002-10)	Caution, hot surface	10

Annex G (informative)

Guidelines on using this standard

~~IEC 60519-1 gives a large number of general requirements that can or cannot be applicable to a particular **EH** or **EPM installation** or equipment. A simple reference without any qualification to IEC 60519-1 is therefore not sufficient. A **manufacturer** of an installation or equipment for which no Particular Requirement exists, should use IEC 60519-1~~

- ~~a) by selection of the most appropriate option(s) from the requirements given in the relevant clauses; and~~
- ~~b) by modification of certain clauses, as necessary, where the particular requirements for the installation or equipment are adequately covered by other relevant standards;~~

~~providing the options selected and the modifications made do not adversely affect the level of protection required for the installation.~~

~~When applying the principles listed above, it is recommended that~~

- ~~— reference be made to the relevant clauses and subclauses of this standard that are complied with, indicating where relevant the applicable option;~~
- ~~— reference be made to the relevant clauses and subclauses of this standard that have been modified or extended for the specific equipment requirements; and~~
- ~~— reference be made directly to the relevant standard, for those requirements for the electrical equipment that are adequately covered by that standard.~~

~~In all cases, expertise is essential to be able to:~~

- ~~— read and understand all of the requirements of IEC 60519-1;~~
- ~~— choose the applicable requirements from IEC 60519-1 where alternatives are given;~~
- ~~— identify alternative or additional particular requirements that differ from the requirements of IEC 60519-1 or are not included in the latter, and that are determined by the installation and its use; and~~
- ~~— specify precisely those particular requirements;~~
- ~~— use this standard for risk assessment purposes.~~

~~Figure 1 of IEC 60519-1 is a block diagram of a typical installation and can be used as the starting point of this task. The complementary Table 2 indicates the clauses and subclauses dealing with particular provisions or equipment. However, IEC 60519-1 is a complex standard and Table 2 can help identify the application options for a particular installation or equipment and gives reference to other relevant standards.~~

~~The primary responsibility of the **manufacturer** with respect to safety of **EH** or **EPM installations** or **equipment** is given in requirement 6.1.1. Subclause 4.4 provides assistance and introduces helpful concepts. Some of the concepts given as well as the information provided on exposure limits in Annex B, Annex C and Annex D do exceed the core responsibility of a **manufacturer** in view of 6.1.1. These aspects can become part of his work as is argued in the Introduction.~~

Annex H **(informative)**

Connection with ISO 13577 series

~~The ISO 13577 series of standards developed by ISO/TC 244 (Industrial furnaces and associated processing equipment) addresses the safety of industrial furnaces and of associated processing equipment. These standards cover thermal processing equipment (TPE) that is using different kinds of fuels and electric energy. The scope of that series and the IEC 60519 series overlap in parts, therefore reciprocal references are used, when practicable.~~

~~Both ISO 13577-1 and this standard are product safety publications and they cover all safety aspects of one or more products within the scope of a single product TC. Both standards reference the other where appropriate and in an unambiguous way. This is detailed in Clause 4 of this standard for the approach where this standard is used as the primary document.~~

~~In the case a **manufacturer** uses ISO 13577-1 as basic standard (type C standard with respect to ISO 12100), he will be referred to IEC 60519-1 for requirements concerning electrical safety, **electroheating**, direct or indirect contact to **hazardous live parts** and effects of electrical overload. It can then be possible to make use only of Clauses 7 and 8 as well as parts of Clauses 13 and 14 including the related annexes of this standard.~~

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Annex A (normative)

List of significant hazards

Table A.1 lists all significant hazards, hazardous situations and events, as far as they are dealt with in this document, that are identified by risk assessment as significant for **EH** or **EPM installation** or **equipment** and that require action to eliminate or reduce the risk.

Table A.1 – List of hazards dealt with in this document

Hazard			Clause/subclause of this document or reference used
Origin	Hazardous situation/event	Potential consequence	
1 Mechanical			ISO 13577-1:2016, ISO 12100:2010
high pressure gases and liquids	bursting of vessel, ejection of (hot) gases, falling or ejection of objects, ejection of (hot) liquids	suffocation, impact, explosion, being thrown, crushing, slipping or tripping,	12.3
movable parts	getting caught by part, getting crunched between parts	shear, crunching	15
vacuum	implosion of vessel, bursting of window	impact, injection or ejection	12.3
2 Electrical			
short-circuit arc live parts parts which have become live under fault conditions		electric shock, burn, shock, electrocution, falling or being thrown	7, 8
		fire, chemical reaction, explosion, projection of molten particles	7, 10, 11
arcing in vacuum	low pressure reduces breakdown voltage of gas	any other (e.g. electric) through overcurrent or disintegration of vacuum system	7, 13.13
insufficient distance to live parts under HV – people/equipment	entering the high-voltage hazard zone	electrical shock, fire, explosion	7, 10, 11
leakage current caused by hot insulation or through water or contamination	static electricity builds up on surface and ignites material	fire, chemical reaction, explosion, projection of molten particles	10, 12
		electric shock	7
prospective circuit breaker not fast enough		shock, any other (for example, mechanical, electrical) as a consequence of equipment failure or overheating	7, 14
prospective short circuit current		fire, any other (for example, mechanical, electrical) as a consequence of equipment failure or overheating	7, 10, 11

Hazard			Clause/subclause of this document or reference used
Origin	Hazardous situation/event	Potential consequence	
inrush current causes relays to weld and stick in 'on'		any other (for example, mechanical, electrical) as a consequence of equipment failure or overheating	7, 14
discharge into electric control or measuring equipment		any other (for example, mechanical, electrical) as a consequence of equipment failure or overheating	7, 14
resonance in electrical equipment (transformers, inductors, capacitors)	sustained resonance generates excessive voltage or current	any other (for example, mechanical, electrical) as a consequence of equipment failure or overheating	13.11
onboard electrical source frequency variation		destruction of power source	6, 7, 14
overload	workload contacts heating means, formation of foam	eruption or ejection of workload	10
undervoltage		any other (for example, mechanical, electrical) as a consequence of equipment failure	6.5
overvoltage	overheating of electric connections, melting of insulation	any other (for example, mechanical, electrical) as a consequence of equipment failure or overheating	6.5
magnetic field		projection or ejection of workload or other metallic parts, effects on medical implants, body heating, neural stimulus, any other (for example, mechanical, electrical) as a consequence of equipment failure or overheating	8
electromagnetic force		ejection of workload or projection of metallic parts, effects on medical implants, body heating, any other (for example, mechanical, electrical) as a consequence of equipment failure or overheating	8
electric field		ejection of workload or projection of metallic parts, effects on medical implants, body heating, any other (for example, mechanical, electrical) as a consequence of equipment failure or overheating	8
arc or plasma generating ozone		breathing harm, destruction of insulation , coatings, parts	8
arc or plasma generating UV light		destruction of insulation , coatings, parts	9

Hazard			Clause/subclause of this document or reference used
Origin	Hazardous situation/event	Potential consequence	
electrostatic phenomena causing arcs		electric shock, any other (for example, mechanical, electrical) as a consequence of equipment failure or overheating	7, 8
3 Thermal			
hot environment	prolonged stay near processing equipment	burn, dehydration, discomfort, dizziness, any other (for example, mechanical, electrical) as a consequence of a human error	9, 10, 11
flame			ISO 13577-2
explosion of gas, dust, aerosols	falling or ejection of objects, ejection of (hot) gases loss of integrity of equipment	any other (for example, mechanical, electrical) as a consequence of equipment failure	11, 13.14, IEC 60079-1 ISO 13577-3
projection or sudden eruption of material	falling or ejection of objects ejection of (hot) gases, ejection of (hot) liquids, thermal energy stored in workload projects hazard	burn, scald, impact, being thrown, crushing, slipping or tripping, explosion, any other (for example, mechanical, electrical) as a consequence of equipment failure	8, 10, 11, 15
failure of cooling		burn, scald, impact, being thrown, crushing, slipping or tripping, explosion, any other (for example, mechanical, electrical) as a consequence of equipment failure or disintegration	12; ISO 13577-1:2016
thermal overload of housing, vacuum system or structural parts			
failure of liquid cooling of enclosure being in contact with liquid workload			
objects or materials with a high temperature	non-sufficient thermal strength of parts of the installation leads to break-up during operation	burn, ignition, explosion, radiation	10
hot liquids, hot liquid flowing out of a vessel, hot liquid flowing into water	falling or ejection of objects, ejection of hot liquids, liquid metal causes sudden steam eruption	burn, scald, poisoning, slipping or tripping, explosion, ejection, any other (for example, mechanical, electrical) as a consequence of equipment failure	10, 11, 12, 15
superheated hot liquids		burn, scald, poisoning, impact, being thrown, crushing, slipping or tripping, explosion, any other (for example, mechanical, electrical) as a consequence of equipment failure	10, 12
hot high pressure gases		scald, burn	10, 12

Hazard			Clause/subclause of this document or reference used
Origin	Hazardous situation/event	Potential consequence	
hot high pressure liquids		scald, burn	10, 12
radiation from heat sources		see "infrared radiation" (No. 7)	9
pressure loss (in workload or cooling liquid)	sudden boiling of liquid	burn, scald, poisoning, impact, being thrown, crushing, slipping or tripping, explosion, any other (for example, mechanical, electrical) as a consequence of equipment failure	12.3
4	Noise		not in the scope
5	Vibration		ISO 13577-1:2016
6 Electromagnetic fields below 300 GHz			
electric field		burn, dizziness, body heating.	8
magnetic field	magnetic field interacts with installation and leads to break-up	any other (for example, mechanical, electrical) as a consequence of equipment failure or overheating	8
magnetic field	magnetic tools or personal belongings in the vicinity of the equipment	projection or ejection of workload or other metallic parts, effects on medical implants, any other as a consequence of equipment failure or operator being hurt	8
7 Radiation – electromagnetic fields above 300 GHz			
ionising radiation		effects on reproductive capability, mutation, cancer, burn, severe illness or death, any other (for example, mechanical, electrical) as a consequence of equipment failure	9.2
ultraviolet radiation		damage to eyes and skin, mutation, cancer of skin	9.3
	not suitable material exposed to radiation	any other caused by failure of parts, coatings	9.3
visible radiation		damage to eyes and skin, burn	9.4
infrared radiation		burn, damage to eyes, any other (for example, mechanical, electrical) as a consequence of equipment failure or overheating	9.4
	excessive heat transfer through radiation	any other caused by failure of parts	9.4, 11
ignition of flammable substance by radiation	for example workload gets stuck, or accumulation of dust	burn, fire, explosion, noxious gases	9, 10, 11; IEC 60079 (all parts)

Hazard			Clause/subclause of this document or reference used
Origin	Hazardous situation/event	Potential consequence	
laser radiation	getting into the beam	damage to eyes and tissue	9.5; IEC 60825-1:2014
	beam hits material	ignition, fire, explosion any other through destruction of parts	9.5, 11; IEC 60825-1:2014
8 Material or substance related			
aerosol, combustible, dust, explosive, fibre, flammable, fluid, fume, gas, mist, oxidizer		breathing difficulties, suffocation, cancer, corrosion, explosion, fire	10, 11, 12, 13.14; ISO 13577-1:2016 ISO 13577-2:2014 ISO 13577-3:2016
workload contains water	wet workload is added to molten workload sudden rise of pressure	ejection of molten workload , any other through destruction of parts	19
deposition of conductive layer on isolator in vacuum	leakage current , arcing	any other (for example, mechanical, electrical) as a consequence of equipment failure or overheating	13.13
9 Ergonomic			
access	moving into hazard zone	any as a consequence of a human being in the wrong place	6.7, 8, 9, 10, 12, 13, 14, 15
design or location of indicators and visual display units		any other (for example, mechanical, electrical) as a consequence of a human error	19.3
design, location or identification of control devices		any other (for example, mechanical, electrical) as a consequence of a human error	14, 19
flicker, dazzling, shadow, stroboscopic effect by the installation		discomfort, fatigue, stress, any other (for example, mechanical, electrical) as a consequence of a human error	13.8, 14
lighting in installation	tripping due to dim lighting not perceiving warning due to glare	any other (for example, mechanical, electrical) as a consequence of a human error	13.8
handheld applicator and open ended devices	overriding safety switch	any other (for example, mechanical, electrical) as a consequence of a human error	13.12
work process design	excessive effort, human errors, human misbehaviour (unintentional or deliberately induced by the design), loss of direct visibility of the working area, painful and tiring postures, repetitive handling at high frequency	any other (for example, mechanical, electrical) as a consequence of a human error	14, 15

Hazard			Clause/subclause of this document or reference used
Origin	Hazardous situation/event	Potential consequence	
10 Associated with the environment in which the installation is used			
General			ISO 12100:2010
electromagnetic disturbance	malfunction of the controls	any other as a consequence of the effect caused by the sources of the hazards on the equipment or parts of the equipment	6.3, 14, 17
insufficient lighting	tripping due to dim lighting, not perceiving warning due to glare	any other (for example, mechanical, electrical) as a consequence of a human error	13.8, 19.2, 19.3, 19.5
flicker, dazzling, shadow, stroboscopic effect by other installations		discomfort, fatigue, stress, any other (for example, mechanical, electrical) as a consequence of a human error	19
height or air pressure	insufficient mass flow of air for cooling	any other (for example mechanical, fire) as a consequence of overheating	6
11 Combination of hazards			
repetitive activity + effort + high environmental temperature		dehydration, loss of awareness, heat stroke	
any combination of flammable material or workload , (heat) energy and oxidiser	fire	any other	11

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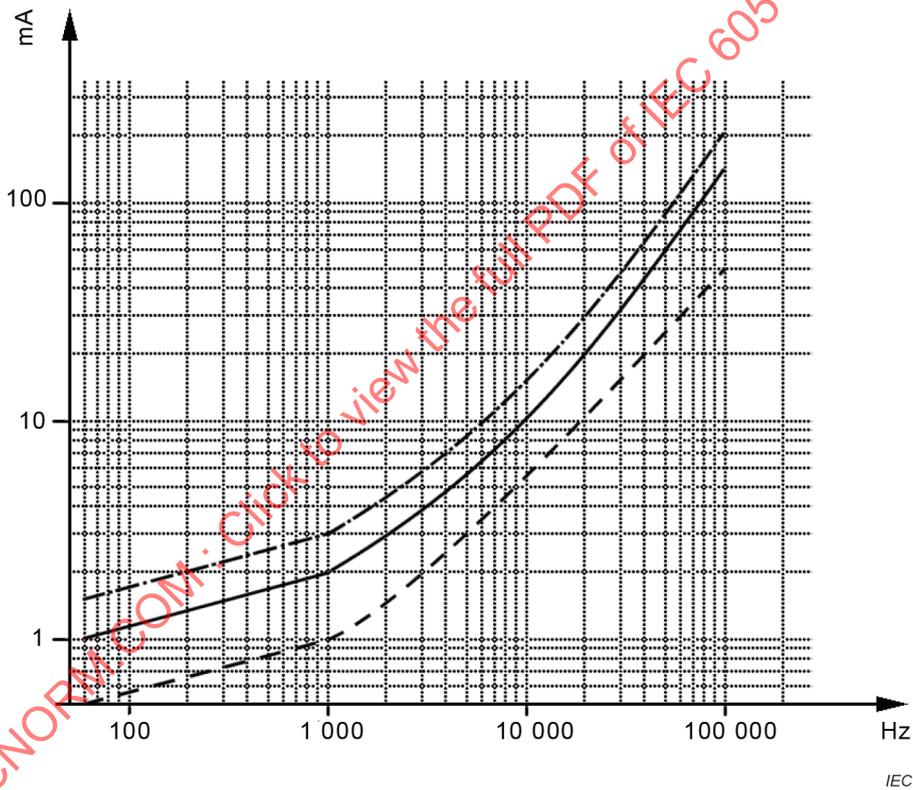
Annex B (normative)

Limits to touch currents

B.1 General

Hazards from **touch currents** are caused by currents flowing through the human body. The root cause of a **touch current** is a **touch voltage**, but a **touch voltage** is often not a sufficient indication for a hazard, as the ensuing current depends on the specifics of the creation of a **touch voltage** and eventual sustainment of a current when touched. Figure B.1 summarises the maximum permissible **touch currents** depending on the frequency of the electric field.

NOTE IEC TS 62996:2017 and IEC TS 60479-2:2017 provide the rationale and basics for these limits, and detailed information on effects on the human body depending on frequency of the field and the contact area.



Key

- (full line) I_{inadv} ; inadvertent touching causing aversion
- - - (dashes) I_{percep} ; approximate perception level in normal environments
- · - (dots/dashes) $I_{gripp} = 1,5 \times I_{inadv}$; gripping or between the feet

NOTE 1 The lines between 60 Hz and 1 kHz are for information purposes only. The graphs are projected between 60 Hz and 1 kHz, to show the connection to mains AC requirements in other standards and similar. IEC 61140:2016, 5.2.7 informs about the limit for perception and pain for DC and mains AC (50 Hz).

NOTE 2 No specifications are provided above 100 kHz, since local overheating (burns) is assumed to then be the determining electric shock mechanism, and thus additionally being dependent on tissue impedances.

Figure B.1 – Maximum allowed touch and contact currents between 1 kHz to 100 kHz

B.2 Risk classes

Table B.1 provides a risk classification based on the limits from Figure B.1 and includes a distinction between

- possible accidental touch of accessible surfaces – i.e. contacts that may or may not happen, with low to very low frequency and on a non-regular basis, and
- intended contacts – i.e. contacts that happen on a regular basis.

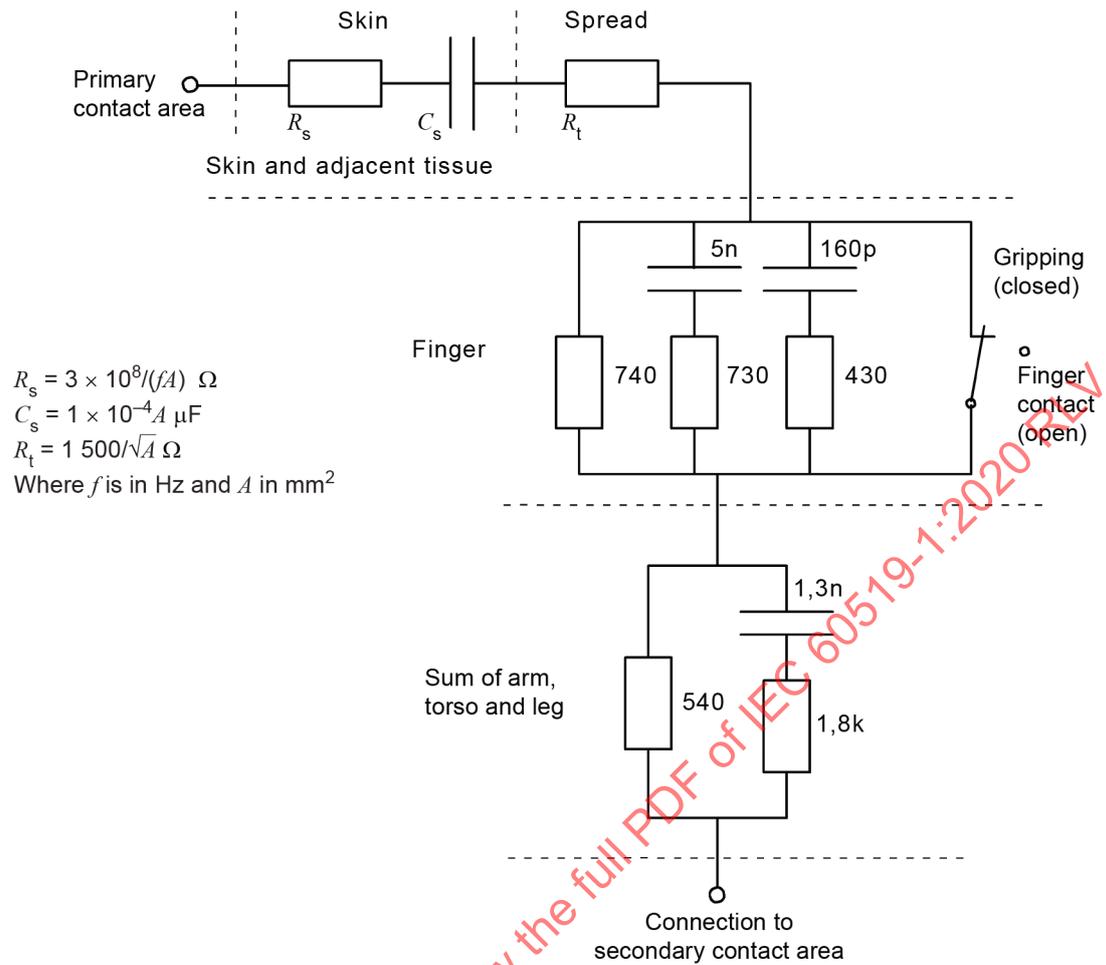
Intended contacts include gripping on rails and at elevated positions, for lifting or handling.

Table B.1 – Risk classification for hazards from touch currents

Risk class		Touch current		Restrictions and protective measures	Information and training
		accidental touching only	touch intended by the manufacturer or recurring		
0	Exempt	Not perceivable, no bodily reaction or hazard – i.e. a factor of 5 below the dashed line in Figure B.1		No restriction	No information needed
1	Low risk	Perceivable, but no other bodily reaction or hazard – i.e. a factor of 2 above the dashed line in Figure B.1		Restrictions 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	Below the dot-dashed line in Figure B.1	Below the full line in Figure B.1	Special restrictions and protective measures essential	Information about hazards, risks and secondary effects to be provided by the manufacturer . If specific training of the operator is deemed necessary by the manufacturer , he shall indicate this
3	High risk	Above the dot-dashed line in Figure B.1	Above the full line in Figure B.1	No access	Information about hazards, risks and secondary effects to be provided by the manufacturer

B.3 Body model

Figure B.2 provides an applicable model for impedances of body parts.



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IEC

Figure B.2 – Complex impedances of various parts of the body, 1 kHz to 6 MHz

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Annex C (normative)

Non coherent optical radiation – Limits and risk classes

C.1 General

Annex C provides a classification of **emission limits** and risk zones according to the general scheme of Table 3. This specific classification is provided in Table C.1.

Table C.1 – Risk classification for optical radiation (UV, VIS, IR)

Risk class		Laser class IEC 60825-1:2014	Restrictions and protective measures	Information and training
0	Exempt	1, 1M	No restriction	No information needed
1	Low risk	2, 2M	Restrictions 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	3R, 3B	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	4	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	4	No access	Information about hazards, risks and secondary effects to be provided by the manufacturer

NOTE 1 Annex C, as well as the consideration of optical radiation, is based on IEC 62471:2006. IEC 62471 is under revision and will be published as IEC 62471-1 in the future. The revision of IEC 62471 is quite substantial, affecting a change from an **exposure** viewpoint to an **emission** framework: this development is (i) in line with the revision of this document, and (ii) has been followed and included here.

NOTE 2 IEC 62471:2006 or the future IEC 62471-1 are the basic documents providing full guidance on all aspects relevant for a full understanding of optical radiation hazards, a more detailed risk assessment, or measurement of **emission**.

The **manufacturer** shall define the boundary of the **EH** or **EPM installation** or **equipment** with respect to the **emission** of radiation according to the rules in Clause C.2. He shall either make use of the **emission limits** defined in Clause C.3 or make his own risk assessment based on intended use. He shall inform the **user** about the used risk classification.

NOTE 3 The risk classes for **emission** provided in this document are based on simple worst case scenarios.

Annex C does not apply to radiation **emission** from lighting.

C.2 Boundary of the installation or equipment and assessment

Emission is defined outside a boundary enclosing the **EH** or **EPM equipment** or installation as defined by the **manufacturer**. This boundary shall be defined by the surface of the equipment, or any **barriers**, doors, etc., that hinder access.

In the absence of physical boundaries, the boundary is defined as the surface up to which an **operator** is intended to near the equipment in **normal operation** or **single fault condition**. Definition and a drawing of this boundary shall be provided to the **user**.

In case of an opening in a furnace, this boundary will be defined by the plane of the outer frame of the opening unless an **operator** is intended to get into this opening during **normal operation** or **single fault condition**.

C.3 Non-coherent optical radiation – Risk classes

C.3.1 Approach

The risk classes are worded in a two-stage approach:

- 1) a general requirement, defining the risk class and to be met always;
- 2) a detailed list being based on some worst case assumptions which shall be met unless the **manufacturer** shows otherwise that the general requirement is met.

C.3.2 Optical radiation – Risk class 0

The **EH** or **EPM installation** or **equipment** does not pose any photobiological hazard inside the zone of risk class 0. Other hazards or risk may still be applicable.

NOTE Persons can stay for any time inside this risk zone without being instructed or informed about hazards from optical radiation.

This is met either for the **EH** or **EPM installation** or **equipment**, or for each single source of **accessible emission** either if it does not emit any significant radiation between 200 nm and 3 000 nm at all or the following applies.

- 1) **Accessible emission** from thermal radiation is either caused by sources with a temperature below 275°C only or is caused by surfaces of higher temperature and smaller view factor (aperture).
- 2) No part of the emitted radiation is focused outside the boundary.
- 3) In case UV or plasma are part of the intended process, it does not generate any **emission** above 1 mW m⁻² in the S(λ) weighted wavelength band between 200 nm to 400 nm or any **emission** above 10 W m⁻² in the wavelength band between 315 nm to 400 nm outside the boundary.
- 4) It does not emit any radiation with a weak visual stimulus.

C.3.3 Risk class 1 (low risk)

The **EH** or **EPM installation** or **equipment** does not pose any photobiological hazard inside the zone of risk class 1 as long as normal behavioural reactions to the **emission** are upheld. Other hazards or risk may still be applicable.

Persons may stay for any time inside this risk zone. They need to be informed about risks arising from overriding their normal aversion reaction. The **user** shall be informed that any task involving an overriding of normal aversion reaction involves additional risks.

NOTE This includes long term monitoring of a process or a surface.

This is met either for the **EH** or **EPM installation** or **equipment**, or for each single source of **accessible emission** if the following applies.

- 1) **Accessible emission** from thermal radiation is either caused by surfaces with a temperature below 400 °C only or is caused from sources of higher temperature and smaller view factor (aperture).
- 2) No part of the emitted radiation is focused outside the boundary.

- 3) In case UV or plasma are part of the intended process, it does not generate any **emission** above 3 mW m^{-2} in the $S(\lambda)$ weighted wavelength band between 200 nm to 400 nm or any **emission** above 33 W m^{-2} in the wavelength band between 315 nm to 400 nm outside the boundary.
- 4) It does not emit any radiation with a weak visual stimulus.

C.3.4 Risk class 2 (moderate risk)

The **EH** or **EPM** installation or equipment does not pose any photobiological hazard inside the zone of risk class 2 as long as operators follow immediately their normal physiological aversion reaction to bright light or normal physiological aversion reaction caused by thermal discomfort.. Other hazards or risk may still be applicable.

The **manufacturer** shall advise the **user** that any intended action inside this zone is only possible with protective measures and that access restrictions are mandatory.

This is met either for the **EH** or **EPM installation** or **equipment**, or for each single source of **accessible emission** if the following applies.

- 1) **Accessible emission** from thermal radiation is either caused by surfaces with a temperature below 550 °C only or is caused from sources of higher temperature and smaller view factor (aperture), but not from surfaces exceeding $2\,500 \text{ °C}$.
- 2) No part of the emitted radiation is focused outside the boundary.
- 3) In case UV or plasma are part of the intended process, it does not generate any **emission** above 30 mW m^{-2} in the $S(\lambda)$ weighted wavelength band between 200 nm to 400 nm or any **emission** above 100 W m^{-2} in the wavelength band between 315 nm to 400 nm outside the boundary.
- 4) It does not emit any radiation with a weak visual stimulus.

C.3.5 Risk class 3 (high risk)

Any equipment that can pose a hazard even for momentary or brief **exposure** to **accessible emission**, or which exceeds the limits for risk class 2 (moderate risk), is classified in risk class 3 (high risk).

C.3.6 Pulsed equipment

For the definition of risk classes for **accessible emission** from pulsed sources covered by this document, 6.2 of IEC 62471:2006 applies accordingly.

C.3.7 Radiation from laser sources

Coherent non-ionising radiation is emitted from lasers. Table C.1 summarises the classification of equipment according to IEC 60825-1:2014 and connects it with the classification used in Clause 4.

Annex D (normative)

Electric and magnetic fields

D.1 General

Annex D provides a classification of limits on field strength, energy flux and risk zones according to the general scheme of Table 3.

The **manufacturer** shall define the boundary of the **EH** or **EPM installation** or **equipment** with respect to the generated electric and magnetic fields emitted by the **EH** or **EPM installation** or **equipment** according to the rules in Clause D.2. He shall either make use of the **emission limits** defined in Clause D.3 or make his own risk assessment based on intended use. He shall inform the **user** about the risk classification used.

NOTE Information about **exposure** limits is given in IEC TS 62996:2017 for electric fields and in IEC TS 62997:2017 for magnetic fields. The information is provided for the understanding of the rationale behind the **emission limits** provided and to enable assessment of **emission** in special cases not covered here, especially for the **near-field region**.

D.2 Boundary of the installation or equipment and assessment

Field strength and energy flux (**emission**) are defined and measured outside the boundary enclosing the **EH** or **EPM equipment** or **installation** as defined by the **manufacturer**. This boundary is defined by the surface of the equipment, or any **barriers**, doors, etc., that hinder access or other easily identifiable surfaces, such as **enclosures**.

In the absence of physical boundaries, the boundary is defined as the surface up to which an **operator** is intended to approach the equipment in **normal operation** or **single fault condition**. The definition and a drawing of this boundary shall be provided to the **user**.

In case of an opening in a furnace, this boundary will be defined by the plane of the outer frame of the opening unless an **operator** is intended to get into this opening during **normal operation** or in **single fault condition**.

All **accessible emission** is measured at a distance of 0,25 m from the accessible surfaces or openings of the **EH** or **EPM installation** or **equipment**, unless otherwise indicated, like surfaces intended to be touched or creating a field with high curvature. Then the **manufacturer** shall provide a risk assessment based on meaningful positions.

All measurements are to be averaged over a minimum time of 1 s for frequencies below 100 kHz and 6 min for frequencies above 100 kHz. Other integration limits may be applied for intermittent operation; the **manufacturer** shall inform the **user** about the integration time used.

Disturbance of the field shall be avoided or reduced to a minimum. Objects placed near the **EH** or **EPM installation** or **equipment** or near the measurement equipment, including personnel undertaking the measurement, are root causes of such disturbances.

D.3 Risk classes

D.3.1 General

The classification depends on the assessment of field strength and energy flux over the complete range of frequencies from 0,25 Hz to 300 GHz for each single location, where the highest single **emission** band defines the risk class. More than one source can contribute to the **emission** at any position.

NOTE The risk classes are based on possible worst case **exposure** from the **EH** or **EPM installation** or **equipment** in the zone.

D.3.2 Risk class 0

The **EH** or **EPM installation** or **equipment** does not pose any hazard from electric or magnetic fields or energy flux inside the zone of risk class 0. Other hazards or risk may still be applicable.

NOTE 1 Persons can stay for any time inside this risk zone without being instructed or informed about hazards caused by electric or magnetic fields.

This is met either for the installation or equipment or for each single source of **emission** if it does not exceed the maximum permissible **exposure** (MPE) limits for the general public, as defined in IEEE C95.6 for 0 Hz to 3 000 Hz and IEEE C95.1 for 3 kHz to 300 GHz.

NOTE 2 These standards define MPEs as undisturbed homogenous fields – no person in the field; thus the definition is identical to the definition of **accessible emission** as defined in this document.

NOTE 3 Local regulations can provide other limits.

D.3.3 Risk class 1 (low risk)

The **EH** or **EPM installation** or **equipment** does not pose any hazard from electric or magnetic fields or energy flux inside the zone of risk class 1, if the **operator** is instructed about residual risks and safe practices and procedures. Persons may stay for any time inside this risk zone. Other hazards or risk may still be applicable.

No separate limits to risk class 1 are identified in this document. The wearing of active implants is not advised in risk class 1 or higher.

The **manufacturer** can identify limits to risk class 1 depending on the specifics of the **accessible emission**.

D.3.4 Risk class 2 (moderate risk)

The **EH** or **EPM installation** or **equipment** does not pose any hazard from electric or magnetic fields or energy flux inside the zone of risk class 2, if the **operator** is instructed about residual risks, safe practices and procedures. Other hazards or risk may still be applicable.

This is met either for the installation or for equipment, or for each single source of **emission** if it does not exceed the maximum permissible **exposure** limits for controlled environment, as defined in IEEE C95.6 for 0 Hz to 3 000 Hz and IEEE C95.1 for 3 kHz to 300 GHz.

NOTE 1 These standards define MPEs as undisturbed homogenous fields – no person in the field; thus the definition is identical to the definition of **accessible emission** as defined in this document.

NOTE 2 Local regulations can provide other limits.

The **manufacturer** can identify other limits to risk class 2 depending on the specifics of the **accessible emission** and the field, as long as the basic requirement for risk class 2 is upheld.

D.3.5 Risk class 3 (high risk)

Any equipment that can pose a hazard even for momentary or brief **exposure**, or which exceeds the limits for risk class 2 (moderate risk), is classified in risk class 3 (high risk).

Annex E (normative)

Surface temperature limits

Annex E provides limits for surface temperatures that can be touched. Limits for accessible surfaces in **normal operation** are provided in Table E.1.

Surfaces that are accessible but exceed these limits in **normal operation** or **single fault condition** shall be marked with symbol IEC 60417-5041:2002-10.

These limits do not apply for surfaces that are heated by their environment to higher temperatures; such surfaces do not need to be marked.

ISO 13732:2006 provides information about the effects from prolonged contact.

Table E.1 – Surface temperature limits in normal operation

Part	Surface material ^a	Limit
enclosure including doors, windows, guards and screens, barriers and obstacles , not intended to be touched	metal, uncoated or anodised	65 °C
	metal, coated with paint or other	65 °C ^b
	plastic and wood	80 °C
	glass and ceramics	80 °C
	small segregated areas, not likely to be touched	100 °C
handles, knobs and other surfaces intended to be touched	metal	55 °C
	plastic and wood	70 °C
	glass and ceramics	65 °C
^a The major constituent, defining the heat transfer rate of the part.		
^b Higher temperature up to 80 °C is allowed when the thermal conductivity of the coating reduces heat transfer.		

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Annex F (normative)

EH, EPM and fire

F.1 Occurrence of fire

A fire hazard occurs if combustible materials and oxidizer in sufficient quantities are in contact with each other and sufficient energy to ignite them is available – refer to the fire tetrahedron depicted in Figure 2 of ISO 19353:2019.

It is the purpose of **EH** and **EPM installations** and **equipment** to transfer heat to a **workload** in **normal operation**. **Single fault conditions** may provide heat at any other position in or near the **EH** or **EPM installation** or **equipment**. Hot surfaces, intense optical radiation, arcs, plasmas, hot gases or liquids are a feature of and are to be expected near or inside **EH installations**. Plasma or static electrical discharges can occur in **EPM installations**. Plasmas, discharges and other electric phenomenon can provide extra energy thus lowering the flame point or lead to ignition. The **normal operation** of an **EH** or **EPM installation** or **equipment** can have the purpose to

- process flammable or combustible material,
- process flammable or combustible material in oxidising atmosphere, like air, and
- raise the temperature of the **workload** above the temperature, where spontaneous ignition of the **workload** is possible or happens.

Accidents can lead to heat or hot material being distributed inside or in the vicinity of the **EH** or **EPM installation** or **equipment**.

F.2 Inherently safe design measures

In all cases where two of the three elements of the fire triangle are part of the **normal operation** of the **EH** or **EPM installation** or **equipment** and any **single fault condition** can introduce the third factor, it is impossible to achieve an inherently safe design.

F.3 Safeguarding and/or complementary protective measures

ISO 19353:2019 provides the general methodology for reducing the risk of fire through safeguarding and/or complementary protective measures.

Any of the following measures, when applicable, reduces the risk of fire, as it minimises the effect from one **single fault condition**:

- a) all measures that prevent electric spark forming at the **workload** or inside the processing volume (see Clauses 7 and 8);
- b) physical separation between electric equipment and processing volume;
- c) limiting thermal energy of materials, parts, components and **workload** – low mass, low temperature, low specific heat capacity;
- d) avoiding non-homogenous heat transfer, especially small zones of very intense power.

The following measures, when applicable, minimise a fire or its spreading:

- e) limiting or minimising availability of air; minimising air flow; minimising physical space filled with air near the **workload**;
- f) providing separate compartments for different steps of processing.

F.4 Information for use

It is obvious, as stated above, that an **EH** or **EPM installation** or **equipment**, that heats potentially flammable material or processes potentially flammable material in oxidising atmosphere, is not inherently safe. Still the **manufacturer** in his own interest shall inform the **user** of fire hazards with respect to the combination of (i) air or oxidising material, (ii) heat or other sources of energy, and (iii) flammable or ignitable material. The **manufacturer** can limit the intended **workload** to that which poses a small or negligible fire risk and instruct the **user** about this.

Only the **user** is able to limit a fire hazard through good working practice like the following:

- a) including the risk of fire in his own risk assessment;
- b) processing intended **workload** only;
- c) applying extra caution, when the **workload** is flammable or can ignite – this includes monitoring the **EH** or **EPM installation** or **equipment** or position where the hazard is pronounced and extinguish the fire at the earliest stage before it creates a hazard;
- d) not stockpiling potentially combustible material near the **EH** or **EPM installation** or **equipment**; "near" is defined as can potentially be ignited either through heat from the **EH** or **EPM installation** or **equipment**, or from fire inside the **EH** or **EPM installation** or **equipment**, or from hot material expelled or flowing from the **EH** or **EPM installation** or **equipment**;

NOTE Heat can be transferred through fields, radiation, convection, conduction, mass flow; radiation and fields can be focused, thus exceeding hazardous limits only at a distance.

- e) cleaning and removing of potentially flammable material from the **EH** or **EPM installation** or **equipment** and its surrounding before it poses a hazard – including aggregation of material inside the **EH** or **EPM installation** or **equipment**;
- f) avoiding ignition through never exceeding **normal operation** and other applicable safe procedures; this includes understanding and safeguarding procedures against overheating, overfilling and other factors that can increase the hazard of fire;
- g) carefully observing the equipment during operation, and early identification of any **single fault condition** that can – if left alone – become a source for a hazard of fire;
- h) early and full maintenance as indicated by the **manufacturer**;
- i) avoiding leakage of potentially flammable substances at or near the **EH** or **EPM installation** or **equipment**;
- j) assuring that only **skilled** and **instructed persons** can operate the **EH** or **EPM installation** or **equipment**;
- k) providing sufficient distance to other equipment and installations to hinder spread of fire between them; this includes extra measures to safeguard installations from each other;
- l) providing sufficient measures for personnel to flee in case of fire.

The **manufacturer** shall instruct the **user** about this when applicable.

Annex G (normative)

Marking and warning

G.1 Electromagnetic field hazards

All areas where **exposure** to hazardous electric or magnetic fields is expected shall be marked when they are risk class 1, risk class 2 or risk class 3 as defined in Annex D or national regulations indicate. Examples of marking presented in Figure G.1 consist of graphical symbols registered in IEC 60417 (see Table G.1 for full reference) and text labels, which state the kind of field, the class and the reference.

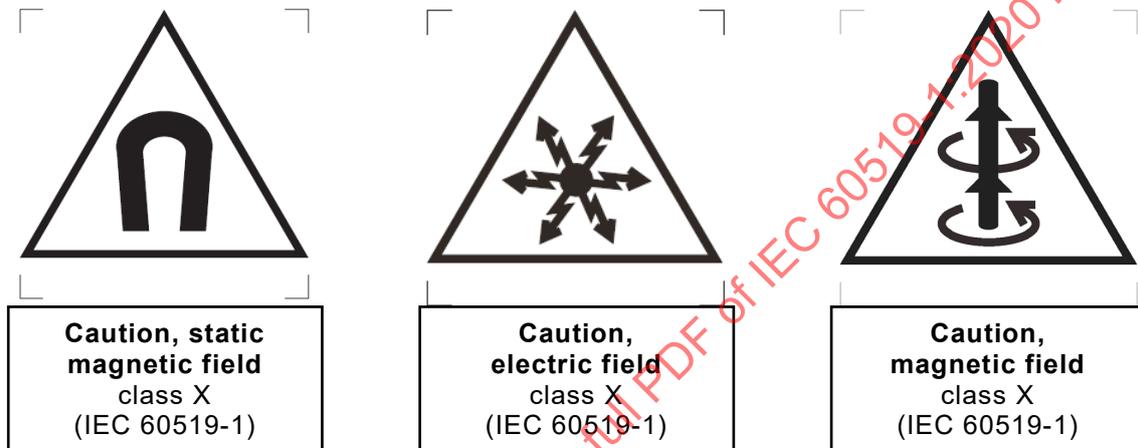


Figure G.1 – Examples of marking for magnetic and electric fields

G.2 Touch currents and surfaces

All surfaces where **exposure** to **touch currents** is expected shall be marked, when they are risk class 1, risk class 2, or risk class 3 as defined in Annex B. Examples of marking given in Figure G.2 consist of graphical symbols registered in IEC 60417 (see Table G.1 for full reference) and text labels, which state the kind of hazard, the class and the reference.

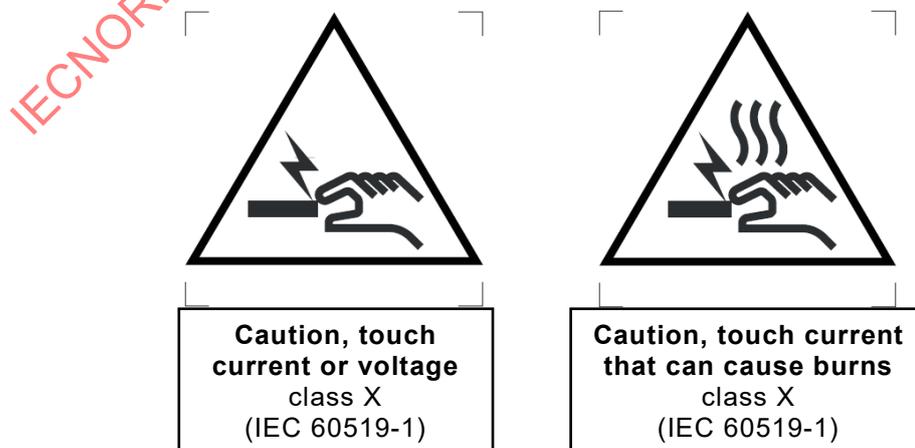


Figure G.2 – Examples of marking for touch current

G.3 Optical radiation hazards

All openings or areas where **exposure** to radiation is expected shall be marked, when they are risk class 1, risk class 2 or risk class 3 as defined in Annex C. Examples of marking given in Figure G.3 consist of graphical symbols registered in IEC 60417 (see Table G.1 for full reference) and text labels, which state the kind of hazard, the class and the reference.

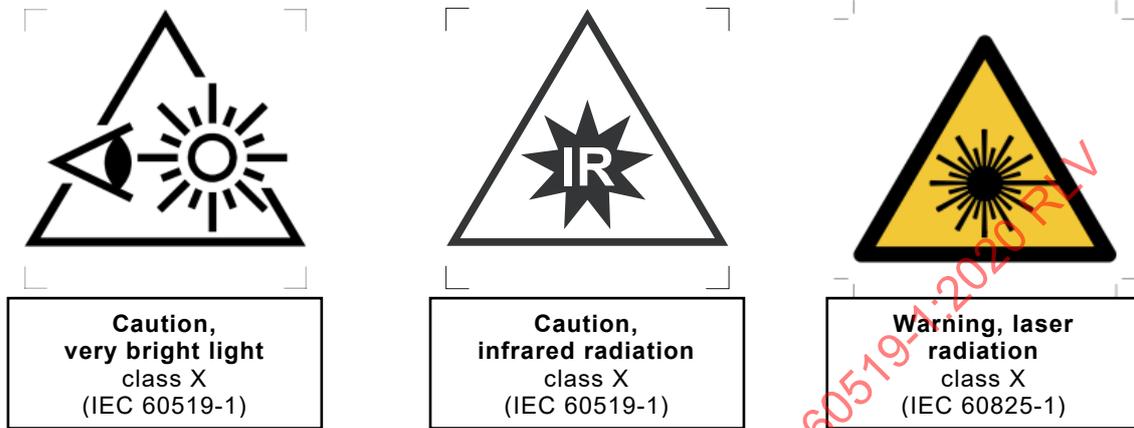


Figure G.3 – Examples of marking for optical radiation

G.4 Symbols and signs used for markings and warnings

Table G.1 provides examples of other symbols and signs applicable on **EH** and **EPM installation** or **equipment**. Applicable signs and symbols from IEC 60417, ISO 7000 or ISO 7010 shall be used to warn **operators**. Safety or warning signs and labels used on the **EH** and **EPM installation** or **equipment** shall be specified in the information for use according to 19.4.

Table G.1 – Examples of symbols and signs for use in EH or EPM installations

Symbol/sign	Reference	Description	Clause
	IEC 60417-5036:2002-10	Dangerous voltage	7
	IEC 60417-6042:2010-11	Caution, risk of electric shock	7
	IEC 60417-6204:2013-07	Caution, static magnetic field hazard	8
	IEC 60417-6205:2014-08	Caution, alternating magnetic nearfield hazard	8
	IEC 60417-6206:2013-07	Caution, electric field hazard	7, 8
	IEC 60417-6207:2013-07	Caution, touch current that can cause burns	7, 8
	IEC 60417-6208:2013-07	Caution, touch current or voltage	7, 8

Symbol/sign	Reference	Description	Clause
	IEC 60417-5019:2006-08	Protective earth; protective ground	7
	IEC 60417-6175:2012-11	Live working, unsuitable for hand-manipulation	7
	ISO 7010-P007:2011-05	No access for people with active implanted cardiac devices	8
	ISO 7010-P014:2011-05	No access for people with metallic implants	8
	ISO 7010-P008:2011-05	No metallic articles or watches	8
	IEC 60417-6166:2012-07	Caution, non-ionizing electromagnetic radiation ; Caution, microwave radiation	8, 9
	IEC 60417-6167:2012-07	Keep out of microwave radiation	8
	IEC 60417-6151:2012-02	Caution, infrared radiation	9
	IEC 60417-6069:2011-08	Caution, very bright light	9
	ISO 7010-W004:2011-05	Warning, laser radiation	9
	IEC 60417-5041:2002-10	Caution, hot surface	10
	IEC 60417-6056:2011-05	Caution, moving fan blades	6, 10, 15
	IEC 602417-6057:2011-05	Caution, moving parts	15
	IEC 60419-6182:2013-09	Installation, electrotechnical expertise	7, 19

Annex H (informative)

Guidelines on using this document

H.1 Guidelines

This document gives a large number of general requirements that can or cannot be applicable to a particular **EH** or **EPM installation** or **equipment**. A simple reference without any qualification to this document is therefore not sufficient. A **manufacturer** of an installation or equipment for which no Particular requirement exists, should use this document

- a) by selection of the most appropriate option(s) from the requirements given in the relevant clauses, and
- b) by modification of certain clauses, as necessary, where the Particular requirements for the installation or equipment are adequately covered by other relevant standards,

providing the options selected and the modifications made do not adversely affect the level of protection required for the installation.

When applying the principles listed above, it is recommended that

- reference be made to the relevant clauses and subclauses of this document that are complied with, indicating where relevant the applicable option,
- reference be made to the relevant clauses and subclauses of this document that have been modified or extended for the specific equipment requirements, and
- reference be made directly to the relevant standard, for those requirements for the **electrical equipment** that are adequately covered by that standard.

In all cases, expertise is essential to be able to

- read and understand all of the requirements of this document,
- choose the applicable requirements from this document where alternatives are given,
- identify alternative or additional Particular requirements that differ from the requirements of this document or are not included in the latter, and that are determined by the installation and its use,
- specify precisely those Particular requirements, and
- use this document for risk assessment purposes.

Figure 1 is a block diagram of a typical installation and can be used as the starting point of this task. The complementary Table 2 indicates the clauses and subclauses dealing with particular provisions or equipment. However, this document is a complex standard and Table 2 can help identify the application options for a particular installation or equipment and gives reference to other relevant standards. Further, Table 2 helps identify those requirements that are applicable and those that are not for a specific installation or equipment.

The primary responsibility of the **manufacturer** with respect to safety of **EH** or **EPM installation** or **equipment** is given in 6.1.1.

H.2 Examples of EH and EPM equipment

Typical industrial equipment in the scope of this document is used in installations with the possible use for

- direct resistance heating,
- indirect resistance heating,
- electric resistance trace heating,
- induction heating,
- using the effect of electromagnetic forces on materials for stirring or other processes,
- arc heating, including submerged arc heating,
- electroslag remelting,
- plasma heating and plasma surface treatment,
- microwave heating and microwave drying,
- dielectric heating and melting,
- processes using electron guns, like melting,
- infrared radiation heating,
- ultraviolet radiation treatment, and
- laser heating.

NOTE The list presents typical examples of applications and is not exhaustive.

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Annex I (informative)

Connection with ISO 13577 (all parts)

The ISO 13577 series of standards developed by ISO/TC 244 (Industrial furnaces and associated processing equipment) addresses the safety of all kinds of thermal processing equipment (TPE) and of industrial furnaces. These standards cover TPE using many kinds of fuels and electric energy for the generation and application of heat. The scope of ISO 13577 (all parts) and IEC 60519 (all parts) overlap in parts; therefore, Annex I provides guidance on how the scopes and their application are connected.

The **manufacturer** can derive his decision from his understanding of the TPE equipment: where any kind of fuel is the sole or basic source of heat, ISO 13577-1:2016 applies.

If the TPE is mainly a machine and involves **electroheating**, the general requirements are given from the application of ISO 13577-1:2016. At least all requirements addressing the electric heating then follow an application of this document.

If the **manufacturer** is designing an **EH** or **EPM installation** of **equipment** that is not a machine, this document is the applicable type C standard.

Both ISO 13577-1:2016 and this document are product safety publications and they cover all safety aspects of one or more products within the scope of a single product TC. Both standards reference each other where appropriate and in an unambiguous way. This document provides orientation and references to ISO 13577 (all parts) in Clause 4, Table 2 and throughout this document where indicated.

In the case a **manufacturer** uses ISO 13577-1:2016 as basic standard (type-C standard with respect to ISO 12100:2010), he will be referred to this document for requirements concerning electrical safety, **electroheating**, direct or indirect contact to **hazardous-live parts** and effects of electrical overload. It can then be possible to make use only of Clauses 7 and 8 as well as applicable parts of Clauses 13, 14 and 18 including the related annexes of this document.

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Annex J (informative)

Requirements specific to the EU and associated countries

J.1 General

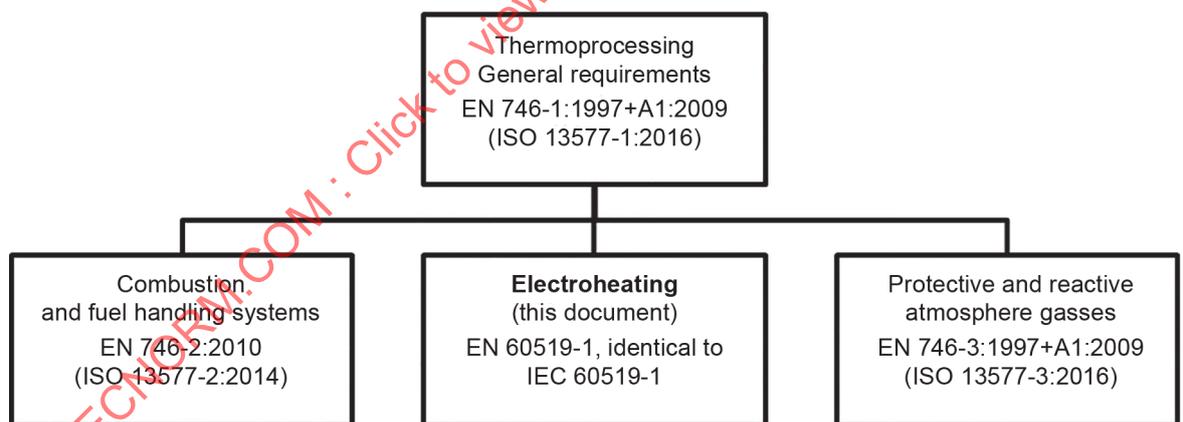
The specific regional requirements given in Annex J are applicable to the EU and associated countries. The requirements of Annex J shall ensure a level of safety at least equivalent to the main body of this document.

J.2 Connection with ISO 13577 series

This document conform with the safety objectives of the Directive 2014/35/EU (Low Voltage Directive) and shall be cited in the Official Journal of the EU (OJEU) under that directive in due time. This document generally conforms with the safety objectives of the Directive 2006/42/EC (Machinery Directive) as well, but is not intended to be published under this directive in the OJEU.

In case the **manufacturer** designs thermoprocessing equipment that is a machine and involves **electroheating**, the general requirements are given from the application of ISO 13577-1:2016. The Particular requirements then follow from a joint application of other parts of the ISO 13577 series and for all aspects connected to **electroheating** from this document. This connection is illustrated in Figure J.1.

NOTE A machine is defined in the Machinery Directive of the European Union 2006/42/EC as "an assembly, fitted with or intended to be fitted with a drive system other than directly applied human or animal effort, consisting of linked parts or components, at least one of which moves, and which are joined together for a specific application".



IEC

Figure J.1 – Hierarchy of standards applicable to thermoprocessing machinery

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IEC 60050-151, *International Electrotechnical Vocabulary – Part 151: Electrical and magnetic devices*

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IEC 60079 (all parts), *Explosive atmospheres*

~~IEC 60204 (all parts), *Safety of machinery – Electrical equipment of machines*~~

IEC 60335 (all parts), *Household and similar electrical appliances – Safety*

IEC ~~TS~~ 60479-1, *Effects of current on human beings and livestock – Part 1: General aspects*

IEC ~~TS~~ 60479-2, *Effects of current on human beings and livestock – Part 2: Special aspects*

~~IEC TR 60479-5, *Effects of current on human beings and livestock – Part 5: Touch voltage threshold values for physiological effects*~~

IEC 60519 (all parts), *Safety in installations for electroheating and electromagnetic processing*

IEC 60601 (all parts), *Medical electrical equipment*

IEC 60974 (all parts), *Arc welding equipment*

~~IEC TS 61000-1-2, *Electromagnetic compatibility (EMC) – Part 1-2: General – Methodology for the achievement of functional safety of electrical and electronic systems including equipment with regard to electromagnetic phenomena*~~

~~IEC TR 61000-3-7, *Electromagnetic compatibility (EMC) – Part 3-7: Limits – Assessment of emission limits for the connection of fluctuating installations to MV, HV and EHV power systems*~~

IEC 61010 (all parts), *Safety requirements for electrical equipment for measurement, control, and laboratory use*

IEC 61140:2001/2016, *Protection against electric shock – Common aspects for installation and equipment*

~~IEC 61140:2001/AMD1:2004~~

~~IEC TS 61201:2007, *Use of conventional touch voltage limits – Application guide*~~

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

IEC TR 62059-11:2002, *Electricity metering equipment – Dependability – Part 11: General concepts*

IEC 62226 (all parts), *Exposure to electric or magnetic fields in the low and intermediate frequency range – Methods for calculating the current density and internal electric field induced in the human body*

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

IEC 62311, *Assessment of electronic and electrical equipment related to human exposure restrictions for electromagnetic fields (0 Hz to 300 GHz)*

IEC TS 62996:2017, *Industrial electroheating and electromagnetic processing equipment – Requirements on touch currents, voltages and electric fields from 1 kHz to 6 MHz*

IEC TS 62997:2017, *Industrial electroheating and electromagnetic processing equipment – Evaluation of hazards caused by magnetic nearfields from 1 Hz to 6 MHz*

IEC Guide 104:2019, *The preparation of safety publications and the use of basic safety publications and group safety publications*

~~IEC Guide 117, Electrotechnical equipment – Temperatures of touchable hot surfaces~~

~~ISO 1999:2013, Acoustics – Estimation of noise-induced hearing loss~~

~~ISO 2631-1:1997, Mechanical vibration and shock – Evaluation of human exposure to whole-body vibration – Part 1: General requirements~~

~~ISO 5349-1:2001, Mechanical vibration – Measurement and evaluation of human exposure to hand-transmitted vibration – Part 1: General requirements~~

~~ISO 7010, Graphical symbols – Safety colours and safety signs – Registered safety signs~~

~~ISO 13577-4, Industrial furnace and associated processing equipment – Safety – Part 4: Protective systems~~

~~ISO 15265:2004, Ergonomics of the thermal environment – Risk assessment strategy for the prevention of stress or discomfort in thermal working conditions~~

~~EN 50413, Basic standard on measurement and calculation procedures for human exposure to electric, magnetic and electromagnetic fields (0 Hz – 300 GHz)~~

~~EN 50445:2008, Product family standard to demonstrate compliance of equipment for resistance welding, arc welding and allied processes with the basic restrictions related to human exposure to electromagnetic fields (0 Hz – 300 GHz)~~

~~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 radio frequency electromagnetic fields, 0–3 kHz~~

~~Council Directive 96/29/EURATOM of 13 May 1996 laying down basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionizing radiation —
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~~arising from physical agents (vibration)–~~

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EN 746-1:1997/AMD1:2009

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EN 746-3:1997, *Industrial thermoprocessing equipment – Part 3: Safety requirements for the generation and use of atmosphere gases*
EN 746-3:1997/AMD1:2009

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EN 1547:2001/AMD1:2009

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IEEE 1597.2-2010, *IEEE Recommended Practice for Validation of Computational Electromagnetics Computer Modeling and Simulations*

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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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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

FOREWORD

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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.

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

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

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.

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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 60071-1:2006¹, *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 61936-1:2010⁷, *Power installations exceeding 1 kV a.c. – Part 1: Common rules*
IEC 61936-1:2010/AMD1:2014

IEC 62061:2005⁸, *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**.

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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	Burn, bodypart heating
High frequency	> 100 kHz to 0,3 GHz	> 100 kHz to 6 MHz	
		> 6 MHz to 0,3 GHz	
Microwave	> 0,3 GHz to 300 GHz		Bodypart heating
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	
Visible	400 nm to 780 nm		Burn of skin and cornea, burn of retina
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

- a) depending on the supply and the output voltage, whichever is the higher value (internal voltages inside the **electrical equipment** may be higher), but
- b) 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**.

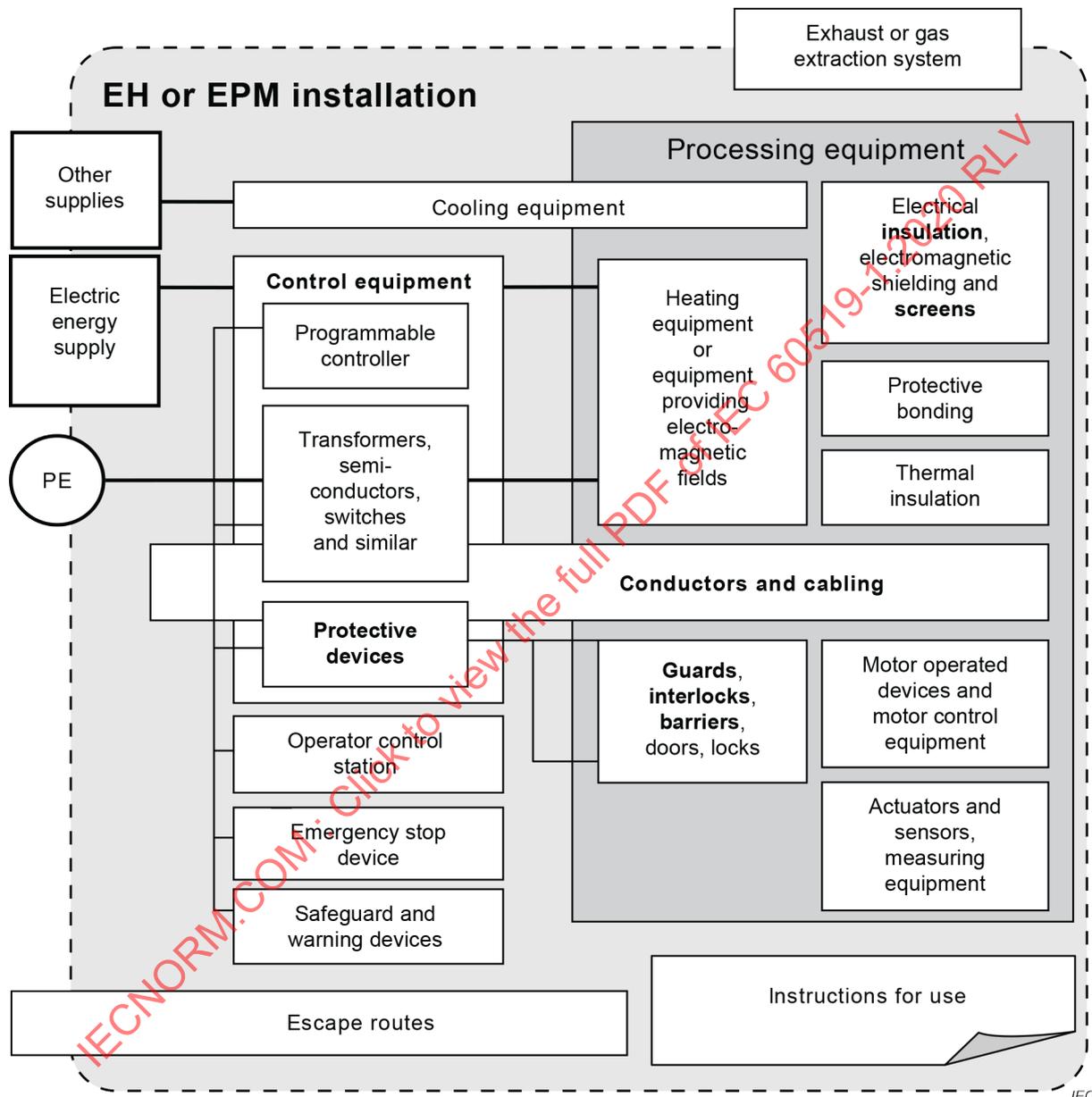


Figure 1 – Block diagram of a typical EH or EPM installation

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 duration

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 $\mu\text{Sv/h}$ 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**.

12.1.2 ISO 13577-2:2014 applies for combustion and fuel handling systems; ISO 13577-3:2016 applies for protective and reactive atmospheres if applicable. For all other fluid systems, the provisions 12.1.3 through 12.1.9 apply.

12.1.3 If, in **normal operation** or **single fault condition**, fluid is likely to be spilt into the **EH** or **EPM installation** or **equipment**,

- a) it shall be designed so that no hazard is possible – for example as a result of the wetting of **insulation** or of internal **hazardous-live parts**,
- b) no corrosion leading to a hazard shall be possible – for example as a result of the contact of potentially aggressive substances with parts likely to be damaged, and
- c) suitable means able to collect or divert the spill shall be positioned.

NOTE Fluids or spills can be regulated with respect to environmental hazards; this can affect the means taken.

If in **normal operation** or **single fault condition**, potentially aggressive substances (such as corrosive, toxic or flammable liquids) are likely to be spilt on parts of the **EH** or **EPM installation** or **equipment**, the possibly affected surfaces shall be made from material not affected by the aggressive substance.

12.1.4 The maximum pressure to which a part of the **EH** or **EPM installation** or **equipment** can be subjected in **normal operation** or **single fault condition** shall not exceed the rated maximum working pressure for the part. The maximum pressure shall be considered to be the highest of the following:

- a) the rated maximum supply pressure specified for an external source;
- b) the pressure setting of an overpressure safety device provided as part of the assembly;
- c) the maximum pressure that can be developed by a pressure generating device that is part of the assembly, unless the pressure is limited by an overpressure safety device.

12.1.5 Fluid-containing parts shall not cause a hazard through rupture or leakage. No intended leakage is allowed from fluid-containing parts intended for toxic, flammable, or otherwise hazardous substances.

12.1.6 Fluid-containing parts of refrigeration systems shall meet the relevant pressure-related requirements of IEC 60335-2-24 or IEC 60335-2-89 as applicable.

12.1.7 Leakage from or into fluid-containing parts at pressures lower than ambient shall not cause a hazard.

12.1.8 Liquid overflowing from any container in the equipment which can be overfilled shall not cause a hazard during **normal operation**, for example as a result of the wetting of **insulation** or of internal parts that are hazardous-live.

Equipment likely to be moved while a container is full of liquid shall be protected against liquid surging out of the container.

12.1.9 Any cleaning, decontamination or disinfection process indicated by the **manufacturer** shall not cause degradation of the equipment or any foreseeable hazard.

12.2 Poisonous and injurious fluids

12.2.1 The **EH** or **EPM installation** or **equipment** shall not liberate hazardous amounts of poisonous or injurious fluids in **normal operation**, or create a hazard in **single fault condition**.

12.2.2 If such fluids are likely to be liberated, they shall be drawn into an extraction system.

12.2.3 If a flow of fluids or particulate matter can pose a hazard due to their temperature or impulse, it shall be diverted from the installation and from the **operator**.

12.2.4 Hazard zones shall be marked and a **barrier** or **obstacle** shall limit accessibility.

12.2.5 **EH** or **EPM installation** or **equipment** drawing in air for any purposes shall not draw in exhaust gas unless necessary for the process or for energy efficiency needs.

12.2.6 The **manufacturer** shall indicate necessary personal protective equipment for such substances or gases that can be liberated during **normal operation** or **single fault condition**.

12.3 Explosion and implosion of pressurised parts or vacuum equipment

12.3.1 Pressurised parts of the **EH** or **EPM installation** or **equipment** including **vacuum** equipment shall be designed to **sustain normal** operation and **single fault conditions** over the intended lifetime.

NOTE ISO 16528-1:2007 can be used unless different national or regional regulations apply.

12.3.2 Components liable to burst, implode or explode if overheated, overcharged, or in other **single fault condition** shall be provided with a pressure release device.

12.3.3 Protection of **operators** by **enclosures** shall be incorporated in the **EH** or **EPM installation** or **equipment** to protect them from debris or expelled parts.

12.3.4 The effect of sudden boiling of liquids at pressure loss and resulting hazards, like spill, explosion, burn and scald shall be taken into account.

13 Specific requirements for components and subassemblies

13.1 General

All components and devices of the **EH** or **EPM installation** or **equipment**

- a) shall be suitable for their intended use,
- b) shall conform to relevant IEC or ISO standards where such exist, and
- c) shall be applied in accordance with their information for use.

13.2 Electrical equipment and conductors

13.2.1 The **electrical equipment** of the **EH** or **EPM installation** or **equipment** shall satisfy the safety requirements identified by the **manufacturer**.

Depending upon the **EH** or **EPM installation** or **equipment**, its intended use and its **electrical equipment**, the designer may select parts of the **electrical equipment** of the installation that are for LV in compliance with relevant parts of the IEC 61439 series and for HV parts in compliance with relevant parts of the IEC 62271 series – see also Annex F of IEC 60204-1:2016.

NOTE IEC 61439 (all parts) specifies requirements for equipment covering a wide range of possible applications of LV switchgear and controlgear assemblies. IEC 62271 (all parts) specifies requirements for equipment covering a wide range of possible applications of HV switchgear and controlgear assemblies.

13.2.2 The dimensioning of electrical conductors depending on maximum current and temperature shall follow IEC 60228:2004 for intended temperatures of the conductors up to 40 °C. Clause 11 of IEC 60335-1:2010 and IEC 60335-1:2010/AMD1:2013 provides calculation methods and tests for assessing the maximum temperature of electric conductors at a temperature exceeding 40 °C and shall be used when applicable.

13.2.3 The proximity and the skin effect shall be taken into account when dimensioning conductors for higher frequencies.

NOTE The penetration depth of the current decreases with increasing frequency. This affects cross sectional area of the conductor and surface to volume ratio. Thus tables of cable current-carrying values relevant for mains frequency (50 Hz/60 Hz) are generally not applicable for installations working at higher frequencies.

13.3 Connection to the electrical supply network and internal connections

13.3.1 The connection to the electrical supply network depends on the type and the voltage of the supply system according to 312 of IEC 60364-1:2005. The conductors shall be in accordance with Clause 12 of IEC 60204-1:2016 for LV and in accordance with Clause 13 of IEC 60204-11:2018 for HV. The conductors shall be identified according to IEC 60445.

13.3.2 The incoming supply conductor shall be in accordance with 5.1 of IEC 60204-1:2016 for LV connection or in accordance with 5.1 of IEC 60204-11:2018 for HV connection.

13.3.3 Interconnecting conductors shall be designed and arranged so that they do not undergo abnormal mechanical stresses in **normal operation**, for example due to bending, tension, flexing, torsion, friction or vibration, or effects of radiation, heat, moisture or vapours liable to damage them. **Single fault condition** shall be considered as well.

13.3.4 Enclosures of conductors shall ensure

- protection of **insulation** of conductors against abrasion and laceration, and
- protection of conductors against tension and torsion.

Enclosures and devices adopted to avoid tensile stress in fixed electrical connections shall not be hazardous-live. They shall also be so designed that any damage of the conductor to be protected from abnormal tensile stresses is prevented.

13.3.5 EH or EPM installation or equipment, or parts of it, which are not permanently connected to the supply network shall meet the following requirements:

- a) it shall have a permanent fixed flexible connecting conductor which can only be removed with the use of a tool;
- b) connections using a sliding contact shall be inaccessible when connected and when disconnected but live;
- c) **live parts** of plug-and-socket devices shall be inaccessible when connected and when disconnected but live;
- d) removable connecting lines shall contain the necessary active and protective conductors clearly identified and laid-up together;
- e) when several plugs are used, an erroneous connection shall be prevented by shape or distinct marking of the plugs.

13.3.6 All flexible wiring shall meet the following requirements:

- a) it shall be provided with protective sheaths; measures taken to ensure protection against tensile stress and torsion shall be readily recognizable;
- b) it shall be protected against excessive flexing at the points of entry; protective sheathing shall be sufficiently long to avoid any damage through bending;
- c) it shall be fixed securely or other means shall avoid any hazard through their position in or near the installation.

13.3.7 All conductors internally or externally cooled with a liquid coolant, and where the coolant circuit is part of the conductor, shall

- a) at least meet the requirements of Clause 12 with respect to the coolant circuit, and

b) be designed such that **leakage currents** do not cause a hazard.

NOTE Some coolants, like water, are conductive or can become conductive; their use can lead to **leakage currents**.

13.4 Isolation and switching

13.4.1 Isolation, switching-off for maintenance, and functional switching shall be provided and be in accordance with the applicable standards, IEC 60204-1 for LV and IEC 60204-11 for HV respectively, or IEC 60364-4-41 and IEC 60364-5-53, when applicable.

13.4.2 Examples of control and auxiliary circuits which, depending on the application, need not to be switched off, are:

- a) lighting and socket-outlet circuits for the connection of repair and maintenance tools, for example lamps or drills (irrespective of their voltage);
- b) circuits supplying under-voltage trips and circuit-breaker closing and tripping devices which are operated at mains voltage, but are not used for control purposes;
- c) auxiliary circuits with ELV;
- d) other auxiliary circuits supplying essential components, for example pumps, fans and drives, as well as cooling equipment, which shall not be switched off during the period of interruption of the mains supply;
- e) uninterruptable power supply circuits providing power to equipment for safety control, computer, human machine interfaces, or closed control TV.

In the case of LV or HV, the circuits mentioned in a) to e) above shall employ cables or insulated conductors segregated from those following the supply disconnecting switch. They shall be connected via separate specially enclosed terminals and shall be provided with a separate disconnecting switch.

In the case specified under item b), this disconnecting switch may not be applied. The circuits, which are not disconnected by the supply-disconnecting switch, shall be clearly indicated in the technical documentation and may be indicated on the equipment.

13.4.3 Switching of direct current or mains frequency currents at HV through the use of circuit breakers is permissible for supply, disconnection and isolation, providing the following conditions exist:

- a) an isolating distance is provided and visible – for example a disconnecting switch or a withdrawn circuit-breaker;
- b) facilities are provided to prevent closing of the isolating switches and providing connection to earth of the outgoing cables or busbars.

13.5 Sensors and actuators safeguarding moving parts

ISO 13855 applies.

13.6 Motors

Clauses 14 and 18 of IEC 60204-1:2016 for LV and Clauses 15 and 19 of IEC 60204-11:2018 for HV installations or equipment apply.

13.7 Non electric-heating means

Combustion based heating means shall conform to ISO 13577-2.

13.8 Lighting

13.8.1 If the ambient lighting is not sufficient to prevent risks – for example areas of shadow or dazzle exist – the **EH** or **EPM installation** or **equipment** shall be designed with integrated lighting. Parts requiring frequent maintenance, inspection or adjustment and not illuminated sufficiently by the ambient light shall be provided with integrated lighting.

13.8.2 The **EH** or **EPM installation** or **equipment** shall be designed and constructed so that there is no area of shadow likely to cause nuisance, that there is no irritating dazzle and that there are no dangerous stroboscopic effects due to the lighting or moving parts.

13.9 Structural parts and stability

13.9.1 The **EH** or **EPM installation** or **equipment** and all its parts shall be sufficiently stable to avoid break-up or collapse during **normal operation** or **single fault condition**.

13.9.2 The **EH** or **EPM installation** or **equipment** shall be sufficiently designed or anchored to avoid tripping, overturning, falling or any uncontrolled movements during **normal operation** or **single fault condition**.

13.9.3 Design of the structural parts or foundations of the **EH** or **EPM installation** or **equipment** shall not generate hazards, for example through the possibility of trapping of the **operator** in **normal operation** or **single fault condition**. This includes hazards from spilled fluids.

13.10 Doors, windows and other openings

13.10.1 Subclauses 11.4 and 11.5 of IEC 60204-1:2016 apply.

13.10.2 Means of access shall be secured by an **interlock**, where the **interlock** eliminates the hazard immediately. Hazards that are not eliminated immediately shall only be accessible by the use of a tool.

Means of access shall be fitted with marking and warning as defined in Annex G.

13.11 Transformers, inductors, capacitors

13.11.1 Refer to 13.1. Subclause 7.2.7 of IEC 60204-1:2016 and 7.2.4 of 60204-11:2018 apply. A **thermal cut-out** shall operate, if over-currents in the secondary circuit of transformers can cause overheating of the winding.

13.11.2 Energy stored in capacitors and inductive components shall be released or discharged safely in **normal operation** or **single fault condition**.

13.11.3 Safe working procedures, methods to safely discharge prior to maintenance or in case of emergency as well as any residual hazards shall be indicated to the **user** of the equipment.

13.12 Handheld applicators

13.12.1 The start of **normal operation** of a **handheld applicator** shall be through the sequential activation of a start switch and an operation switch. The switches shall be located at such a distance from each other that simultaneous activation by a single hand is not possible.

Both switches shall be biased-off switches, i.e. switches that automatically return to the off position when their actuating member is released. The start switch enables the operation switch and the operation switch enables **normal operation**.

The **handheld applicator** shall indicate its operation to the **operator** through a signal lamp or comparable means.

13.12.2 In case operation of the **handheld applicator** generates a hazardous field when lifted off a **workload** surface, it shall have an **interlock** that deactivates operation when it is removed from the **workload**.

13.12.3 Screens or **barriers** shall prevent the placement of hands or other bodyparts near the active part of the **handheld applicator** if it emits hazardous fields.

Such **screens** or **barriers** shall only be removable with a tool; their mechanical stability shall be sufficient in consideration of their expected handling by the **operator**.

13.12.4 An applicable warning as defined in Annex G for the type of field shall be affixed and visible near the active part of the **handheld applicator**.

13.13 Vacuum system

Arcing inside a **vacuum** system shall not create a hazard.

13.14 Protective and reactive gas generator

In case the **EH** or **EPM installation** or equipment includes a generator for protective or reactive gases, Clause 11 of this document and ISO 13577-3:2016 apply.

14 Control of the installation or equipment

14.1 General

The need for **operator** intervention shall be limited. If intervention is necessary, it shall be conducted safely and with ease.

Subclauses 14.2 through 14.7 define requirements based on this general concept.

NOTE The decision to use functional safety concepts is beyond the scope of this document. ISO 13577-4:2014 provides an illustration, when the application of IEC 61508-1:2010 or ISO 13849-1:2015 becomes necessary.

14.2 Operator control unit

14.2.1 Any **operator** control unit shall be

- a) clearly visible and identifiable, using standardised symbols where appropriate,
- b) positioned in such a way as to be safely operated without hesitation or loss of time and without ambiguity,
- c) located outside a hazard zone – the sole exception being emergency stops, and
- d) positioned in such a way that the operation cannot cause additional risks.

14.2.2 Any **operator** control unit or the control system with **EH** or **EPM installations** or **equipment** with defined hazard zones shall

- a) be positioned in a way that enables the **operator** to ensure that no one is inside a hazard zone,
- b) give acoustic, visual or a combination of both warnings before the installation is started, and
- c) assist the **operator** to assure that starting is prevented while someone is inside a hazard zone.

Persons inside a hazard zone or otherwise potentially being exposed to any hazard shall have sufficient time to leave the hazard zone or prevent starting.

NOTE In large installations the **operator** may not be able to see all hazard zones.

14.2.3 The provisions of Clause 10 of IEC 60204-1:2016 for LV and those of Clause 10 of IEC 60204-11:2018 for HV installations or equipment for **operator** control units and **operator-machine** interfaces apply.

14.2.4 If there is more than one **operator** control unit, the control system shall assure that the use of one of them precludes the use of the others, except for emergency stops; the use of stop controls may be kept. Each **operator** control unit shall be provided with all the required control devices without the **operators** hindering or putting each other into a hazardous situation. For details, refer to 9.2.3 of IEC 60204-1:2016. Each unit shall be provided with controls to stop some or all of the functions of the equipment or installation, depending on the relevant hazards, so that safety is ensured during and after the stop.

14.2.5 Any **operator** control unit shall be designed or protected in such a way that the desired effect, where a hazard is involved,

- a) can only be achieved by a deliberate action, and
- b) is manufactured to withstand foreseeable forces.

Particular attention shall be paid to emergency stop devices as these are liable to be subjected to considerable forces in case of an emergency.

14.3 Emergency stop

14.3.1 Emergency stop devices shall be in accordance with 10.7 of IEC 60204-1:2016.

14.3.2 All emergency stop devices shall be clearly identifiable, clearly visible and quickly accessible.

14.3.3 Once the active operation of an emergency stop has ceased following a stop or switching off command, the effect of this command shall be sustained until it is reset. This reset shall be possible only by a manual action at the device where the command has been initiated. The reset of the command shall not restart the equipment but only permit restarting.

14.3.4 The emergency stop signal shall stop the hazardous process as quickly as possible, without creating additional risks. It can trigger or permit the triggering of safeguarding actions. The emergency stop function shall be available and operational at all times, regardless of the operating mode. Emergency stop devices shall be a back-up to other safeguarding measures; they shall not be a substitute for them.

14.3.5 The sequence of emergency stopping operations (e.g. fan and conveyor motors in relation to main processing circuits) shall be taken into account by the **manufacturer** during design and shall be specified in the information for use.

14.4 Control systems and their safety functions

14.4.1 Control systems shall be designed and constructed in such a way as to minimise the occurrence of hazardous situations with the aim of achieving adequate reduction of risks, or prevent hazardous situations. In particular, they shall be designed and constructed in such a way that

- they can withstand the intended operating stresses and external influences,
- a fault in the hardware or the software of the control system does not lead to hazardous situations,
- errors in the control system logic do not lead to hazardous situations, and

- reasonably foreseeable human error during operation does not lead to hazardous situations.

It is not always possible to fully avoid all hazards; in this case, an adequate reduction of risks shall be reached and documented by the **manufacturer**.

NOTE Adequate risk reduction can be reached through suitable functional safety as defined in IEC 61508-1:2010 or ISO 13849-1:2015.

14.4.2 Start functions shall be initiated by a start button. Start functions shall initiate the energizing of the relevant circuit. Start shall not be automatic if this can create a hazard. In case push buttons are used, separate push-buttons for "Start" and "Stop" shall be provided.

14.4.3 Interlocks shall be provided to secure correct sequential starting.

14.4.4 Stop functions shall override related start functions. The installation shall not be prevented from stopping if a stop signal has been given. Where more than one control station is provided, the stop command from any control station shall be effective.

14.4.5 For operating modes, 9.2.3 of IEC 60204-1:2016 applies with the addition that "motion" shall include "heating" and "processing".

14.4.6 For suspension of safety functions or protective measures, 9.3.6 of IEC 60204-1:2016 applies.

14.4.7 For cableless control system, 9.2.4 of IEC 60204-1:2016 applies.

14.4.8 For emergency operations, 9.2.3.4 of IEC 60204-1:2016 applies.

14.4.9 For control functions in the event of failure, 9.4 of IEC 60204-1:2016 applies.

14.5 Controlgear

14.5.1 Sensors and actuators shall be selected and mounted taking into account all conditions during **normal operation** and foreseeable **single fault condition** – for example temperature, mechanical action or electromagnetic phenomena.

14.5.2 Actuators shall be in accordance with 10.2 of IEC 60204-1:2016.

14.5.3 Indicator lights and displays shall be in accordance with 10.3 of IEC 60204-1:2016.

14.5.4 Control circuits shall comply with 9.1 of IEC 60204-1:2016.

14.5.5 When photocouplers are used as a means of **galvanic separation**, for example in semi-conductor converters, clearance and creepage distances shall be specified as minimum values according to

- IEC 60071-1:2006 and IEC 60071-1:2006/AMD1:2010 for the upstream or power network side, and
- IEC 60664-1:2007 for the downstream or converter side.

14.5.6 An earth fault on any control circuit operating below 200 Hz shall neither cause inadvertent switching on nor prevent switching off.

- In order to fulfil this requirement, it is recommended that one side of the control transformer(s) be earthed and coils and contacts be connected accordingly. Unearthed control circuits fed from the transformer shall be provided with an **insulation-monitoring** device, which either indicates an earth fault or interrupts the circuit automatically after an

earth fault. The direct current internal resistance of the **insulation**-monitoring device shall be at least 50 kΩ. For certain electronic devices, much higher values of this resistance may be necessary.

- b) In the case of control transformers with an earthed centre tap, a differential current circuit-breaker shall be used.
- c) For control circuits in which single-pole earthing is required for operational reasons, the **manufacturer** shall provide for earthing. Such operational reasons can be, for example the use of electromagnetic clutches having an internal earth or of control circuits with electronic components. In this case, separate control transformers or one control transformer with several isolated secondary windings shall be used.

14.5.7 In case of earthed control circuit supplies, refer to Figure 7 and 9.4.3.1 of IEC 60204-1:2016.

14.6 Protective devices

14.6.1 Protective devices including **interlocks** protecting an **operator** from a hazard shall prevent the **operator** from being exposed to the hazard before the hazard is removed. It shall meet the following requirements specified in 14.6.2 to 14.6.7.

14.6.2 Protective devices shall not obstruct the **normal operation** or the view onto the **EH** or **EPM installation** or **equipment** as being necessary for safe operation.

14.6.3 Only after the action has been reversed or cancelled, which caused the **protective device** to give a stop command, shall the **protective device** and thus the **EH** or **EPM installation** or **equipment** be reactivated by means of an intentional action.

14.6.4 Protective devices for the protection of an **operator** shall be designed such that a fault in the **protective device** cannot cause a hazard – i.e. any fault of the **protective device** is a fault to safety. In most cases, this implies that any **protective device** shall give a stop command if it is not fully effective.

14.6.5 Protective devices shall not easily be bypassed or made non-operational.

NOTE "Easily" implies without the use of a tool.

14.6.6 Protective devices reacting in case of any short-circuit shall be adequately sized for the switching elements in the control circuits.

14.6.7 Adjustable **protective devices** and systems shall be adjustable only with the use of a tool or be protected by a password.

14.6.8 Normal operation includes the correct setting of any adjustable **protective device**. Incorrect setting of a **protective device** is a **single fault condition**.

14.7 Over-temperature protection devices and systems

Over-temperature **protective devices** and systems designed to operate in **single fault condition** shall be

- a) designed and tested to ensure reliable function, and
- b) rated so that components or materials whose temperatures are intended to be limited by the device do not exceed the relevant temperature limits of Clause 10 or other defined limits.

Over-temperature **protective devices** shall be separated from any temperature control system. This applies not only to the temperature sensing means but also to all disconnecting devices in the circuits to be de-energised.

14.8 Overpressure safety device

An overpressure safety device shall not react or release in **normal operation**. It shall conform to the following requirements.

- a) It shall be connected as close as possible to the fluid-containing parts of the system that it is intended to protect.
- b) It shall be installed so as to provide easy access for inspection, maintenance and repair.
- c) It shall not be capable of being adjusted without the use of a tool.
- d) It shall be located so that a discharge does not cause hazard to **operators**; especially it shall have its discharge opening so located and directed that the released material is not directed towards the **operator**.
- e) The **EH** or **EPM installation** or **equipment** shall be designed such that no pressure release device is obstructed.
- f) It shall have its discharge opening located and any discharge directed so that operation of the device does not deposit material on parts, if that could cause a hazard.
- g) It shall have adequate discharge capacity to ensure that the pressure cannot exceed the rated maximum working pressure of the system.
- h) There shall be no shut-off valve between an overpressure safety device and the parts that it is intended to protect.

15 Protection against mechanical hazards

15.1 With respect to mechanical hazards, the **manufacturer** shall refer to ISO 13577-1:2016, if applicable. In all other cases, the requirements 15.2 through 15.11 apply.

15.2 No accessible part of the **EH** or **EPM installation** or **equipment** shall have rough surfaces, sharp edges or angles posing a hazard.

15.3 Any moving part that poses a hazard shall be prevented from becoming a risk through **guards** or **protective devices**. ISO 14120:2015 applies for design and construction, assuring the mechanical stability of **guards**.

15.4 Sufficient precautions shall be implemented to prevent any hazardous situation from expelled parts, fluids (Clause 12) or **workload**.

15.5 It shall either be impossible that an **operator** gets trapped inside any part of an installation or equipment or, if this is impossible to achieve, means to summon help shall be installed. If an **operator** can be trapped inside the installation, sufficient means for escape or an emergency stop from the inside shall be installed.

15.6 Zones where a human body or bodyparts can be exposed to trapping, crushing, shearing, impact, cutting, entanglement, drawing in, stabbing or abrasion shall be inaccessible. Such a hazard zone is considered not to present a mechanical hazard if

- a) the gaps of the zone comply with the dimensions specified in Tables 13 and 14 of IEC 61010-1:2010,
- b) the distances separating the **operator** from the hazard zone exceed the values specified in ISO 13857:2008, and
- c) **guards** and protective measures prevent access.

If this is impossible for **normal operation**, other measures shall adequately reduce the risk.

15.7 The speed of movement of any part of the equipment that can come into contact with the **operator**, and where contact of the **operator** with the equipment can result in a hazardous situation, shall be limited so that the **operator** can adequately react to the moving part without resulting in an unacceptable risk.

15.8 Control elements shall be so positioned, recessed, or protected by other means that they cannot be accidentally actuated, resulting in unacceptable risk.

15.9 The risk due to over-travel (travel past the range limits) of equipment parts shall be reduced to an acceptable level. End stops or other stopping means shall be provided to act as the ultimate travel limiting measure in both **normal operation** and in **single fault condition**. Such means shall have the mechanical strength to withstand the intended loading. The over-travel (stopping distance) of such movement, occurring after operation of a control to stop the movement, shall not result in an unacceptable risk.

15.10 When a part of the equipment has been stopped, any drift away from the stopping position, for whatever reason other than intended action through the control devices, shall be prevented or shall be such that it does not cause a hazard.

15.11 If the **operator** is supposed to move about or stand on the installation or equipment, sufficient means to prevent slipping, tripping or falling shall be implemented.

16 Protection against hazards resulting from use

16.1 Particular hazards in processing of food, feed, cosmetics and similar intended for human or animal consumption

16.1.1 Hygiene hazards differ from other hazards because they are hazards for consumers of the **workload** being processed. They usually do not pose a hazard for the **operator**. Hygiene risks are associated with the ability of the equipment to be freed from product debris and micro-organisms, and thus preventing product contamination.

16.1.2 Particular hygienic and contamination hazards exist in the processing of **workload** like food, beverages, animal feed, pharmaceuticals and cosmetics and shall be considered. The equipment shall in that case fulfil the relevant requirements of ISO 14159:2002 and applicable national regulations. Furthermore, such **workload** shall not be contaminated during pasteurization, sterilization or other processing, resulting in hazardous products.

16.1.3 Interaction of cleaning or disinfection agents or their residuals with the processing equipment shall be considered. The **manufacturer** shall include information on safe to use agents in the information for use. The **manufacturer** shall indicate cleaning or disinfection agents that are not safe to use.

16.2 Combination equipment

If the equipment is intended to be used in combination with other equipment, any hazard due to the combination shall be considered.

17 EMC

17.1 Radio frequency interference

17.1.1 With respect to the **processing frequency** of the **EH** or **EPM installation** or **equipment**, Clause 4 of CISPR 11:2015 applies.

17.1.2 With respect to limits of electromagnetic disturbances caused by the **EH** or **EPM installation** or **equipment**, Clause 6 of CISPR 11:2015, CISPR 11:2015/AMD1:2016 and CISPR 11:2015/AMD2:2019 applies.

17.2 Immunity

The **EH** or **EPM installation** or **equipment** shall be able to work properly under the electromagnetic disturbances being expected at its intended position. IEC 61000-6-2:2016 applies in general and IEC 61000-6-7:2014 applies for all equipment intended to provide safety functions.

18 Verification and testing

18.1 General

Compliance of the **EH** or **EPM installation** or **equipment** with the applicable safety requirements of this document including protective measures shall be verified by one or a combination of the following methods;

- a) examination of drawings or calculations;
- b) visual inspection;
- c) measurement;
- d) **functional test**;
- e) numerical modelling.

Table 5 lists methods of verification with respect to the specific requirements of this document. The applied method and result of the verification shall be documented.

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Table 5 – Methods for the verification of requirements

Sub-clause	Requirement or measure relating to	Verification done by				
		examination	visual inspection	measurement	functional test	numerical modelling
		18.4	18.5	18.6	18.7	18.8
6.4	Physical environment and operating conditions for electrical equipment caused by operation of the processing equipment	✓	✓	(✓)		(✓)
6.5	Power supply	✓	✓	(✓)		
6.6	Access	✓	✓		✓	
6.7	Ergonomic aspects	✓	✓			
6.8	Transport and storage	✓	✓			
6.9	Provisions for handling	✓	✓			
6.10	Consumables and replaceable parts	✓	✓			
7	Protection against hazards from electric shock	refer to ISO 14120:2015				
7.3	General provisions	✓	✓			
7.4	Basic protection	✓	✓			
7.4.6	At frequencies exceeding 200 Hz, potential grading of the circuit shall be controlled by the following means.	✓	✓	✓		
7.5	Provisions for protection in electric single fault condition	✓	✓			
7.6	Protective equipotential bonding	✓	✓	✓		
7.7	Additional provisions for fault protection for frequencies above 200 Hz	✓	✓			
7.8	Currents in protective conductors	✓	✓	✓	✓	(✓)
7.9	Touch current and touch voltage	✓	✓	✓		(✓)
7.10	Conductors and insulations at high temperature	✓	✓	(✓)		(✓)
7.11	Non-electric faults	✓	✓			
8.2	Magnetic fields	✓	✓	✓		(✓)
8.3	Magnetic fields below 1 Hz	✓	✓	✓		(✓)
8.4	Local electric fields	✓	✓	✓		(✓)
8.5	Requirements related to barriers and screens	✓	✓			
8.6	Requirements related to objects worn, carried or held by persons	✓	✓			
9.2	Installation or equipment generating ionizing radiation	✓	✓	✓		(✓)
9.3	Ultraviolet radiation	✓	✓	✓		(✓)
9.4	Visible and infrared radiation	✓	✓	✓		(✓)
9.5	Laser sources	refer to IEC 60825-1				
10.2	Surface temperature limits for protection against burn	✓	✓	✓		
10.3	Hazards caused by working conditions		✓			(✓)
10.4	Temperature resistance of components	✓	✓			
10.5	Cooling	✓	✓	✓		
10.6	Over-temperature protection	✓	✓			
11	Protection against hazards from fire	✓	✓			

Sub-clause	Requirement or measure relating to	Verification done by				
		examination	visual inspection	measurement	functional test	numerical modelling
		18.4	18.5	18.6	18.7	18.8
12.2	Poisonous and injurious fluids	✓	✓	✓		
12.3	Explosion and implosion of pressurised parts or vacuum equipment	✓	✓			
13.2	Electrical equipment and conductors	✓	✓	✓	✓	
13.3	Connection to the electrical supply network and internal connections	✓	✓		✓	
13.4	Isolation and switching	✓	✓		✓	
13.5	Sensors and actuators safeguarding moving parts	refer to ISO 13855:2010				
13.6	Motors	✓	✓			
13.7	Non electric-heating means	refer to ISO 13577-2:2014				
13.8	Lighting	✓	✓			
13.9	Structural parts and stability	✓	✓			
13.10	Doors, windows and other openings	✓	✓			
13.11	Transformers, inductors, capacitors	✓	✓			
13.12	Handheld applicators	✓	✓		✓	
13.13	Vacuum system	✓	✓			
13.14	Protective and reactive gas generator	refer to ISO 13577-3:2016				
14	Control of the installation or equipment	✓	✓		✓	
15	Protection against mechanical hazards	✓	✓	✓		
16.1	Particular hazards in processing of food, feed, cosmetics and similar intended for human or animal consumption	✓	✓	✓		
16.2	Combination equipment	✓		✓		
17	EMC			✓	✓	
19	Information for use	✓				
Key ✓ mandatory when applicable (✓) non mandatory, but preferred						

18.2 Performing measurements and tests

18.2.1 Accuracy of measuring equipment and measurement methods shall conform to IEC 60398:2015, as relevant.

18.2.2 This document defines some tests at cold state and other tests under **normal operation** conditions. The test conditions of **normal operation** shall be the most unfavourable conditions causing the maximum expected stress to the installation and the highest probability or strength of hazards in the range of **normal operation** specified by the **manufacturer**.

18.2.3 This document does not define tests under **single fault condition** as these can result in serious damage to the installation.

NOTE IEC 61010-1:2010 can be used in combination with this document to develop verification means for **single fault condition** or for type testing.

18.3 Verification of requirements from references

This document references to other standards, where applicable. Such reference includes requirements and the verification of these requirements when given in those standards.

18.4 Examination of drawings or calculations

The examination of drawings and calculations shall be done to verify if all parts of the **EH** or **EPM installation** or **equipment** comply with the applicable requirements of this document.

18.5 Visual inspection

Visual inspection of the **EH** or **EPM installation** or **equipment** shall be done to compare the erected installation with the drawings. This visual inspection shall ensure the following:

- a) the installation has been erected as defined in the drawings;
- b) all markings and warnings have been affixed;
- c) all **barriers, obstacles, guards** and similar protective means are in place;
- d) all **barriers, guards** and similar protective means intended to be removed with a tool are only removable with the use of a tool;
- e) all protective measures are adequate and exist and all earthing provisions and equipotential connections are in accordance with the drawings.
- f) all **insulations** are in place, clean and in intended state.

A first cold state visual inspection is usually done after mounting and prior to any hot state tests. Further visual inspection can be carried out after finishing all hot state tests of commissioning. This second visual inspection ensures that the parts of the **EH** or **EPM installation** or **equipment** subject to heat, **electromagnetic fields**, intense radiation or to other influences causing wear are still in their intended state. Linings, heating elements, thermal **insulation** and refractories, **barriers**, doors, gates, **windows**, lips, systems for transporting or positioning the **workload** are inspected with the focus on drop-out, crack, distortion, unusual abrasion, burn-through, oxidization and creep.

18.6 Measurements

18.6.1 Environment and operating conditions inside the processing equipment

This measurement verifies if the assumed conditions used for the design are met. It can be impossible to measure all relevant values.

18.6.2 Impedance of protective bonding

The measurement defined in 6.5.2.4 of IEC 61010-1:2010 applies for plug connected equipment.

The measurement defined in 6.5.2.5 of IEC 61010-1:2010 applies for permanently connected equipment.

18.6.3 Insulation resistance measurement

The measurement defined in 18.3 of IEC 60204-1:2016 applies for **insulation** resistance measurement at LV; the measurement defined in 19.3 of IEC 60204-11:2018 applies for **insulation** resistance measurement at HV and up to 200 Hz. In addition to the requirements from the references the tests shall be performed in the cold state.

Measurements above 200 Hz are under consideration.

18.6.4 Measurement of electric or magnetic fields

IEC 61786-2:2014 applies for measurements of electric or magnetic fields in the range of frequencies between 1 Hz and 100 kHz, and IEC 61786-1:2013 applies for measurement instruments.

Measurements above 100 kHz are under consideration.

18.6.5 Touch current measurement

The measurement of **touch currents** shall adhere to IEC 60990:2016 between 0 Hz and 1 kHz. The provided method can be used above that frequency for large contact area situations.

18.6.6 Measurement of ionising radiation

Conformity is checked by measuring the amount of radiation emitted in the most unfavourable conditions, when maximum ionising radiation occurs; equipment containing X-ray sources is set to produce the maximum possible level of radiation. The method of determining the amount of radiation shall be effective over the range of possible radiation energies.

18.6.7 Measurement of non-coherent optical irradiation

18.6.7.1 For the measurement of non-coherent optical radiation, Clause 5 of IEC 62471:2006 applies with the clarifications in 18.6.7.2 to 18.6.7.8 and including requirements given in Annex C.

18.6.7.2 Separated locations of the installation, like separate doors or **windows** are separate sources of radiation, as defined in 9.1.2 and can belong to different risk classes. They shall be assessed and verified separately.

18.6.7.3 Usually no controlled environment is possible to achieve. Thus the measurement conditions and an assessment of the influence of measurement conditions on the quality of the measured data shall be part of the measurement report. Measurement conditions shall be reported as part of the evaluation and the assignment of risk classification.

18.6.7.4 To maintain stable output during the measurement process and provide reproducible results, the **EH** or **EPM installation** or **equipment** shall be seasoned for an appropriate period of time prior to measurement. During the initial period of operation, the output characteristic will change as components oxidise, age, or come otherwise to a state of near equilibrium. If measurements are taken with unseasoned installations, the variations within the measurement period and between measurements can be significant. The necessary ageing period depends on the specific installation and the environment. It varies with different types of installations and it can be impossible to reach sufficient ageing for assessment during commissioning. In this case, measurement shall be done again at a later stage of equipment lifetime.

18.6.7.5 Careful checks shall ensure that other sources of radiation like nearby equipment or ovens, hot **workload**, hot **screens**, or reflections do not add significantly to the measured signal.

18.6.7.6 All measuring equipment for non-spectrally resolved measurement of irradiance or radiance shall be of class 3.0 or better. For thermal or broad-band radiation the measuring equipment shall have a flat or constant spectral response between 400 nm and 10 µm, a flat response between 200 nm and 20 µm is preferred. For non-thermal radiation, the measuring equipment shall have a flat or constant spectral response over the complete wavelength-range of the source. The measuring equipment shall be sufficiently stabilised to avoid any drift exceeding the limits.

NOTE 1 This can be a thermally stabilised pyroelectric detector for thermal radiation.

NOTE 2 Non thermal sources include LEDs and many types of UV emitter.

18.6.7.7 Annex B of IEC 62471:2006 applies for spectrally resolved measurements. The accuracy of the measurement results shall be calculated and stated. Measurement inaccuracy should not exceed 30 % of the lowest classification limit in absolute values.

18.6.7.8 Usually large areas need to be assessed; therefore a scanning procedure over the surface contributing to the **emission** from one source shall be used, assuring that more than 90 % of the emitted power is inside the scanned area.

18.6.8 Measurement of coherent optical radiation

All measurements of radiation from laser sources shall adhere to IEC 60825-1:2014.

18.6.9 Surface temperature measurement

Verification of accessible surfaces shall be done according to 5.4. of ISO 13732-1:2006.

18.6.10 Temperature of structural components subject to heat

For measurement equipment, methods and requirements, 6.5 of IEC 60398:2015 applies. The assessment shall provide the temperatures under the worst case conditions in **normal operation** or other condition specific to the installation or equipment. Measurement positions shall provide information about critical parts or positions, i.e. parts or positions exposed to maximum heat stress or temperature.

18.7 Functional tests

18.7.1 Protection by automatic disconnection of supply

Subclause 18.2 of IEC 60204-1:2016 applies for LV and 19.2 of IEC 60204-11:2018 for HV.

18.7.2 Voltage test

For LV installations or equipment, the test of 18.4 of IEC 60204-1:2016 applies, for HV installations the test from 19.4 of IEC 60204-11:2018.

18.7.3 Dielectric test

The test given in Clause 13 of IEC 60335-1:2010, IEC 60335-1:2010/AMD1:2013 and IEC 60335-1:2010/AMD2:2016 applies, when applicable.

18.7.4 Accessibility of live parts

18.7.4.1 Inaccessibility of any **live parts** for LV shall be checked by tests defined according to IEC 60529:1989, 12.3.1.

18.7.4.2 Inaccessibility of any **live parts** for HV shall be checked by tests defined according to IEC 60529:1989, 12.3.2.

18.7.4.3 Verification of inaccessibility defined through use of ISO 13857:2008 is done according to that standard through examination and visual inspection.

18.7.5 Protective devices and systems

Protective systems are tested by applying the signal expected from the **protective device** in a fault to the electric circuit that should react.

18.8 Numerical calculations and modelling

18.8.1 General

The accuracy of any calculation shall at least be sufficient for the problem to be solved or comparable to the achievable accuracy of measurements. This defines the needed accuracy of the implemented geometrical setup and minimum grid resolution or number of cells, surface elements, time resolution, bands or rays used as well as the used physical or thermochemical data.

The use of calculated data instead of measurements shall be stated in the technical documentation.

The documentation of the calculation shall include

- a) the geometrical setup used,
- b) all relevant modelling data and a description of the models used,
- c) the software and version used,
- d) the set parameters of the software that influence the result,
- e) the method used for verification of the accuracy of the used models and the calculation itself, and
- f) all results used for classification.

It shall be possible, from the documentation, to implement the models again and to make the calculation again on another system or with another software.

The documentation of the calculation shall be kept at the **manufacturer** of the equipment. It shall be kept either over the expected lifetime of the equipment or over a time defined by national regulations.

18.8.2 Numerical assessment of short circuit currents

For the assessment of short circuit currents, IEC 60909-0:2016 shall be used; for the effects of short circuit currents, IEC 60865-1:2011 is applicable.

18.8.3 Numerical assessment of electric or magnetic emission

A numerical assessment of the interaction between the **EH** or **EPM installation** or **equipment** and exposed persons with respect to electric or magnetic fields and induced electric fields in bodyparts may be used to assess the induced currents in bodyparts of exposed persons in case of complex geometries or for such applications where the underlying assumptions for calculating a reference level are not sound (the **near-field region**) and if the calculation reaches a sufficient accuracy.

The use of computational electrodynamics for assessing external fields, internal electric field, specific absorption rate (SAR) or contact current is a numerical experiment and accuracy depends inter alia on

- the model of the source, the model of the installation and the model of the human body,
- the calculation method used, and

– the spatial and temporal resolution.

The documentation of the calculation shall include in addition to the list of 18.8.1

- a) the geometries and electromagnetic properties of all conductors and objects relevant to the calculation, and
- b) the grid and resolution or mesh and voxel data.

For **accessible emission** caused by strongly curved magnetic nearfields in the range between 1 Hz and 6 MHz, the methods in IEC TS 62997:2017 of employing source geometry and current can be applied.

For **accessible emission** caused by electric fields in the range between 1 kHz and 6 MHz interacting with specified bodyparts and other objects in specified onerous positions and thus resulting in an inhomogeneous field, the methods in IEC TS 62996:2017 can be applied.

NOTE IEEE 1597 (all parts) provides a method and guide for the validation of numeric models for electromagnetics and can be used.

18.8.4 Numerical assessment of optical radiation emission

The assessment of **emission** and subsequent classification can be based on ray tracing calculation of irradiance and radiance at all positions relevant for risk assessment instead of measurements and if a comparable accuracy is reached by the calculation.

As ray tracing is a numerical experiment, the demands on position and orientation of virtual detectors are the same as for physical detectors during measurements.

The calculation of radiance or irradiance, depending on the defined spatial angles or angular subtenses shall follow the same procedure as for measurements defined in 18.6.7 or 18.6.8.

The documentation of the calculation shall include in addition to the list of 18.8.1

- a) all relevant modelling data and a description of the models used for involved surfaces, their scattering behaviour, diffuse or specular reflection,
- b) the set parameters of the software that influence the result, like splitting of rays, maximum number of split rays followed, minimum amount of energy in a single ray, randomisation method, and
- c) number of rays used, energy lost due to numerical effects.

19 Information for use

19.1 General requirements

19.1.1 The **manufacturer** of the **EH** or **EPM Installation** or **equipment** shall provide information for use of the equipment consisting of communication links such as texts, words, signs, signals, symbols or diagrams, used separately or in combination to convey information to the **user**.

Information about the intended use of the **EH** or **EPM Installation** or **equipment** shall be provided, taking into account its operating modes, measures required to ensure its intended and correct use, in particular information on residual risks.

19.1.2 The information for use shall cover separately or in combination transport, assembly and installation, commissioning, use (including operations like setting, teaching, programming, process changeover, operation, cleaning, fault finding and maintenance) of the **EH** or **EPM installation** or **equipment**, and if applicable de-commissioning, dismantling and disposal.

19.2 Location and nature of the information for use

The **manufacturer** shall decide whether the information for use or parts of it are given

- a) in or on the **EH** or **EPM Installation** or **equipment** itself,
- b) in accompanying documents,
- c) on the packaging, or
- d) by other means such as signals and warnings outside the **EH** or **EPM installation** or **equipment**.

This decision shall be based on the risk, the time when the information is needed and the design of the installation.

19.3 Signalling and warning devices

Visual signals (e.g. flashing lights) or acoustic signals (e.g. sirens) shall be used to warn **operators** or **ordinary persons** of an impending hazardous event (for example start-up of the **EH** or **EPM installation** or over-temperature). The following requirements shall be met:

- a) signals shall be emitted before the occurrence of the hazardous event;
- b) signals shall be unambiguous and shall be clearly recognized by the **operator**;
- c) signals shall be clearly perceived and differentiated from all other signals used.

If warning devices are used, they shall be designed and located such that checking for proper operation is easy. The information for use shall determine procedures for verifying proper operation of warning devices.

The **manufacturer** shall consider the risk of "sensorial saturation" when designing the warning devices. This risk results from too many visual or acoustic signals, which can lead to ignoring or defeating the warning devices by the **operator**.

19.4 Markings, pictograms, written warnings

19.4.1 The **EH** or **EPM installation** or **equipment** shall be marked on nameplate(s) at least with the following data in a visible and legible manner:

- a) serial number, if any, or name of the **EH** or **EPM installation** or **equipment**;
- b) name and address of the **manufacturer** or authorised representative;
- c) year of construction;
- d) year of modification, if applicable;
- e) number of phases and rated input voltage; when the **EH** or **EPM installation** or **equipment** is intended to be used at different rated supply voltages, the association of the particular voltage and corresponding supply terminals as well as the type of connection shall be indicated on the nameplate;
- f) type and value of rated input current;
- g) rated input power; in case of **EH** or **EPM installation** or **equipment** for several voltage ranges, the maximum values for the power input pertaining to the voltage ranges shall be stated;
- h) input frequency and rated **processing frequency** or range of **processing frequencies**, where appropriate, shall be stated;
- i) class and group of the **EH** or **EPM installation** or **equipment** according to CISPR 11:2015 and CISPR 11:2015/AMD1:2016, if applicable.

19.4.2 The **EH** or **EPM installation** or **equipment** shall be marked with all information that is necessary for its safe use, for example

- the maximum **workload** or output to be processed,
- the maximum operation temperature,
- the atmosphere to be used (e.g. non-flammable, explosive, toxic, pressure range), if specific,
- the necessity to wear personal protective equipment, and
- **guard** or **barrier** adjustment data.

19.4.3 Appropriate warnings shall be displayed, in particular against hazards, which cannot be immediately perceived, such as caused by HV, ionizing radiation, non-ionizing radiation or **electromagnetic fields**.

19.4.4 IEC 60204-1:2016, 16.2, applies for the marking of electrical features.

Letters, words or symbols shall identify control and signalling devices.

Identification of conductors shall be in accordance with 13.2 of IEC 60204-1:2016.

The electrical components and their references to the circuit diagram in the documentation shall be durably marked. The designation shall comply with the indications on the circuit diagram.

19.4.5 The **EH** or **EPM installation** or **equipment** shall bear all markings which are necessary to indicate its compliance with applicable requirements.

19.4.6 Information printed directly on the **EH** or **EPM installation** or **equipment** shall be permanent and remain legible throughout the expected life of the equipment.

Markings shall be durable, legible and clearly visible. Markings shall be in the language of the country in which the equipment is to be installed, unless agreed differently. Written warnings shall be drawn up in the language of the country in which the equipment will be used for the first time and, on request, in the language understood by **operators**.

Markings, symbols, signs and written warnings shall be readily understandable and unambiguous, especially as regards the part of the function(s) of the equipment to which they are related. Readily understandable pictograms should be used in preference to written warnings. Graphical symbols shall conform to IEC 60417 and ISO 7000. Signs, labels or signboards shall be designed according to ISO 3864-1:2011. Annex G provides examples of relevant symbols and safety signs.

19.5 Instruction handbook

19.5.1 The instruction handbook, including technical documentation and manuals for installation, commissioning, operation, maintenance, and decommissioning, shall be provided in paper form and can be accompanied by electronic data, unless local law allows for electronic data only.

19.5.2 The instruction handbook shall conform with IEC 82079-1:2012 and shall contain at least the following information relating to transport, handling and storage of the installation or equipment, including but not limited to:

- a) storage condition for the **EH** or **EPM installation** or **equipment** or parts of it;
- b) dimension, mass, position of the centre of gravity;
- c) indication for handling – for example, drawings indicating application points for lifting equipment.

19.5.3 The instruction handbook shall contain at least the following information relating to installing and commissioning of the **EH** or **EPM installation** or **equipment**, including but not limited to:

- a) fixing/anchoring and vibration dampening requirements, or foundation if necessary;
- b) mandatory earth terminals in the vicinity of parts of the **EH** or **EPM installation** or **equipment** where it is necessary for maintenance and inspection that conductors and bare conductive parts are earthed after switching off the supply;
- c) if the **EH** or **EPM installation** or **equipment** is sent unassembled to the **user**, specific instructions on unpacking of the equipment, checklist of parts, plan of the configuration, plan for installation of all parts and a connection schedule of parts – IEC 61082-1:2014 applies;
- d) instructions for connecting the **EH** or **EPM installation** or **equipment** to sources for working fluids, including their permissible pressures (this includes water, hydraulic liquids, pressurized air, protective and reactive gases and other working fluids);
- e) instructions for connecting the **EH** or **EPM installation** or **equipment** to the power supply, especially tolerable voltage and frequency fluctuations, and including protection against electrical overloading;
- f) test plan including all tests performed prior to connecting or operating the **EH** or **EPM installation** or **equipment**;
- g) assembly and mounting conditions;
- h) space needed for use and maintenance of the **EH** or **EPM installation** or **equipment**;
- i) permissible conditions of the environment – for example temperature, moisture, vibration, **electromagnetic radiation**, intended atmosphere and atmospheric pressure;
- j) recommendation about process waste removal or disposal, if applicable;
- k) recommendation for the implementation of protective measures, safety distances, safety signs and signals by the **user**.

19.5.4 The instruction handbook shall contain information relating to the **EH** or **EPM installation** or **equipment** itself, such as the following:

- a) detailed description of the equipment, its fittings, **guards** and other **protective devices**;
- b) the comprehensive range of applications for which the **EH** or **EPM installation** or **equipment** is intended, including prohibited usages;
- c) diagrams, especially schematic representation of safety functions in conformity with Clause 17 of IEC 60204-1:2016;
- d) data on radiation, gases, vapours and dust emitted by the **EH** or **EPM installation** or **equipment**, including if applicable reference to the measurement methods used;
- e) technical documentation of the **electrical equipment** in conformity with Clause 17 of IEC 60204-1:2016;
- f) documents attesting that the **EH** or **EPM installation** or **equipment** complies with mandatory and regulatory requirements;
- g) explicit warning, if **emission** from the **EH** or **EPM installation** or **equipment** can cause a hazard;
- h) explicit warning, if making the **EH** or **EPM installation** or **equipment** electrically live for the purpose of measurement and inspection causes excessive stress to electrical **insulation**, including if applicable instructions for such tests and the maximum voltage to be applied.

19.5.5 The instruction handbook shall contain information relating to the use of the **EH** or **EPM installation** or **equipment**, such as that related to or describing the following:

- a) intended use;
- b) manual controls (actuators);

- c) setting, adjustment and the list of setting values and adjusting values of the **EH** or **EPM Installation** or **equipment** at the completion of the commissioning test;
- d) modes and means for start-up, operation and stopping (for example emergency stop);
- e) residual risks;
- f) particular risks which can be generated by certain applications, by the use of certain fittings, and about specific safeguards necessary for such applications;
- g) reasonably foreseeable misuse and prohibited applications;
- h) procedure for fault identification, location and for repair;
- i) safe procedure for restarting after an intervention or after a fault;
- j) personal protective equipment to be used;
- k) required training.

19.5.6 The instruction handbook shall contain information for maintenance, such as the following:

- a) nature and frequency of inspection for safety functions;
- b) specification of the spare parts to be used, when these can affect the health and safety of the **operator**;
- c) instruction relating to maintenance operations which require a definite technical knowledge or particular skills and hence need to be carried out exclusively by a **skilled person**;
- d) instruction relating to maintenance actions, like replacement of parts, which do not require specific skills and hence can be carried out by the **operator**;
- e) drawings and diagrams enabling the **operator** to carry out his task, especially during maintenance or fault finding;
- f) maintenance items which can only be conducted by the equipment **manufacturer** or its designated representative;
- g) instructions, drawings and diagrams related to maintenance;
- h) necessary consumables, such as cleaning and disinfection agents or lubricants;
- i) type and specific characteristics of fuses.

19.5.7 The instruction handbook or other written instructions shall contain information for maintenance of **electrical equipment** of the **EH** or **EPM installation** or **equipment**, such as the following:

- a) necessary testing of the resistance of earth circuits during maintenance;
- b) mandatory testing of equipotential bonding and **insulation** resistance values of the conductors to earth and to each other during maintenance;
- c) procedure for discharging capacitors and checking the absence of voltage on capacitors, if applicable;
- d) instructions on escape routes during maintenance;
- e) procedures for maintenance work with equipment live – the voltage shall not exceed the LV limits;
- f) preparation of the **EH** or **EPM installation** or **equipment** for maintenance through switch off, connection to earth and short-circuiting;
- g) instructions for maintenance in potentially flammable environments – no live circuit or the replacement of a lamp or fuse is usually tolerable under such conditions – or procedure for removing flammable atmospheres from the **EH** or **EPM installation** or **equipment**;
- h) instructions for maintenance in areas liable to contain toxic gases, or procedures for removing the toxic gases prior to work.

19.5.8 The instruction handbook or other written instructions shall contain information for de-commissioning, dismantling or disposal.

19.5.9 The instruction handbook or other written instructions shall contain information for emergency situations, such as

- a) the operating procedure to be followed in the event of an accident or breakdown,
- b) the type of fire-fighting equipment to be used,
- c) warning of possible **emission** or leakage of hazardous substance(s) and, if possible, an indication of means for fighting their effects, and
- d) instructions on the application of first aid to the victims of accidents of electrical origin.

19.5.10 If the instruction handbook or other written instructions contain maintenance instructions provided for **skilled persons** and maintenance instructions provided for **instructed persons**, they shall appear clearly separated from each other.

19.5.11 The instruction handbook or other written instructions shall contain relevant information concerning hazards to specific groups of persons – for example pregnant women or people wearing implanted active medical devices.

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Annex A (normative)

List of significant hazards

Table A.1 lists all significant hazards, hazardous situations and events, as far as they are dealt with in this document, that are identified by risk assessment as significant for **EH** or **EPM installation** or **equipment** and that require action to eliminate or reduce the risk.

Table A.1 – List of hazards dealt with in this document

Hazard			Clause/subclause of this document or reference used
Origin	Hazardous situation/event	Potential consequence	
1 Mechanical			ISO 13577-1:2016, ISO 12100:2010
high pressure gases and liquids	bursting of vessel, ejection of (hot) gases, falling or ejection of objects, ejection of (hot) liquids	suffocation, impact, explosion, being thrown, crushing, slipping or tripping,	12.3
movable parts	getting caught by part, getting crunched between parts	shear, crunching,	15
vacuum	implosion of vessel, bursting of window	impact, injection or ejection	12.3
2 Electrical			
short-circuit arc live parts parts which have become live under fault conditions		electric shock, burn, shock, electrocution, falling or being thrown	7, 8
		fire, chemical reaction, explosion, projection of molten particles	7, 10, 11
arcing in vacuum	low pressure reduces breakdown voltage of gas	any other (e.g. electric) through overcurrent or disintegration of vacuum system	7, 13.13
insufficient distance to live parts under HV – people/equipment	entering the high-voltage hazard zone	electrical shock, fire, explosion	7, 10, 11
leakage current caused by hot insulation or through water or contamination	static electricity builds up on surface and ignites material	fire, chemical reaction, explosion, projection of molten particles	10, 12
		electric shock	7
prospective circuit breaker not fast enough		shock, any other (for example, mechanical, electrical) as a consequence of equipment failure or overheating	7, 14
prospective short circuit current		fire, any other (for example, mechanical, electrical) as a consequence of equipment failure or overheating	7, 10, 11

Hazard			Clause/subclause of this document or reference used
Origin	Hazardous situation/event	Potential consequence	
inrush current causes relays to weld and stick in 'on'		any other (for example, mechanical, electrical) as a consequence of equipment failure or overheating	7, 14
discharge into electric control or measuring equipment		any other (for example, mechanical, electrical) as a consequence of equipment failure or overheating	7, 14
resonance in electrical equipment (transformers, inductors, capacitors)	sustained resonance generates excessive voltage or current	any other (for example, mechanical, electrical) as a consequence of equipment failure or overheating	13.11
onboard electrical source frequency variation		destruction of power source	6, 7, 14
overload	workload contacts heating means, formation of foam	eruption or ejection of workload	10
undervoltage		any other (for example, mechanical, electrical) as a consequence of equipment failure	6.5
overvoltage	overheating of electric connections, melting of insulation	any other (for example, mechanical, electrical) as a consequence of equipment failure or overheating	6.5
magnetic field		projection or ejection of workload or other metallic parts, effects on medical implants, body heating, neural stimulus, any other (for example, mechanical, electrical) as a consequence of equipment failure or overheating	8
electromagnetic force		ejection of workload or projection of metallic parts, effects on medical implants, body heating, any other (for example, mechanical, electrical) as a consequence of equipment failure or overheating	8
electric field		ejection of workload or projection of metallic parts, effects on medical implants, body heating, any other (for example, mechanical, electrical) as a consequence of equipment failure or overheating	8
arc or plasma generating ozone		breathing harm, destruction of insulation , coatings, parts	8
arc or plasma generating UV light		destruction of insulation , coatings, parts	9

Hazard			Clause/subclause of this document or reference used
Origin	Hazardous situation/event	Potential consequence	
electrostatic phenomena causing arcs		electric shock, any other (for example, mechanical, electrical) as a consequence of equipment failure or overheating	7, 8
3 Thermal			
hot environment	prolonged stay near processing equipment	burn, dehydration, discomfort, dizziness, any other (for example, mechanical, electrical) as a consequence of a human error	9, 10, 11
flame			ISO 13577-2
explosion of gas, dust, aerosols	falling or ejection of objects, ejection of (hot) gases loss of integrity of equipment	any other (for example, mechanical, electrical) as a consequence of equipment failure	11, 13.14, IEC 60079-1 ISO 13577-3
projection or sudden eruption of material	falling or ejection of objects ejection of (hot) gases, ejection of (hot) liquids, thermal energy stored in workload projects hazard	burn, scald, impact, being thrown, crushing, slipping or tripping, explosion, any other (for example, mechanical, electrical) as a consequence of equipment failure	8, 10, 11, 15
failure of cooling		burn, scald, impact, being thrown, crushing, slipping or tripping, explosion, any other (for example, mechanical, electrical) as a consequence of equipment failure or disintegration	12; ISO 13577-1:2016
thermal overload of housing, vacuum system or structural parts			
failure of liquid cooling of enclosure being in contact with liquid workload			
objects or materials with a high temperature	non-sufficient thermal strength of parts of the installation leads to break-up during operation	burn, ignition, explosion, radiation	10
hot liquids, hot liquid flowing out of a vessel, hot liquid flowing into water	falling or ejection of objects, ejection of hot liquids, liquid metal causes sudden steam eruption	burn, scald, poisoning, slipping or tripping, explosion, ejection, any other (for example, mechanical, electrical) as a consequence of equipment failure	10, 11, 12, 15
superheated hot liquids		burn, scald, poisoning, impact, being thrown, crushing, slipping or tripping, explosion, any other (for example, mechanical, electrical) as a consequence of equipment failure	10, 12
hot high pressure gases		scald, burn	10, 12

Hazard			Clause/subclause of this document or reference used
Origin	Hazardous situation/event	Potential consequence	
hot high pressure liquids		scald, burn	10, 12
radiation from heat sources		see "infrared radiation" (No. 7)	9
pressure loss (in workload or cooling liquid)	sudden boiling of liquid	burn, scald, poisoning, impact, being thrown, crushing, slipping or tripping, explosion, any other (for example, mechanical, electrical) as a consequence of equipment failure	12.3
4 Noise			not in the scope
5 Vibration			ISO 13577-1:2016
6 Electromagnetic fields below 300 GHz			
electric field		burn, dizziness, body heating.	8
magnetic field	magnetic field interacts with installation and leads to break-up	any other (for example, mechanical, electrical) as a consequence of equipment failure or overheating	8
magnetic field	magnetic tools or personal belongings in the vicinity of the equipment	projection or ejection of workload or other metallic parts, effects on medical implants, any other as a consequence of equipment failure or operator being hurt	8
7 Radiation – electromagnetic fields above 300 GHz			
ionising radiation		effects on reproductive capability, mutation, cancer, burn, severe illness or death, any other (for example, mechanical, electrical) as a consequence of equipment failure	9.2
ultraviolet radiation		damage to eyes and skin, mutation, cancer of skin	9.3
	not suitable material exposed to radiation	any other caused by failure of parts, coatings	9.3
visible radiation		damage to eyes and skin, burn	9.4
infrared radiation		burn, damage to eyes, any other (for example, mechanical, electrical) as a consequence of equipment failure or overheating	9.4
	excessive heat transfer through radiation	any other caused by failure of parts	9.4, 11
ignition of flammable substance by radiation	for example workload gets stuck, or accumulation of dust	burn, fire, explosion, noxious gases	9, 10, 11; IEC 60079 (all parts)

Hazard			Clause/subclause of this document or reference used
Origin	Hazardous situation/event	Potential consequence	
laser radiation	getting into the beam	damage to eyes and tissue	9.5; IEC 60825-1:2014
	beam hits material	ignition, fire, explosion any other through destruction of parts	9.5, 11; IEC 60825-1:2014
8 Material or substance related			
aerosol, combustible, dust, explosive, fibre, flammable, fluid, fume, gas, mist, oxidizer		breathing difficulties, suffocation, cancer, corrosion, explosion, fire	10, 11, 12, 13.14; ISO 13577-1:2016 ISO 13577-2:2014 ISO 13577-3:2016
workload contains water	wet workload is added to molten workload sudden rise of pressure	ejection of molten workload , any other through destruction of parts	19
deposition of conductive layer on isolator in vacuum	leakage current , arcing	any other (for example, mechanical, electrical) as a consequence of equipment failure or overheating	13.13
9 Ergonomic			
access	moving into hazard zone	any as a consequence of a human being in the wrong place	6.7, 8, 9, 10, 12, 13, 14, 15
design or location of indicators and visual display units		any other (for example, mechanical, electrical) as a consequence of a human error	19.3
design, location or identification of control devices		any other (for example, mechanical, electrical) as a consequence of a human error	14, 19
flicker, dazzling, shadow, stroboscopic effect by the installation		discomfort, fatigue, stress, any other (for example, mechanical, electrical) as a consequence of a human error	13.8, 14
lighting in installation	tripping due to dim lighting not perceiving warning due to glare	any other (for example, mechanical, electrical) as a consequence of a human error	13.8
handheld applicator and open ended devices	overriding safety switch	any other (for example, mechanical, electrical) as a consequence of a human error	13.12
work process design	excessive effort, human errors, human misbehaviour (unintentional or deliberately induced by the design), loss of direct visibility of the working area, painful and tiring postures, repetitive handling at high frequency	any other (for example, mechanical, electrical) as a consequence of a human error	14, 15

Hazard			Clause/subclause of this document or reference used
Origin	Hazardous situation/event	Potential consequence	
10 Associated with the environment in which the installation is used			
General			ISO 12100:2010
electromagnetic disturbance	malfunction of the controls	any other as a consequence of the effect caused by the sources of the hazards on the equipment or parts of the equipment	6.3, 14, 17
insufficient lighting	tripping due to dim lighting, not perceiving warning due to glare	any other (for example, mechanical, electrical) as a consequence of a human error	13.8, 19.2, 19.3, 19.5
flicker, dazzling, shadow, stroboscopic effect by other installations		discomfort, fatigue, stress, any other (for example, mechanical, electrical) as a consequence of a human error	19
height or air pressure	insufficient mass flow of air for cooling	any other (for example mechanical, fire) as a consequence of overheating	6
11 Combination of hazards			
repetitive activity + effort + high environmental temperature		dehydration, loss of awareness, heat stroke	
any combination of flammable material or workload , (heat) energy and oxidiser	fire	any other	11

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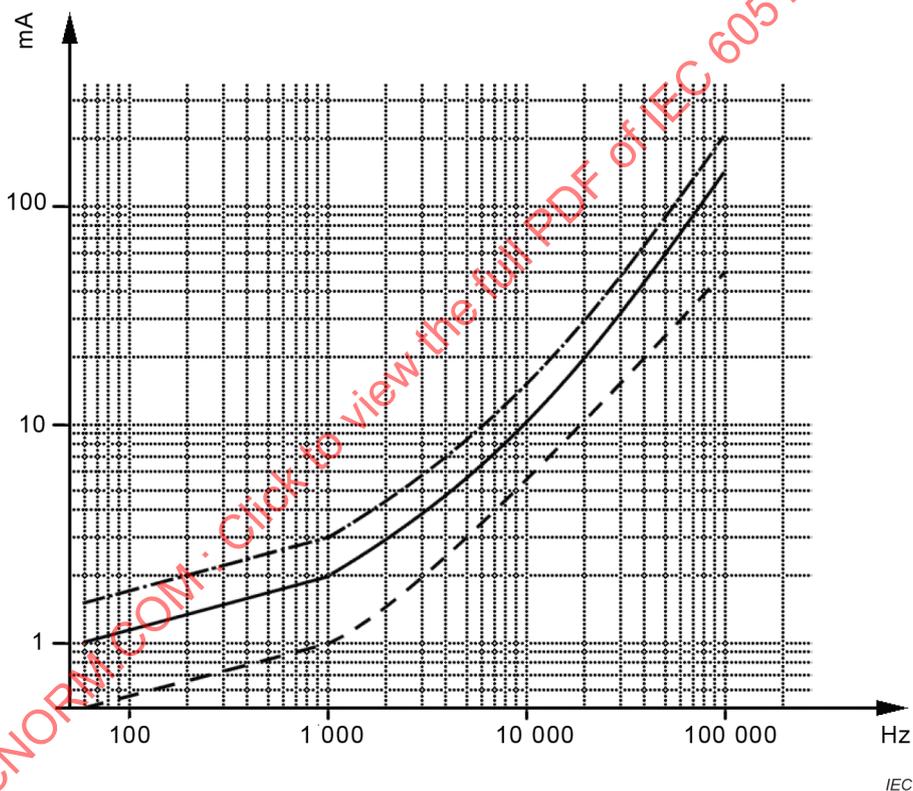
Annex B (normative)

Limits to touch currents

B.1 General

Hazards from **touch currents** are caused by currents flowing through the human body. The root cause of a **touch current** is a **touch voltage**, but a **touch voltage** is often not a sufficient indication for a hazard, as the ensuing current depends on the specifics of the creation of a **touch voltage** and eventual sustainment of a current when touched. Figure B.1 summarises the maximum permissible **touch currents** depending on the frequency of the electric field.

NOTE IEC TS 62996:2017 and IEC TS 60479-2:2017 provide the rationale and basics for these limits, and detailed information on effects on the human body depending on frequency of the field and the contact area.



Key

- (full line) I_{inadv} ; inadvertent touching causing aversion
- - - (dashes) I_{percep} ; approximate perception level in normal environments
- · - (dots/dashes) $I_{gripp} = 1,5 \times I_{inadv}$; gripping or between the feet

NOTE 1 The lines between 60 Hz and 1 kHz are for information purposes only. The graphs are projected between 60 Hz and 1 kHz, to show the connection to mains AC requirements in other standards and similar. IEC 61140:2016, 5.2.7 informs about the limit for perception and pain for DC and mains AC (50 Hz).

NOTE 2 No specifications are provided above 100 kHz, since local overheating (burns) is assumed to then be the determining electric shock mechanism, and thus additionally being dependent on tissue impedances.

Figure B.1 – Maximum allowed touch and contact currents between 1 kHz to 100 kHz

B.2 Risk classes

Table B.1 provides a risk classification based on the limits from Figure B.1 and includes a distinction between

- possible accidental touch of accessible surfaces – i.e. contacts that may or may not happen, with low to very low frequency and on a non-regular basis, and
- intended contacts – i.e. contacts that happen on a regular basis.

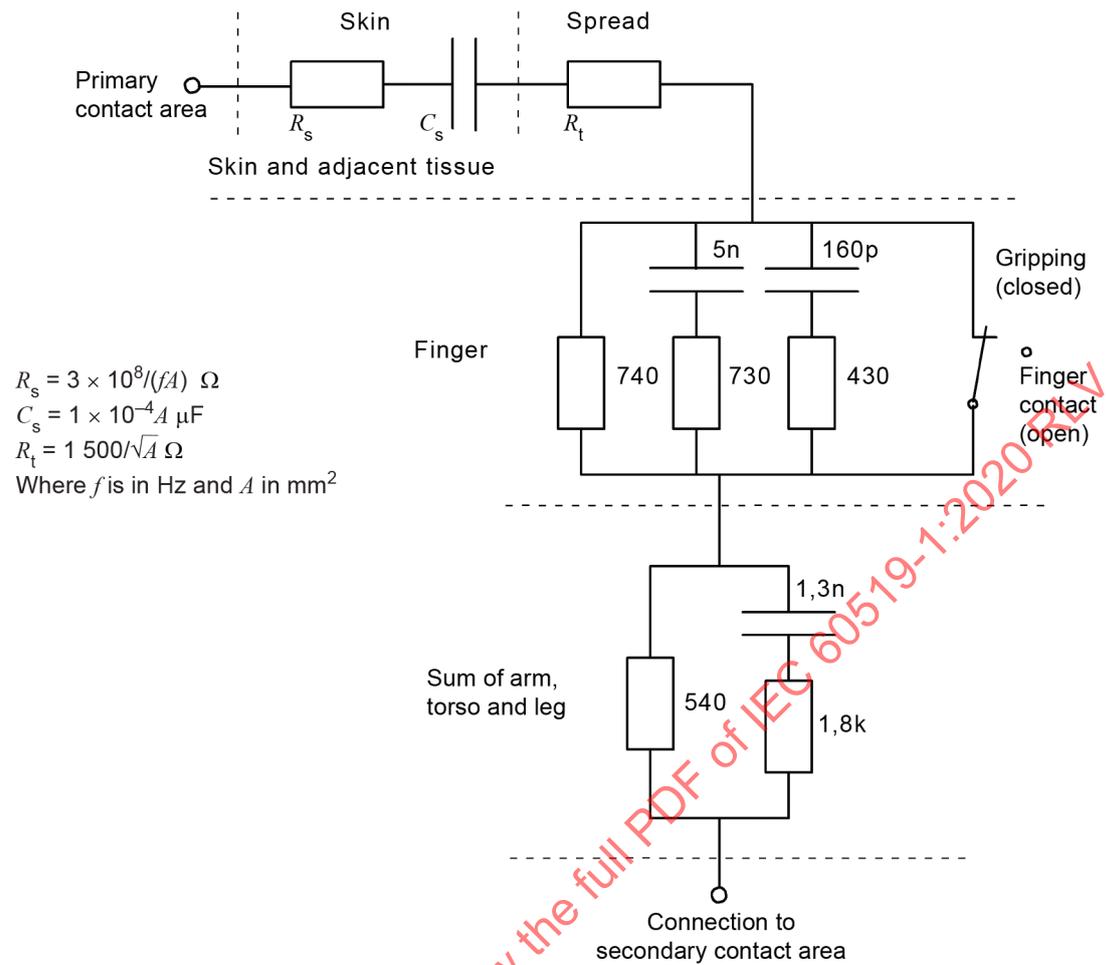
Intended contacts include gripping on rails and at elevated positions, for lifting or handling.

Table B.1 – Risk classification for hazards from touch currents

Risk class		Touch current		Restrictions and protective measures	Information and training
		accidental touching only	touch intended by the manufacturer or recurring		
0	Exempt	Not perceivable, no bodily reaction or hazard – i.e. a factor of 5 below the dashed line in Figure B.1		No restriction	No information needed
1	Low risk	Perceivable, but no other bodily reaction or hazard – i.e. a factor of 2 above the dashed line in Figure B.1		Restrictions 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	Below the dot-dashed line in Figure B.1	Below the full line in Figure B.1	Special restrictions and protective measures essential	Information about hazards, risks and secondary effects to be provided by the manufacturer . If specific training of the operator is deemed necessary by the manufacturer , he shall indicate this
3	High risk	Above the dot-dashed line in Figure B.1	Above the full line in Figure B.1	No access	Information about hazards, risks and secondary effects to be provided by the manufacturer

B.3 Body model

Figure B.2 provides an applicable model for impedances of body parts.



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IEC

Figure B.2 – Complex impedances of various parts of the body, 1 kHz to 6 MHz

Annex C (normative)

Non coherent optical radiation – Limits and risk classes

C.1 General

Annex C provides a classification of **emission limits** and risk zones according to the general scheme of Table 3. This specific classification is provided in Table C.1.

Table C.1 – Risk classification for optical radiation (UV, VIS, IR)

Risk class		Laser class IEC 60825-1:2014	Restrictions and protective measures	Information and training
0	Exempt	1, 1M	No restriction	No information needed
1	Low risk	2, 2M	Restrictions 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	3R, 3B	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	4	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	4	No access	Information about hazards, risks and secondary effects to be provided by the manufacturer

NOTE 1 Annex C, as well as the consideration of optical radiation, is based on IEC 62471:2006. IEC 62471 is under revision and will be published as IEC 62471-1 in the future. The revision of IEC 62471 is quite substantial, affecting a change from an **exposure** viewpoint to an **emission** framework: this development is (i) in line with the revision of this document, and (ii) has been followed and included here.

NOTE 2 IEC 62471:2006 or the future IEC 62471-1 are the basic documents providing full guidance on all aspects relevant for a full understanding of optical radiation hazards, a more detailed risk assessment, or measurement of **emission**.

The **manufacturer** shall define the boundary of the **EH** or **EPM installation** or **equipment** with respect to the **emission** of radiation according to the rules in Clause C.2. He shall either make use of the **emission limits** defined in Clause C.3 or make his own risk assessment based on intended use. He shall inform the **user** about the used risk classification.

NOTE 3 The risk classes for **emission** provided in this document are based on simple worst case scenarios.

Annex C does not apply to radiation **emission** from lighting.

C.2 Boundary of the installation or equipment and assessment

Emission is defined outside a boundary enclosing the **EH** or **EPM equipment** or installation as defined by the **manufacturer**. This boundary shall be defined by the surface of the equipment, or any **barriers**, doors, etc., that hinder access.

In the absence of physical boundaries, the boundary is defined as the surface up to which an **operator** is intended to near the equipment in **normal operation** or **single fault condition**. Definition and a drawing of this boundary shall be provided to the **user**.

In case of an opening in a furnace, this boundary will be defined by the plane of the outer frame of the opening unless an **operator** is intended to get into this opening during **normal operation** or **single fault condition**.

C.3 Non-coherent optical radiation – Risk classes

C.3.1 Approach

The risk classes are worded in a two-stage approach:

- 1) a general requirement, defining the risk class and to be met always;
- 2) a detailed list being based on some worst case assumptions which shall be met unless the **manufacturer** shows otherwise that the general requirement is met.

C.3.2 Optical radiation – Risk class 0

The **EH** or **EPM installation** or **equipment** does not pose any photobiological hazard inside the zone of risk class 0. Other hazards or risk may still be applicable.

NOTE Persons can stay for any time inside this risk zone without being instructed or informed about hazards from optical radiation.

This is met either for the **EH** or **EPM installation** or **equipment**, or for each single source of **accessible emission** either if it does not emit any significant radiation between 200 nm and 3 000 nm at all or the following applies.

- 1) **Accessible emission** from thermal radiation is either caused by sources with a temperature below 275°C only or is caused by surfaces of higher temperature and smaller view factor (aperture).
- 2) No part of the emitted radiation is focused outside the boundary.
- 3) In case UV or plasma are part of the intended process, it does not generate any **emission** above 1 mW m⁻² in the S(1) weighted wavelength band between 200 nm to 400 nm or any **emission** above 10 W m⁻² in the wavelength band between 315 nm to 400 nm outside the boundary.
- 4) It does not emit any radiation with a weak visual stimulus.

C.3.3 Risk class 1 (low risk)

The **EH** or **EPM installation** or **equipment** does not pose any photobiological hazard inside the zone of risk class 1 as long as normal behavioural reactions to the **emission** are upheld. Other hazards or risk may still be applicable.

Persons may stay for any time inside this risk zone. They need to be informed about risks arising from overriding their normal aversion reaction. The **user** shall be informed that any task involving an overriding of normal aversion reaction involves additional risks.

NOTE This includes long term monitoring of a process or a surface.

This is met either for the **EH** or **EPM installation** or **equipment**, or for each single source of **accessible emission** if the following applies.

- 1) **Accessible emission** from thermal radiation is either caused by surfaces with a temperature below 400 °C only or is caused from sources of higher temperature and smaller view factor (aperture).
- 2) No part of the emitted radiation is focused outside the boundary.

- 3) In case UV or plasma are part of the intended process, it does not generate any **emission** above 3 mW m^{-2} in the $S(\lambda)$ weighted wavelength band between 200 nm to 400 nm or any **emission** above 33 W m^{-2} in the wavelength band between 315 nm to 400 nm outside the boundary.
- 4) It does not emit any radiation with a weak visual stimulus.

C.3.4 Risk class 2 (moderate risk)

The **EH** or **EPM** installation or equipment does not pose any photobiological hazard inside the zone of risk class 2 as long as operators follow immediately their normal physiological aversion reaction to bright light or normal physiological aversion reaction caused by thermal discomfort.. Other hazards or risk may still be applicable.

The **manufacturer** shall advise the **user** that any intended action inside this zone is only possible with protective measures and that access restrictions are mandatory.

This is met either for the **EH** or **EPM installation** or **equipment**, or for each single source of **accessible emission** if the following applies.

- 1) **Accessible emission** from thermal radiation is either caused by surfaces with a temperature below $550 \text{ }^\circ\text{C}$ only or is caused from sources of higher temperature and smaller view factor (aperture), but not from surfaces exceeding $2\,500 \text{ }^\circ\text{C}$.
- 2) No part of the emitted radiation is focused outside the boundary.
- 3) In case UV or plasma are part of the intended process, it does not generate any **emission** above 30 mW m^{-2} in the $S(\lambda)$ weighted wavelength band between 200 nm to 400 nm or any **emission** above 100 W m^{-2} in the wavelength band between 315 nm to 400 nm outside the boundary.
- 4) It does not emit any radiation with a weak visual stimulus.

C.3.5 Risk class 3 (high risk)

Any equipment that can pose a hazard even for momentary or brief **exposure** to **accessible emission**, or which exceeds the limits for risk class 2 (moderate risk), is classified in risk class 3 (high risk).

C.3.6 Pulsed equipment

For the definition of risk classes for **accessible emission** from pulsed sources covered by this document, 6.2 of IEC 62471:2006 applies accordingly.

C.3.7 Radiation from laser sources

Coherent non-ionising radiation is emitted from lasers. Table C.1 summarises the classification of equipment according to IEC 60825-1:2014 and connects it with the classification used in Clause 4.

Annex D (normative)

Electric and magnetic fields

D.1 General

Annex D provides a classification of limits on field strength, energy flux and risk zones according to the general scheme of Table 3.

The **manufacturer** shall define the boundary of the **EH** or **EPM installation** or **equipment** with respect to the generated electric and magnetic fields emitted by the **EH** or **EPM installation** or **equipment** according to the rules in Clause D.2. He shall either make use of the **emission limits** defined in Clause D.3 or make his own risk assessment based on intended use. He shall inform the **user** about the risk classification used.

NOTE Information about **exposure** limits is given in IEC TS 62996:2017 for electric fields and in IEC TS 62997:2017 for magnetic fields. The information is provided for the understanding of the rationale behind the **emission limits** provided and to enable assessment of **emission** in special cases not covered here, especially for the **near-field region**.

D.2 Boundary of the installation or equipment and assessment

Field strength and energy flux (**emission**) are defined and measured outside the boundary enclosing the **EH** or **EPM equipment** or **installation** as defined by the **manufacturer**. This boundary is defined by the surface of the equipment, or any **barriers**, doors, etc., that hinder access or other easily identifiable surfaces, such as **enclosures**.

In the absence of physical boundaries, the boundary is defined as the surface up to which an **operator** is intended to approach the equipment in **normal operation** or **single fault condition**. The definition and a drawing of this boundary shall be provided to the **user**.

In case of an opening in a furnace, this boundary will be defined by the plane of the outer frame of the opening unless an **operator** is intended to get into this opening during **normal operation** or in **single fault condition**.

All **accessible emission** is measured at a distance of 0,25 m from the accessible surfaces or openings of the **EH** or **EPM installation** or **equipment**, unless otherwise indicated, like surfaces intended to be touched or creating a field with high curvature. Then the **manufacturer** shall provide a risk assessment based on meaningful positions.

All measurements are to be averaged over a minimum time of 1 s for frequencies below 100 kHz and 6 min for frequencies above 100 kHz. Other integration limits may be applied for intermittent operation; the **manufacturer** shall inform the **user** about the integration time used.

Disturbance of the field shall be avoided or reduced to a minimum. Objects placed near the **EH** or **EPM installation** or **equipment** or near the measurement equipment, including personnel undertaking the measurement, are root causes of such disturbances.

D.3 Risk classes

D.3.1 General

The classification depends on the assessment of field strength and energy flux over the complete range of frequencies from 0,25 Hz to 300 GHz for each single location, where the highest single **emission** band defines the risk class. More than one source can contribute to the **emission** at any position.

NOTE The risk classes are based on possible worst case **exposure** from the **EH** or **EPM installation** or **equipment** in the zone.

D.3.2 Risk class 0

The **EH** or **EPM installation** or **equipment** does not pose any hazard from electric or magnetic fields or energy flux inside the zone of risk class 0. Other hazards or risk may still be applicable.

NOTE 1 Persons can stay for any time inside this risk zone without being instructed or informed about hazards caused by electric or magnetic fields.

This is met either for the installation or equipment or for each single source of **emission** if it does not exceed the maximum permissible **exposure** (MPE) limits for the general public, as defined in IEEE C95.6 for 0 Hz to 3 000 Hz and IEEE C95.1 for 3 kHz to 300 GHz.

NOTE 2 These standards define MPEs as undisturbed homogenous fields – no person in the field; thus the definition is identical to the definition of **accessible emission** as defined in this document.

NOTE 3 Local regulations can provide other limits.

D.3.3 Risk class 1 (low risk)

The **EH** or **EPM installation** or **equipment** does not pose any hazard from electric or magnetic fields or energy flux inside the zone of risk class 1, if the **operator** is instructed about residual risks and safe practices and procedures. Persons may stay for any time inside this risk zone. Other hazards or risk may still be applicable.

No separate limits to risk class 1 are identified in this document. The wearing of active implants is not advised in risk class 1 or higher.

The **manufacturer** can identify limits to risk class 1 depending on the specifics of the **accessible emission**.

D.3.4 Risk class 2 (moderate risk)

The **EH** or **EPM installation** or **equipment** does not pose any hazard from electric or magnetic fields or energy flux inside the zone of risk class 2, if the **operator** is instructed about residual risks, safe practices and procedures. Other hazards or risk may still be applicable.

This is met either for the installation or for equipment, or for each single source of **emission** if it does not exceed the maximum permissible **exposure** limits for controlled environment, as defined in IEEE C95.6 for 0 Hz to 3 000 Hz and IEEE C95.1 for 3 kHz to 300 GHz.

NOTE 1 These standards define MPEs as undisturbed homogenous fields – no person in the field; thus the definition is identical to the definition of **accessible emission** as defined in this document.

NOTE 2 Local regulations can provide other limits.

The **manufacturer** can identify other limits to risk class 2 depending on the specifics of the **accessible emission** and the field, as long as the basic requirement for risk class 2 is upheld.

D.3.5 Risk class 3 (high risk)

Any equipment that can pose a hazard even for momentary or brief **exposure**, or which exceeds the limits for risk class 2 (moderate risk), is classified in risk class 3 (high risk).

Annex E (normative)

Surface temperature limits

Annex E provides limits for surface temperatures that can be touched. Limits for accessible surfaces in **normal operation** are provided in Table E.1.

Surfaces that are accessible but exceed these limits in **normal operation** or **single fault condition** shall be marked with symbol IEC 60417-5041:2002-10.

These limits do not apply for surfaces that are heated by their environment to higher temperatures; such surfaces do not need to be marked.

ISO 13732:2006 provides information about the effects from prolonged contact.

Table E.1 – Surface temperature limits in normal operation

Part	Surface material ^a	Limit
enclosure including doors, windows, guards and screens, barriers and obstacles , not intended to be touched	metal, uncoated or anodised	65 °C
	metal, coated with paint or other	65 °C ^b
	plastic and wood	80 °C
	glass and ceramics	80 °C
	small segregated areas, not likely to be touched	100 °C
handles, knobs and other surfaces intended to be touched	metal	55 °C
	plastic and wood	70 °C
	glass and ceramics	65 °C
^a The major constituent, defining the heat transfer rate of the part. ^b Higher temperature up to 80 °C is allowed when the thermal conductivity of the coating reduces heat transfer.		

Annex F (normative)

EH, EPM and fire

F.1 Occurrence of fire

A fire hazard occurs if combustible materials and oxidizer in sufficient quantities are in contact with each other and sufficient energy to ignite them is available – refer to the fire tetrahedron depicted in Figure 2 of ISO 19353:2019.

It is the purpose of **EH** and **EPM installations** and **equipment** to transfer heat to a **workload** in **normal operation**. **Single fault conditions** may provide heat at any other position in or near the **EH** or **EPM installation** or **equipment**. Hot surfaces, intense optical radiation, arcs, plasmas, hot gases or liquids are a feature of and are to be expected near or inside **EH installations**. Plasma or static electrical discharges can occur in **EPM installations**. Plasmas, discharges and other electric phenomenon can provide extra energy thus lowering the flame point or lead to ignition. The **normal operation** of an **EH** or **EPM installation** or **equipment** can have the purpose to

- process flammable or combustible material,
- process flammable or combustible material in oxidising atmosphere, like air, and
- raise the temperature of the **workload** above the temperature, where spontaneous ignition of the **workload** is possible or happens.

Accidents can lead to heat or hot material being distributed inside or in the vicinity of the **EH** or **EPM installation** or **equipment**.

F.2 Inherently safe design measures

In all cases where two of the three elements of the fire triangle are part of the **normal operation** of the **EH** or **EPM installation** or **equipment** and any **single fault condition** can introduce the third factor, it is impossible to achieve an inherently safe design.

F.3 Safeguarding and/or complementary protective measures

ISO 19353:2019 provides the general methodology for reducing the risk of fire through safeguarding and/or complementary protective measures.

Any of the following measures, when applicable, reduces the risk of fire, as it minimises the effect from one **single fault condition**:

- a) all measures that prevent electric spark forming at the **workload** or inside the processing volume (see Clauses 7 and 8);
- b) physical separation between electric equipment and processing volume;
- c) limiting thermal energy of materials, parts, components and **workload** – low mass, low temperature, low specific heat capacity;
- d) avoiding non-homogenous heat transfer, especially small zones of very intense power.

The following measures, when applicable, minimise a fire or its spreading:

- e) limiting or minimising availability of air; minimising air flow; minimising physical space filled with air near the **workload**;
- f) providing separate compartments for different steps of processing.

F.4 Information for use

It is obvious, as stated above, that an **EH** or **EPM installation** or **equipment**, that heats potentially flammable material or processes potentially flammable material in oxidising atmosphere, is not inherently safe. Still the **manufacturer** in his own interest shall inform the **user** of fire hazards with respect to the combination of (i) air or oxidising material, (ii) heat or other sources of energy, and (iii) flammable or ignitable material. The **manufacturer** can limit the intended **workload** to that which poses a small or negligible fire risk and instruct the **user** about this.

Only the **user** is able to limit a fire hazard through good working practice like the following:

- a) including the risk of fire in his own risk assessment;
- b) processing intended **workload** only;
- c) applying extra caution, when the **workload** is flammable or can ignite – this includes monitoring the **EH** or **EPM installation** or **equipment** or position where the hazard is pronounced and extinguish the fire at the earliest stage before it creates a hazard;
- d) not stockpiling potentially combustible material near the **EH** or **EPM installation** or **equipment**; "near" is defined as can potentially be ignited either through heat from the **EH** or **EPM installation** or **equipment**, or from fire inside the **EH** or **EPM installation** or **equipment**, or from hot material expelled or flowing from the **EH** or **EPM installation** or **equipment**;

NOTE Heat can be transferred through fields, radiation, convection, conduction, mass flow; radiation and fields can be focused, thus exceeding hazardous limits only at a distance.

- e) cleaning and removing of potentially flammable material from the **EH** or **EPM installation** or **equipment** and its surrounding before it poses a hazard – including aggregation of material inside the **EH** or **EPM installation** or **equipment**;
- f) avoiding ignition through never exceeding **normal operation** and other applicable safe procedures; this includes understanding and safeguarding procedures against overheating, overfilling and other factors that can increase the hazard of fire;
- g) carefully observing the equipment during operation, and early identification of any **single fault condition** that can – if left alone – become a source for a hazard of fire;
- h) early and full maintenance as indicated by the **manufacturer**;
- i) avoiding leakage of potentially flammable substances at or near the **EH** or **EPM installation** or **equipment**;
- j) assuring that only **skilled** and **instructed persons** can operate the **EH** or **EPM installation** or **equipment**;
- k) providing sufficient distance to other equipment and installations to hinder spread of fire between them; this includes extra measures to safeguard installations from each other;
- l) providing sufficient measures for personnel to flee in case of fire.

The **manufacturer** shall instruct the **user** about this when applicable.

Annex G (normative)

Marking and warning

G.1 Electromagnetic field hazards

All areas where **exposure** to hazardous electric or magnetic fields is expected shall be marked when they are risk class 1, risk class 2 or risk class 3 as defined in Annex D or national regulations indicate. Examples of marking presented in Figure G.1 consist of graphical symbols registered in IEC 60417 (see Table G.1 for full reference) and text labels, which state the kind of field, the class and the reference.

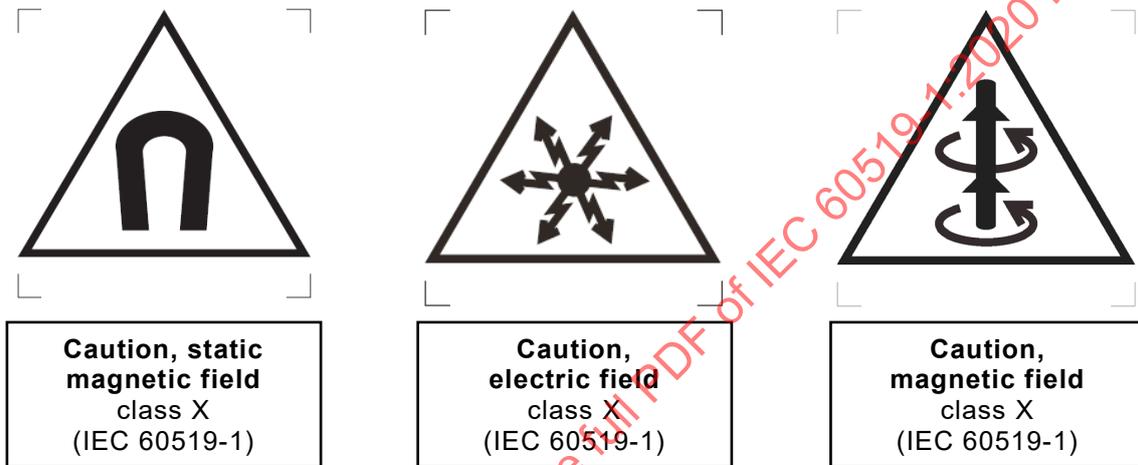


Figure G.1 – Examples of marking for magnetic and electric fields

G.2 Touch currents and surfaces

All surfaces where **exposure** to **touch currents** is expected shall be marked, when they are risk class 1, risk class 2, or risk class 3 as defined in Annex B. Examples of marking given in Figure G.2 consist of graphical symbols registered in IEC 60417 (see Table G.1 for full reference) and text labels, which state the kind of hazard, the class and the reference.

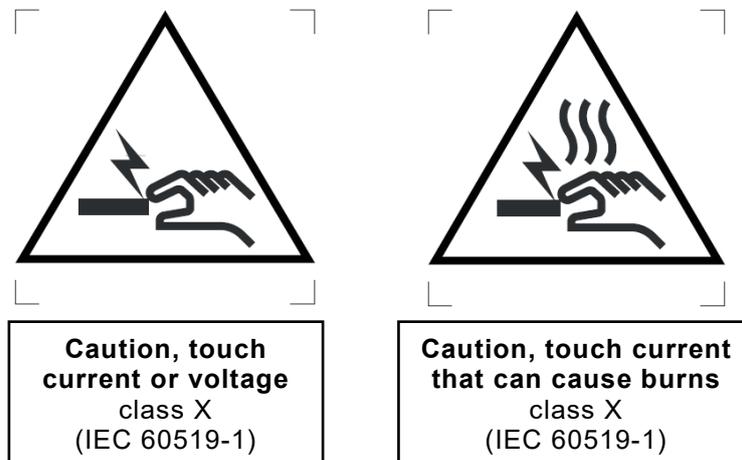


Figure G.2 – Examples of marking for touch current

G.3 Optical radiation hazards

All openings or areas where **exposure** to radiation is expected shall be marked, when they are risk class 1, risk class 2 or risk class 3 as defined in Annex C. Examples of marking given in Figure G.3 consist of graphical symbols registered in IEC 60417 (see Table G.1 for full reference) and text labels, which state the kind of hazard, the class and the reference.

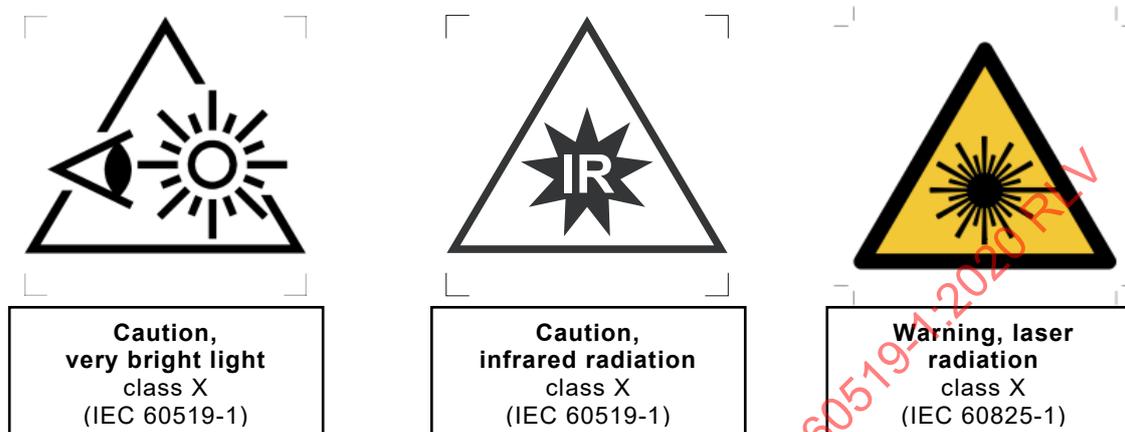


Figure G.3 – Examples of marking for optical radiation

G.4 Symbols and signs used for markings and warnings

Table G.1 provides examples of other symbols and signs applicable on **EH** and **EPM installation** or **equipment**. Applicable signs and symbols from IEC 60417, ISO 7000 or ISO 7010 shall be used to warn **operators**. Safety or warning signs and labels used on the **EH** and **EPM installation** or **equipment** shall be specified in the information for use according to 19.4.

Table G.1 – Examples of symbols and signs for use in EH or EPM installations

Symbol/sign	Reference	Description	Clause
	IEC 60417-5036:2002-10	Dangerous voltage	7
	IEC 60417-6042:2010-11	Caution, risk of electric shock	7
	IEC 60417-6204:2013-07	Caution, static magnetic field hazard	8
	IEC 60417-6205:2014-08	Caution, alternating magnetic nearfield hazard	8
	IEC 60417-6206:2013-07	Caution, electric field hazard	7, 8
	IEC 60417-6207:2013-07	Caution, touch current that can cause burns	7, 8
	IEC 60417-6208:2013-07	Caution, touch current or voltage	7, 8

Symbol/sign	Reference	Description	Clause
	IEC 60417-5019:2006-08	Protective earth; protective ground	7
	IEC 60417-6175:2012-11	Live working, unsuitable for hand-manipulation	7
	ISO 7010-P007:2011-05	No access for people with active implanted cardiac devices	8
	ISO 7010-P014:2011-05	No access for people with metallic implants	8
	ISO 7010-P008:2011-05	No metallic articles or watches	8
	IEC 60417-6166:2012-07	Caution, non-ionizing electromagnetic radiation ; Caution, microwave radiation	8, 9
	IEC 60417-6167:2012-07	Keep out of microwave radiation	8
	IEC 60417-6151:2012-02	Caution, infrared radiation	9
	IEC 60417-6069:2011-08	Caution, very bright light	9
	ISO 7010-W004:2011-05	Warning, laser radiation	9
	IEC 60417-5041:2002-10	Caution, hot surface	10
	IEC 60417-6056:2011-05	Caution, moving fan blades	6, 10, 15
	IEC 602417-6057:2011-05	Caution, moving parts	15
	IEC 60419-6182:2013-09	Installation, electrotechnical expertise	7, 19

Annex H (informative)

Guidelines on using this document

H.1 Guidelines

This document gives a large number of general requirements that can or cannot be applicable to a particular **EH** or **EPM installation** or **equipment**. A simple reference without any qualification to this document is therefore not sufficient. A **manufacturer** of an installation or equipment for which no Particular requirement exists, should use this document

- a) by selection of the most appropriate option(s) from the requirements given in the relevant clauses, and
- b) by modification of certain clauses, as necessary, where the Particular requirements for the installation or equipment are adequately covered by other relevant standards,

providing the options selected and the modifications made do not adversely affect the level of protection required for the installation.

When applying the principles listed above, it is recommended that

- reference be made to the relevant clauses and subclauses of this document that are complied with, indicating where relevant the applicable option,
- reference be made to the relevant clauses and subclauses of this document that have been modified or extended for the specific equipment requirements, and
- reference be made directly to the relevant standard, for those requirements for the **electrical equipment** that are adequately covered by that standard.

In all cases, expertise is essential to be able to

- read and understand all of the requirements of this document,
- choose the applicable requirements from this document where alternatives are given,
- identify alternative or additional Particular requirements that differ from the requirements of this document or are not included in the latter, and that are determined by the installation and its use,
- specify precisely those Particular requirements, and
- use this document for risk assessment purposes.

Figure 1 is a block diagram of a typical installation and can be used as the starting point of this task. The complementary Table 2 indicates the clauses and subclauses dealing with particular provisions or equipment. However, this document is a complex standard and Table 2 can help identify the application options for a particular installation or equipment and gives reference to other relevant standards. Further, Table 2 helps identify those requirements that are applicable and those that are not for a specific installation or equipment.

The primary responsibility of the **manufacturer** with respect to safety of **EH** or **EPM installation** or **equipment** is given in 6.1.1.

H.2 Examples of EH and EPM equipment

Typical industrial equipment in the scope of this document is used in installations with the possible use for

- direct resistance heating,
- indirect resistance heating,
- electric resistance trace heating,
- induction heating,
- using the effect of electromagnetic forces on materials for stirring or other processes,
- arc heating, including submerged arc heating,
- electroslag remelting,
- plasma heating and plasma surface treatment,
- microwave heating and microwave drying,
- dielectric heating and melting,
- processes using electron guns, like melting,
- infrared radiation heating,
- ultraviolet radiation treatment, and
- laser heating.

NOTE The list presents typical examples of applications and is not exhaustive.

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Annex I (informative)

Connection with ISO 13577 (all parts)

The ISO 13577 series of standards developed by ISO/TC 244 (Industrial furnaces and associated processing equipment) addresses the safety of all kinds of thermal processing equipment (TPE) and of industrial furnaces. These standards cover TPE using many kinds of fuels and electric energy for the generation and application of heat. The scope of ISO 13577 (all parts) and IEC 60519 (all parts) overlap in parts; therefore, Annex I provides guidance on how the scopes and their application are connected.

The **manufacturer** can derive his decision from his understanding of the TPE equipment: where any kind of fuel is the sole or basic source of heat, ISO 13577-1:2016 applies.

If the TPE is mainly a machine and involves **electroheating**, the general requirements are given from the application of ISO 13577-1:2016. At least all requirements addressing the electric heating then follow an application of this document.

If the **manufacturer** is designing an **EH** or **EPM installation** or **equipment** that is not a machine, this document is the applicable type C standard.

Both ISO 13577-1:2016 and this document are product safety publications and they cover all safety aspects of one or more products within the scope of a single product TC. Both standards reference each other where appropriate and in an unambiguous way. This document provides orientation and references to ISO 13577 (all parts) in Clause 4, Table 2 and throughout this document where indicated.

In the case a **manufacturer** uses ISO 13577-1:2016 as basic standard (type-C standard with respect to ISO 12100:2010), he will be referred to this document for requirements concerning electrical safety, **electroheating**, direct or indirect contact to **hazardous-live parts** and effects of electrical overload. It can then be possible to make use only of Clauses 7 and 8 as well as applicable parts of Clauses 13, 14 and 18 including the related annexes of this document.

Annex J (informative)

Requirements specific to the EU and associated countries

J.1 General

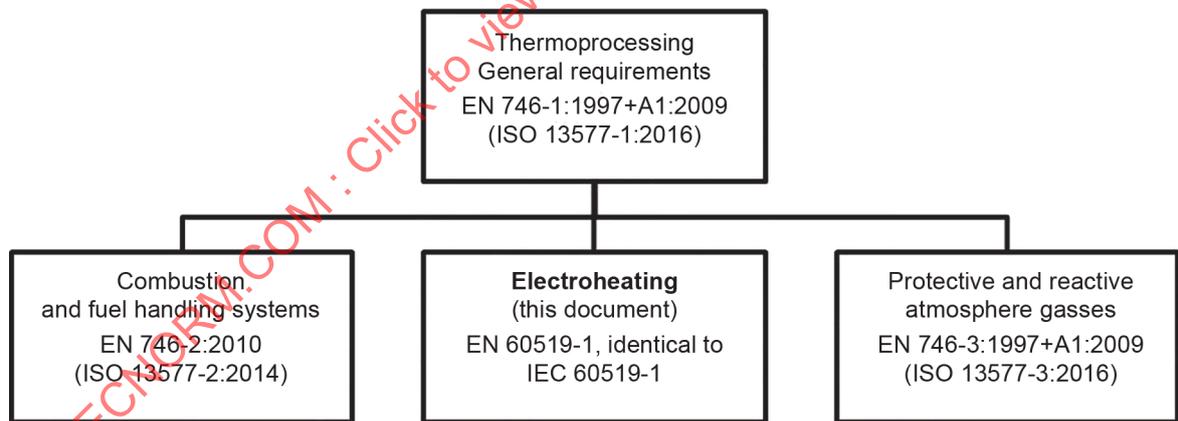
The specific regional requirements given in Annex J are applicable to the EU and associated countries. The requirements of Annex J shall ensure a level of safety at least equivalent to the main body of this document.

J.2 Connection with ISO 13577 series

This document conform with the safety objectives of the Directive 2014/35/EU (Low Voltage Directive) and shall be cited in the Official Journal of the EU (OJEU) under that directive in due time. This document generally conforms with the safety objectives of the Directive 2006/42/EC (Machinery Directive) as well, but is not intended to be published under this directive in the OJEU.

In case the **manufacturer** designs thermoprocessing equipment that is a machine and involves **electroheating**, the general requirements are given from the application of ISO 13577-1:2016. The Particular requirements then follow from a joint application of other parts of the ISO 13577 series and for all aspects connected to **electroheating** from this document. This connection is illustrated in Figure J.1.

NOTE A machine is defined in the Machinery Directive of the European Union 2006/42/EC as "an assembly, fitted with or intended to be fitted with a drive system other than directly applied human or animal effort, consisting of linked parts or components, at least one of which moves, and which are joined together for a specific application".



IEC

Figure J.1 – Hierarchy of standards applicable to thermoprocessing machinery

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COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

**SÉCURITÉ DANS LES INSTALLATIONS DESTINÉES AU TRAITEMENT
ÉLECTROTHERMIQUE ET ÉLECTROMAGNÉTIQUE –****Partie 1: Exigences générales****AVANT-PROPOS**

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La Norme internationale IEC 60519-1 a été établie par le comité d'études 27 de l'IEC: Chauffage électrique industriel et traitement électromagnétique.

Cette sixième édition annule et remplace la cinquième édition parue en 2015. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

- a) suppression du bruit du domaine d'application;
- b) clarification des exigences relatives à la CEM;

- c) classification des risques associés aux dangers, fondée sur l'émission pour toutes les fréquences de traitement;
- d) clarification des limites entre l'IEC 60519 (toutes les parties) et l'ISO 13577 (toutes les parties).

Le texte de cette Norme internationale est issu des documents suivants:

FDIS	Rapport de vote
27/1121/FDIS	27/1123/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à l'approbation de cette Norme internationale.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2.

Dans le présent document, les caractères d'imprimerie suivants sont utilisés:

- exigences et définitions: caractères romains;
- NOTES: petits caractères romains;
- **termes** utilisés dans l'ensemble de la présente norme qui ont été définis à l'Article 3: **caractères gras**.

Une liste de toutes les parties de la série IEC 60519, publiées sous le titre général *Sécurité dans les installations destinées au traitement électrothermique et électromagnétique*, peut être consultée sur le site web de l'IEC.

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INTRODUCTION

Les présentes exigences générales s'appliquent à tous les **équipements** industriels **EH** et **EPM**, à moins qu'une exception ne soit indiquée dans les Exigences particulières traitant d'un équipement spécifique dans d'autres parties de la série IEC 60519. Les dispositions des autres parties de la série IEC 60519 qui s'appliquent directement à des types spécifiques d'équipement prévalent sur les dispositions du présent document.

L'Annexe I et l'Annexe J fournissent une orientation quant à l'application de l'ISO 13577-1 conjointement au présent document.

Le présent document part du principe que les installations ou les équipements sont exploités et entretenus exclusivement par un personnel composé de **personnes qualifiées ou averties**.

Le présent document est destiné à vérifier que l'**installation** ou l'**équipement EH** ou **EPM** satisfait à ses exigences de sécurité en matière de conception, d'essais d'acceptation sur site, d'essais individuels de série ou d'examen.

L'Annexe H fournit un guide d'utilisation du présent document et une liste de processus industriels **EH** et **EPM** types.

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SÉCURITÉ DANS LES INSTALLATIONS DESTINÉES AU TRAITEMENT ÉLECTROTHERMIQUE ET ÉLECTROMAGNÉTIQUE –

Partie 1: Exigences générales

1 Domaine d'application

La présente partie de l'IEC 60519 spécifie les exigences générales de sécurité relatives aux installations ou équipements industriels destinés à l'**électrothermie (EH)** et aux technologies de traitement fondées sur l'**électrothermie** ainsi qu'au **traitement électromagnétique des matériaux (EPM)**. Le présent document traite des dangers significatifs, des situations dangereuses ou des événements dangereux liés aux **équipements** industriels **EH** et **EPM**, tels qu'ils sont répertoriés dans l'Annexe A, dans des **conditions de fonctionnement normal** et en **condition de premier défaut** ainsi que dans des conditions de mauvaise utilisation raisonnablement prévisibles.

Le présent document spécifie les exigences destinées à être satisfaites par le **constructeur** pour assurer la sécurité des personnes et des biens pendant le cycle de vie complet de l'équipement, de sa conception à sa mise en service, son exploitation, sa maintenance, son examen, jusqu'à sa mise à l'arrêt définitif, ainsi qu'en cas de **condition de premier défaut** prévisible pouvant se produire dans l'équipement.

La tension assignée des **équipements EH** et **EPM** peut se situer dans la plage de basse tension; des informations détaillées sont fournies en 4.2.

Le présent document ne s'applique pas aux équipements et appareils couverts par les domaines d'application de:

- l'IEC 60079 (toutes les parties) – c'est-à-dire les équipements destinés à l'utilisation dans des atmosphères potentiellement explosives;
- l'IEC 60335 (toutes les parties) – c'est-à-dire les appareils électrodomestiques, commerciaux et analogues, y compris le chauffage de locaux;
- l'IEC 60601 (toutes les parties) – c'est-à-dire l'équipement électromédical;
- l'IEC 60974 (toutes les parties) – c'est-à-dire le matériel de soudage à l'arc;
- l'IEC 61010 (toutes les parties) – c'est-à-dire le matériel utilisé en laboratoire.

Le présent document ne spécifie pas les exigences relatives aux essais de type.

NOTE L'équipement industriel couvert par le présent document est généralement produit sous la forme d'une seule unité ou d'un petit nombre d'unités; une telle unité a généralement une très grande valeur et peut provoquer de graves dommages en cas de désintégration.

Le présent document ne traite pas de la sécurité des données ni des dangers engendrés par un défaut de sûreté.

2 Références normatives

Les documents suivants cités dans le texte constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60071-1:2006¹, *Coordination de l'isolement – Partie 1: Définitions, principes et règles*
IEC 60071-1:2006/AMD1:2010

IEC 60204-1:2016, *Sécurité des machines – Équipement électrique des machines – Partie 1: Exigences générales*

IEC 60204-11:2018, *Sécurité des machines – Équipement électrique des machines – Partie 11: Exigences pour les équipements fonctionnant à des tensions supérieures à 1 000 V en courant alternatif ou 1 500 V en courant continu et ne dépassant pas 36 kV*

IEC 60228:2004, *Âmes des câbles isolés*

IEC 60335-1:2010², *Appareils électrodomestiques et analogues – Sécurité – Partie 1: Exigences générales*

IEC 60335-1:2010/AMD1:2013

IEC 60335-1:2010/AMD2:2016

IEC 60335-2-24, *Appareils électrodomestiques et analogues – Sécurité – Partie 2-24: Règles particulières pour les appareils de réfrigération, les sorbetières et les fabriques de glace*

IEC 60335-2-89, *Appareils électrodomestiques et analogues – Sécurité – Partie 2-89: Exigences particulières pour les appareils de réfrigération et fabriques de glace à usage commercial avec une unité de fluide frigorigène ou un motocompresseur incorporés ou à distance*

IEC 60364-1:2005, *Installations électriques à basse tension – Partie 1: Principes fondamentaux, détermination des caractéristiques générales, définitions*

IEC 60364-4-41:2005³, *Installations électriques à basse tension – Partie 4-41: Protection pour assurer la sécurité – Protection contre les chocs électriques*

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

IEC 60364-4-42:2010⁴, *Installations électriques basse tension – Partie 4-42: Protection pour assurer la sécurité – Protection contre les effets thermiques*

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

IEC 60364-4-44:2007⁵, *Installations électriques à basse tension – Partie 4-44: Protection pour assurer la sécurité – Protection contre les perturbations de tension et les perturbations électromagnétiques*

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

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

¹ Il existe une version consolidée de cette publication comprenant l'IEC 60071-1:2006 et l'IEC 60071-1:2006/AMD1:2010.

² Il existe une version consolidée de cette publication comprenant l'IEC 60335-1:2010, l'IEC 60335-1:2010/AMD1:2013 et l'IEC 60335-1:2010/AMD2:2016.

³ Il existe une version consolidée de cette publication comprenant l'IEC 60364-4-41:2005 et l'IEC 60364-4-41:2005/AMD1:2017.

⁴ Il existe une version consolidée de cette publication comprenant l'IEC 60364-4-42:2010 et l'IEC 60364-4-42:2010/AMD1:2014.

⁵ Il existe une version consolidée de cette publication comprenant l'IEC 60364-4-44:2007, l'IEC 60364-4-44:2007/AMD1:2015 et l'IEC 60364-4-44:2007/AMD2:2018.

IEC 60364-5-53:2001⁶, *Installations électriques des bâtiments – Partie 5-53: Choix et mise en œuvre des matériels électriques – Sectionnement, coupure et commande*
IEC 60364-5-53:2001/AMD1:2002
IEC 60364-5-53:2001/AMD2:2015

IEC 60364-5-54:2011, *Installations électriques basse-tension – Partie 5-54: Choix et mise en œuvre des matériels électriques – Installations de mise à la terre et conducteurs de protection*

IEC 60398:2015, *Installations pour traitement électrothermique et électromagnétique – Méthodes générales d'essai de fonctionnement*

IEC 60417, *Symboles graphiques utilisables sur le matériel* (disponible à l'adresse <http://www.graphical-symbols.info/equipment>)

IEC 60445:2017, *Principes fondamentaux et de sécurité pour les interfaces homme-machine, le marquage et l'identification – Identification des bornes de matériels, des extrémités de conducteurs et des conducteurs*

IEC 60529:1989, *Degrés de protection procurés par les enveloppes (Code IP)*

IEC 60664-1:2007, *Coordination de l'isolement des matériels dans les systèmes (réseaux) à basse tension – Partie 1: Principes, exigences et essais*

IEC 60825-1:2014, *Sécurité des appareils à laser – Partie 1: Classification des matériels et exigences*

IEC 60865-1:2011, *Courants de court-circuit – Calcul des effets – Partie 1: Définitions et méthodes de calcul*

IEC 60909-0:2016, *Courants de court-circuit dans les réseaux triphasés à courant alternatif – Partie 0: Calcul des courants*

IEC 60990:2016, *Méthodes de mesure du courant de contact et du courant dans le conducteur de protection*

IEC 61000-6-2:2016, *Compatibilité électromagnétique (CEM) – Partie 6-2: Normes génériques – Norme d'immunité pour les environnements industriels*

IEC 61000-6-7:2014, *Compatibilité électromagnétique (CEM) – Partie 6-7: Normes génériques – Exigences d'immunité pour les équipements visant à exercer des fonctions dans un système lié à la sécurité (sécurité fonctionnelle) dans des sites industriels*

IEC 61010-1:2010, *Règles de sécurité pour appareils électriques de mesurage, de régulation et de laboratoire – Partie 1: Exigences générales*

IEC 61082-1:2014, *Établissement des documents utilisés en électrotechnique – Partie 1: Règles*

IEC 61310-1:2007, *Sécurité des machines – Indication, marquage, manœuvre – Partie 1: Exigences pour les signaux visuels, acoustiques et tactiles*

IEC 61310-2:2007, *Sécurité des machines – Indication, marquage, manœuvre – Partie 2: Exigences pour le marquage*

⁶ Il existe une version consolidée de cette publication comprenant l'IEC 60364-5-53:2001, l'IEC 60364-5-53:2001/AMD1:2002 et l'IEC 60364-5-53:2001/AMD2:2015.

IEC 61310-3:2007, *Sécurité des machines – Indication, marquage, manœuvre – Partie 3: Exigences sur la position et le fonctionnement des organes de commande*

IEC 61439 (toutes les parties), *Ensembles d'appareillage à basse tension*

IEC 61508-1:2010, *Sécurité fonctionnelle des systèmes électriques/électroniques/électroniques programmables relatifs à la sécurité – Partie 1: Exigences générales*

IEC 61786-1:2013, *Mesure de champs magnétiques continus et de champs magnétiques et électriques alternatifs dans la plage de fréquences de 1 Hz à 100 kHz dans leur rapport à l'exposition humaine – Partie 1: Exigences applicables aux instruments de mesure*

IEC 61786-2:2014, *Mesure de champs magnétiques continus et de champs magnétiques et électriques alternatifs dans la plage de fréquences de 1 Hz à 100 kHz dans leur rapport à l'exposition humaine – Partie 2: Norme de base pour les mesures*

IEC 61936-1:2010⁷, *Installations électriques en courant alternatif de puissance supérieure à 1 kV – Partie 1: Règles communes*
IEC 61936-1:2010/AMD1:2014

IEC 62061:2005⁸, *Sécurité des machines – Sécurité fonctionnelle des systèmes de commande électriques, électroniques et électroniques programmables relatifs à la sécurité*
IEC 62061:2005/AMD1:2012
IEC 62061:2005/AMD2:2015

IEC 62271 (toutes les parties), *Appareillage à haute tension*

IEC 62471:2006, *Sécurité photobiologique des lampes et des appareils utilisant des lampes*

IEC 82079-1:2012, *Établissement des instructions d'utilisation – Structure, contenu et présentation – Partie 1: Principes généraux et exigences détaillées*

CISPR 11:2015⁹, *Appareils industriels, scientifiques et médicaux – Caractéristiques de perturbations radioélectriques – Limites et méthodes de mesure*
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, *Symboles graphiques – Couleurs de sécurité et signaux de sécurité – Partie 1: Principes de conception pour les signaux de sécurité et les marquages de sécurité*

ISO 6385:2016, *Principes ergonomiques de la conception des systèmes de travail*

⁷ Il existe une version consolidée de cette publication comprenant l'IEC 61936-1:2010 et l'IEC 61936-1:2010/AMD1:2014.

⁸ Il existe une version consolidée de cette publication comprenant l'IEC 62061:2005, l'IEC 62061:2005/AMD1:2012 et l'IEC 62061:2005/AMD2:2015.

⁹ Il existe une version consolidée de cette publication comprenant la CISPR 11:2015, la CISPR 11:2015/AMD1:2016 et la CISPR 11:2015/AMD2:2019.

ISO 7000, *Symboles graphiques utilisables sur le matériel* (disponible à l'adresse <http://www.graphical-symbols.info/equipment>)

ISO 7010, *Symboles graphiques – Couleurs de sécurité et signaux de sécurité – Signaux de sécurité enregistrés*

ISO 12100:2010, *Sécurité des machines – Principes généraux de conception – Appréciation du risque et réduction du risque*

ISO 13577-1:2016, *Industrial furnaces and associated processing equipment – Safety – Part 1: General requirements* (disponible en anglais seulement)

ISO 13577-2:2014, *Industrial furnaces and associated processing equipment – Safety – Part 2: Combustion and fuel handling systems* (disponible en anglais seulement)

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

ISO 13732-1:2006, *Ergonomie des ambiances thermiques – Méthodes d'évaluation de la réponse humaine au contact avec des surfaces – Partie 1: Surfaces chaudes*

ISO 13849-1:2015, *Sécurité des machines – Parties des systèmes de commande relatives à la sécurité – Partie 1: Principes généraux de conception*

ISO 13850:2015, *Sécurité des machines – Fonction d'arrêt d'urgence – Principes de conception*

ISO 13855:2010, *Sécurité des machines – Positionnement des moyens de protection par rapport à la vitesse d'approche des parties du corps*

ISO 13857:2008, *Sécurité des machines – Distances de sécurité empêchant les membres supérieurs et inférieurs d'atteindre les zones dangereuses*

ISO 14119:2013, *Sécurité des machines – Dispositifs de verrouillage associés à des protecteurs – Principes de conception et de choix*

ISO 14120:2015, *Sécurité des machines – Protecteurs – Prescriptions générales pour la conception et la construction des protecteurs fixes et mobiles*

ISO 14159:2002, *Sécurité des machines – Prescriptions relatives à l'hygiène lors de la conception des machines*

ISO 19353:2019, *Sécurité des machines – Prévention et protection contre l'incendie*

3 Termes, définitions et termes abrégés

Pour les besoins du présent document, les termes et définitions suivants s'appliquent.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse <http://www.electropedia.org/>
- ISO Online browsing platform: disponible à l'adresse <http://www.iso.org/obp>

3.1 Concepts généraux

3.1.1

électrothermie

EH

DÉCONSEILLÉ: énergie électrothermique

conversion de l'énergie électrique en chaleur à des fins d'utilisation

Note 1 à l'article: L'abréviation "EH" est dérivée du terme anglais développé correspondant "electroheating".

3.1.2

traitement électromagnétique des matériaux

EPM

interaction entre une énergie ou des forces électromagnétiques et des matériaux à des fins d'utilisation

Note 1 à l'article: L'**EPM** peut inclure le chauffage, entre autres.

Note 2 à l'article: L'abréviation "EPM" est dérivée du terme anglais développé correspondant "electromagnetic processing of materials".

3.1.3

champ électromagnétique

EMF

champ électrique ou magnétique ou une combinaison de champs électriques et magnétiques à variation temporelle

Note 1 à l'article: L'abréviation "EMF" est dérivée du terme anglais développé correspondant "electromagnetic field".

3.1.4

rayonnement électromagnétique

propagation du **champ électromagnétique** transportant l'énergie

EXEMPLE Rayonnement d'hyperfréquences ou rayonnement optique (infrarouge, visible et ultraviolet).

3.1.5

région de champ proche

<d'un champ électromagnétique> région proche d'une antenne où prédominent les effets d'un **champ électromagnétique** ne se propageant pas

Note 1 à l'article: La **région de champ proche** est encore subdivisée en **région de champ proche** réactif, qui est la plus proche de la structure rayonnante et qui contient la plus grande partie de l'énergie stockée, et en **région de champ proche** rayonnant où le champ de rayonnement prédomine sur le champ réactif, mais ne présente pas le caractère essentiel d'onde plane et a une structure complexe.

Note 2 à l'article: La partie non rayonnante des **champs électromagnétiques** prédomine nettement dans une région s'étendant sur une distance d'environ 0,5 longueur d'onde à partir de l'antenne.

3.1.6

constructeur

producteur de l'**équipement** ou de l'**installation EH** ou **EPM** responsable de la conformité au présent document

Note 1 à l'article: Selon le sens entendu par ce document, le **constructeur** peut être également un fournisseur, un distributeur, un importateur ou un mandataire.

3.1.7

utilisateur

partie responsable de l'exploitation et de la maintenance de l'**équipement** ou de l'**installation EH** ou **EPM**, de la mise en service jusqu'à la mise à l'arrêt définitif

3.1.8

personne qualifiée

personne formée

personne ayant la formation, les connaissances et l'expérience appropriées pour lui permettre de percevoir les risques et d'éviter les dangers que peut présenter le type d'installation ou d'équipement, y compris de superviser les **personnes averties**

Note 1 à l'article: Le terme **personne formée** est utilisé dans l'ISO 13577 (toutes les parties).

3.1.9

personne avertie

personne informée ou surveillée par des **personnes qualifiées** pour lui permettre de percevoir les risques et d'éviter les dangers que peut présenter une installation ou un équipement

3.1.10

opérateur

personne qualifiée ou **avertie** réalisant une ou plusieurs tâches lors de l'exploitation, du réglage, de la maintenance, de la réparation ou du démontage d'une installation ou d'un équipement

3.1.11

personne ordinaire

personne ni formée ni qualifiée qui n'est pas en mesure de percevoir les risques et d'éviter les dangers, pour laquelle une **exposition** peut être nocive à des niveaux inférieurs à ceux des **opérateurs**

EXEMPLE Personne appartenant au grand public: femme enceinte, personne âgée ou handicapée, mais pas un enfant.

3.1.12

vide

pression inférieure à 30 000 Pa

Note 1 à l'article: Défini comme une pression inférieure à toute pression environnementale s'exerçant sur la surface terrestre.

Note 2 à l'article: Le **vide** est divisé en plages de pression, comme suit:

- **vide** grossier de 100 Pa à 10 000 Pa;
- **vide** moyen de 0,1 Pa à 100 Pa;
- **vide** poussé de 10^{-5} Pa à 0,1 Pa;
- **ultravide** au-dessous de 10^{-5} Pa.

3.2 Équipement et état de l'équipement

3.2.1

équipement électrique

ensemble d'éléments utilisés pour générer, convertir, transmettre, distribuer ou utiliser l'énergie électrique, tels que les convertisseurs, les transformateurs, les condensateurs, l'appareillage, les appareils de mesure, **les dispositifs de protection** et les canalisations

3.2.2

équipement électrothermique

équipement EH

DÉCONSEILLÉ: équipement d'électrothermie

équipement dans lequel le travail électrique est converti en chaleur à des fins d'utilisation

Note 1 à l'article: L'abréviation "EH" est dérivée du terme anglais développé correspondant "electroheating".

3.2.3

équipement de traitement électromagnétique des matériaux équipement EPM

équipement dans lequel une énergie ou une force électromagnétique est fournie pour le **traitement électromagnétique des matériaux**

Note 1 à l'article: L'abréviation "EPM" est dérivée du terme anglais développé correspondant "electromagnetic processing of materials".

3.2.4

installation électrothermique installation EH

DÉCONSEILLÉ: installation d'électrothermie

installation composée d'**équipements électrothermiques**, d'**équipements électriques** et d'équipements mécaniques nécessaires à son fonctionnement et son exploitation

Note 1 à l'article: L'abréviation "EH" est dérivée du terme anglais développé correspondant "electroheating".

3.2.5

installation de traitement électromagnétique des matériaux installation EPM

installation composée d'**équipements de traitement électromagnétique des matériaux**, d'**équipements électriques** et d'équipements mécaniques nécessaires à son fonctionnement et son exploitation

Note 1 à l'article: L'abréviation "EPM" est dérivée du terme anglais développé correspondant "electromagnetic processing of materials".

3.2.6

conditions de fonctionnement normal

fonctionnement de l'installation ou de l'équipement comme cela est spécifié par le **constructeur**, en accord avec l'**utilisateur**

3.2.7

charge de travail

objet ou matériau en cours de traitement

Note 1 à l'article: Le terme "charge" a une signification différente. Il est utilisé et défini en conséquence dans les Exigences particulières de l'IEC 60519 (toutes les parties), le cas échéant.

3.2.8

condition de premier défaut

condition dans laquelle il existe un défaut d'une protection simple (mais pas d'une protection renforcée), d'un composant ou d'un dispositif unique

Note 1 à l'article: Si une **condition de premier défaut** engendre une ou plusieurs autres conditions de défaut, toutes sont considérées comme une seule **condition de premier défaut**.

Note 2 à l'article: Une **condition de premier défaut** peut ou peut ne pas avoir une incidence sur le processus ou le fonctionnement prévu de l'**installation** ou de l'**équipement EH** ou **EPM**.

Note 3 à l'article: Un incident qui provoque l'arrêt du **fonctionnement normal**, qui cause directement des dangers ou qui entraîne une désintégration directe de l'**installation** ou de l'**équipement EH** ou **EPM** ou de pièces de ceux-ci n'est pas une **condition de premier défaut** au sens de cette définition; il s'agit alors d'un dommage majeur, d'une avarie, d'un accident.

[SOURCE: IEC Guide 104:2019, 3.8, modifiée – Les Notes 2 et 3 ont été ajoutées.]

3.2.9

condition de premier défaut électrique

état dans lequel un moyen de protection contre les chocs électriques est défectueux ou un défaut est présent, ce qui peut entraîner un danger

Note 1 à l'article: Une **condition de premier défaut électrique** est identique à une **condition de premier défaut** telle que définie dans l'IEC 61140:2016.

[SOURCE: IEC 61140:2016, 3.1.4, modifiée – Le terme original "condition de premier défaut" a été remplacé par "**condition de premier défaut électrique**" et la note a été remplacée par une nouvelle note.]

3.2.10

fréquence de traitement

DÉCONSEILLÉ: fréquence de production

fréquence de fonctionnement de l'**équipement** ou de l'**installation EH** ou **EPM** à laquelle le courant ou le champ est appliqué à la **charge de travail**

Note 1 à l'article: Des plages spécifiques de **fréquences de traitement** sont définies dans le Tableau 1.

3.3 Pièces et accessoires

3.3.1

enveloppe

enceinte assurant le type et le degré de protection approprié pour l'application prévue

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

3.3.2

fenêtre

partie d'une **enveloppe** qui permet le passage d'un certain type de rayonnement

3.3.3

barrière

objet physique limitant l'accès à l'**équipement** ou à l'**enveloppe** de cet équipement, qui peut être seulement retiré au moyen d'un outil ou est verrouillé

Note 1 à l'article: Une **barrière** peut être physiquement séparée de l'équipement, mais fait partie intégrante de l'installation.

Note 2 à l'article: Les **barrières** sont généralement transparentes au champ électrique, magnétique ou au rayonnement de traitement.

3.3.4

protecteur

barrière intégrée à l'équipement

3.3.5

obstacle

élément empêchant l'accès, qui est fixé pour éviter sa suppression accidentelle, mais retirable sans outil ni clé

3.3.6

dispositif de protection

<électrique>

dispositif électrique qui réduit un risque

EXEMPLE Commande bimanuelle, tapis ou bord sensible à la pression, barre et câble de déclenchement, rideau lumineux, scanner à laser.

3.3.7

écran

dispositif destiné à réduire la pénétration d'un **champ** électrique, magnétique ou **électromagnétique** dans une région déterminée

[SOURCE: IEC 60050-151:2001, 151-13-09, modifiée – Le deuxième terme "blindage (électromagnétique)" a été omis.]

3.3.8

verrouillage

dispositif ou système **de protection** mécanique ou électrique empêchant une action qui peut présenter un danger

3.3.9

coupe-circuit thermique

protecteur thermique

dispositif qui coupe l'alimentation de l'équipement lorsqu'une température prédéterminée est dépassée

Note 1 à l'article: Les **coupe-circuits thermiques** ne sont pas réarmables et sont remplacés à chaque fois qu'ils ont fonctionné; les **protecteurs thermiques** sont réarmables.

3.3.10

applicateur portatif

dispositif facilement déplaçable permettant d'appliquer un champ électrique ou magnétique ou un **rayonnement électromagnétique** à une **charge de travail**

EXEMPLE Applicateurs par contact qui sont en contact direct avec la **charge de travail** à traiter; applicateurs par insertion à insérer dans la **charge de travail**; applicateurs à bobine comme les bobines d'induction portatives; lampes et luminaires irradiant une **charge de travail**.

Note 1 à l'article: "Facilement déplaçable" implique la légèreté.

3.3.11

moyens d'accès

toutes les caractéristiques de l'**installation** ou de l'**équipement EH** ou **EPM** qui peuvent être ouvertes ou retirées et permettent d'accéder à un danger ou à une zone de danger

Note 1 à l'article: Les **moyens d'accès** peuvent faire partie intégrante de l'**enveloppe**, des **obstacles** ou des **portes**.

Note 2 à l'article: Les **moyens d'accès** peuvent être fixés à l'aide d'un **verrouillage**.

3.4 Concepts relatifs à la sécurité

3.4.1

essai fonctionnel

manière d'essayer les fonctions d'un système sans prendre en compte sa structure interne

[SOURCE: IEC TR 62059-11:2002, 3.6, modifiée – La note a été supprimée.]

3.4.2

partie active

conducteur ou partie conductrice destiné à être sous tension en **service normal**, y compris le conducteur de neutre, mais par convention, excepté le conducteur PEN, le conducteur PEM ou le conducteur PEL

Note 1 à l'article: La notion n'implique pas nécessairement un risque de choc électrique.

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

3.4.3

partie active dangereuse

partie active qui peut provoquer, dans certaines conditions, un choc électrique nuisible

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

3.4.4

zone de danger haute tension

zone limitée par un espace minimal autour des **parties actives dangereuses** de l'équipement haute tension sans protection complète contre le contact direct

Note 1 à l'article: Pénétrer dans une **zone de danger haute tension** est considéré comme étant équivalent à toucher des **parties actives dangereuses**.

3.4.5

tension de contact effective

tension entre des parties conductrices touchées simultanément par une personne ou un animal

Note 1 à l'article: La valeur de la **tension de contact effective** peut être sensiblement influencée par l'impédance de la personne ou de l'animal en contact électrique avec ces parties conductrices.

[SOURCE: IEC 60050-195:1998, 195-05-11, modifiée – L'autre terme "tension de toucher effective" n'est pas utilisé dans le présent document.]

3.4.6

courant de contact

courant électrique traversant le corps d'une personne ou d'un animal lorsqu'une **tension de contact effective** est présente et un chemin électrique disponible

3.4.7

courant de fuite

courant électrique qui, dans des conditions normales de fonctionnement, s'écoule à travers un chemin électrique non désiré

3.4.8

choc électrique induit

effet physiologique causé par un champ électrique induit à l'intérieur du corps humain

Note 1 à l'article: Effet généralement observé dans la **région de champ proche** d'un **champ électromagnétique**; il ne nécessite pas le contact avec un conducteur. Les effets sont essentiellement les mêmes que ceux d'un choc électrique causé par contact avec un conducteur, par exemple une brûlure ou une réaction nerveuse.

3.4.9

isolation

matériaux isolants nécessaires pour assurer le fonctionnement convenable de l'équipement et la protection contre les chocs électriques

Note 1 à l'article: L'**isolation** fait également référence à l'action d'**isolation**.

Note 2 à l'article: Dans certaines circonstances, le matériau d'**isolation** thermique peut également exécuter la fonction d'**isolation** électrique.

3.4.10

isolation principale

isolation des **parties actives dangereuses** qui assure la protection principale

Note 1 à l'article: Cette notion n'est pas applicable à l'**isolation** exclusivement utilisée à des fins fonctionnelles.

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

3.4.11

séparation électrique

séparation galvanique (terme déconseillé)

action ou moyen d'empêcher la conduction électrique entre deux circuits électriques prévus pour échanger de la puissance ou des signaux

Note 1 à l'article: Une **séparation électrique** peut être obtenue, par exemple, au moyen d'un transformateur de séparation (de circuits) ou d'un optocoupleur.

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

3.4.12

émission

<en tant que concept> énergie émise par une source sous la forme d'un champ, de particules, d'un agent chimique, d'une pression ou d'un autre agent physique

3.4.13

émission

<pour l'évaluation> énergie détectable émise par et détectable en dehors des limites d'une **installation** ou d'un **équipement EH** ou **EPM** en l'absence d'un individu ou d'un animal perturbant le champ ou l'écoulement de l'énergie

3.4.14

exposition

réception ou absorption par une personne ou un animal de l'énergie émise

Note 1 à l'article: La détermination de l'énergie absorbée peut nécessiter la présence de la personne exposée ou de l'animal exposé lors de l'**émission**.

3.4.15

émission accessible

niveau de rayonnement ou champ déterminé à une distance donnée de l'**installation** ou de l'**équipement EH** ou **EPM** et accessible dans des **conditions de fonctionnement normal** ou en **condition de premier défaut**

3.4.16

limite d'émission

émission accessible maximale admise pour une classe de risque particulière

3.5 Termes abrégés

EH **electroheating (électrothermie)**

TBT très basse tension (au-dessous de 50 V à la fréquence du réseau)

CEM compatibilité électromagnétique

EPM **electromagnetic processing of materials (traitement électromagnétique des matériaux)**

HT haute tension (au-dessus de 1 000 V à la fréquence du réseau)

IR infrared radiation (rayonnement infrarouge)

LED light-emitting diode (diode électroluminescente)

BT basse tension (plage entre 50 V et 1 000 V à la fréquence du réseau)

MW microwave (hyperfréquences)

PE protective earthing conductor (conducteur de terre de protection)

PEL protective earthing conductor being a line conductor as well (conducteur de terre de protection, qui est également un conducteur de ligne)

PEM protective earthing conductor being a mid-point conductor as well (conducteur de terre de protection, qui est également un conducteur médian)

PEN protective earthing conductor being a neutral conductor as well (conducteur de terre de protection, qui est également un conducteur neutre)

DAS débit d'absorption spécifique (d'énergie)

UV ultraviolet radiation (rayonnement ultraviolet)

VIS visible radiation (rayonnement visible)

4 Classification et subdivision des équipements et des installations

4.1 Classification par fréquence de traitement

Les installations et équipements EH et EPM sont classés en fonction de leur fréquence de traitement. Le Tableau 1 répertorie les types d'équipements et leurs plages de fréquences de traitement ainsi que leurs limites de fréquence relatives à la sécurité. Une installation EH ou EPM peut inclure plusieurs types d'équipements EH ou EPM.

Tableau 1 – Équipements, fréquence de traitement et limites de fréquence relatives à la sécurité

Type d'équipement	Plage de fréquences ^a définissant le type d'équipement	Plage de fréquences ^b utilisée pour les limites de sécurité	Dangers associés à la plage de fréquences
Courant continu ^c ou champ stationnaire	0 Hz	0 Hz ou pas de changement de polarité	Choc électrique, stimulus nerveux, étourdissement
Basse fréquence	> 0 Hz à < 60 Hz		Choc électrique, brûlure, pas de lâcher-prise, stimulus nerveux
Fréquence du réseau	50 Hz ou 60 Hz		
Moyenne fréquence	> 60 Hz à 100 kHz	> 60 Hz à 100 kHz	Brûlure, échauffement de parties du corps
Haute fréquence	> 100 kHz à 0,3 GHz	> 100 kHz à 6 MHz	
		> 6 MHz à 0,3 GHz	Échauffement de parties du corps
Hyperfréquences	> 0,3 GHz à 300 GHz		Brûlure de la peau et de la cornée
Infrarouge	780 nm à 1 mm	IR-C 3 000 nm à 1 mm	
		IR-B 1 400 nm à 3 000 nm	
		IR-A 780 nm à 1 400 nm	Brûlure de la peau et de la cornée,
Visible	400 nm à 780 nm		brûlure de la rétine
Ultraviolet ^d	10 nm à 400 nm	UV-A 315 nm à 400 nm	Brûlure de la peau et de la cornée, cancer de la peau
		UV-B 280 nm à 315 nm	
		UV-C 100 nm à 280 nm	
		EUV 10 nm à 100 nm	
Laser	10 nm à 1 mm (> 300 GHz à 30 PHz)		Brûlure de la peau, de la cornée et de la rétine
^a Fréquence de traitement assignée. ^b Les valeurs des longueurs d'onde en espace libre correspondantes sont également données dans le cas du rayonnement optique. ^c Type de courant continu – équipement sans changement de polarité prévu, mais comprenant un dispositif de marche/arrêt. ^d La définition du rayonnement UV est conforme à l'IEC 62471:2006; un rayonnement compris entre 380 nm et 400 nm est généralement détecté.			

4.2 Classification par tension

La tension d'alimentation d'une installation ou d'un équipement est classée en tant que

- très basse tension (TBT) à une fréquence du réseau inférieure à 50 V (valeur efficace) ou un courant continu inférieur à 120 V,
- basse tension (BT) à une fréquence du réseau comprise entre 50 V et 1 000 V (valeur efficace) ou un courant continu compris entre 120 V et 1 500 V, et

- haute tension (HT) à une fréquence du réseau supérieure à 1 000 V (valeur efficace) ou un courant continu supérieur à 1 500 V.

NOTE Les définitions de la TBT et de la bande de tension 1, de la BT et de la bande de tension 2 et de la HT et de la bande de tension 3 sont identiques. Les tensions inférieures à une fréquence du réseau de 25 V ou un courant continu de 60 V ne présentent pas de risque pour une **personne ordinaire** dans la plupart des circonstances (une exception est possible dans des conditions humides).

Cette distinction doit être faite pour l'installation et pour les pièces telles que définies en 4.3.1 et

- a) en fonction de l'alimentation et de la tension de sortie, la valeur la plus haute étant prise en compte (les tensions internes de l'**équipement électrique** peuvent être supérieures), mais
- b) indépendamment de la tension de processus ou de la tension interne de l'installation ou de l'équipement.

Les différentes pièces d'une installation peuvent être classées comme TBT, BT ou HT.

4.3 Subdivision des installations et des équipements

4.3.1 Subdivision en pièces

Une **installation EH** ou **EPM** se compose de pièces diverses et spécifiques. La Figure 1 présente le schéma de principe d'une installation de référence type. Il détermine la limite des installations et équipements. Toutes les pièces ne sont pas forcément incluses dans tous les types d'**installation EH** ou **EPM**.

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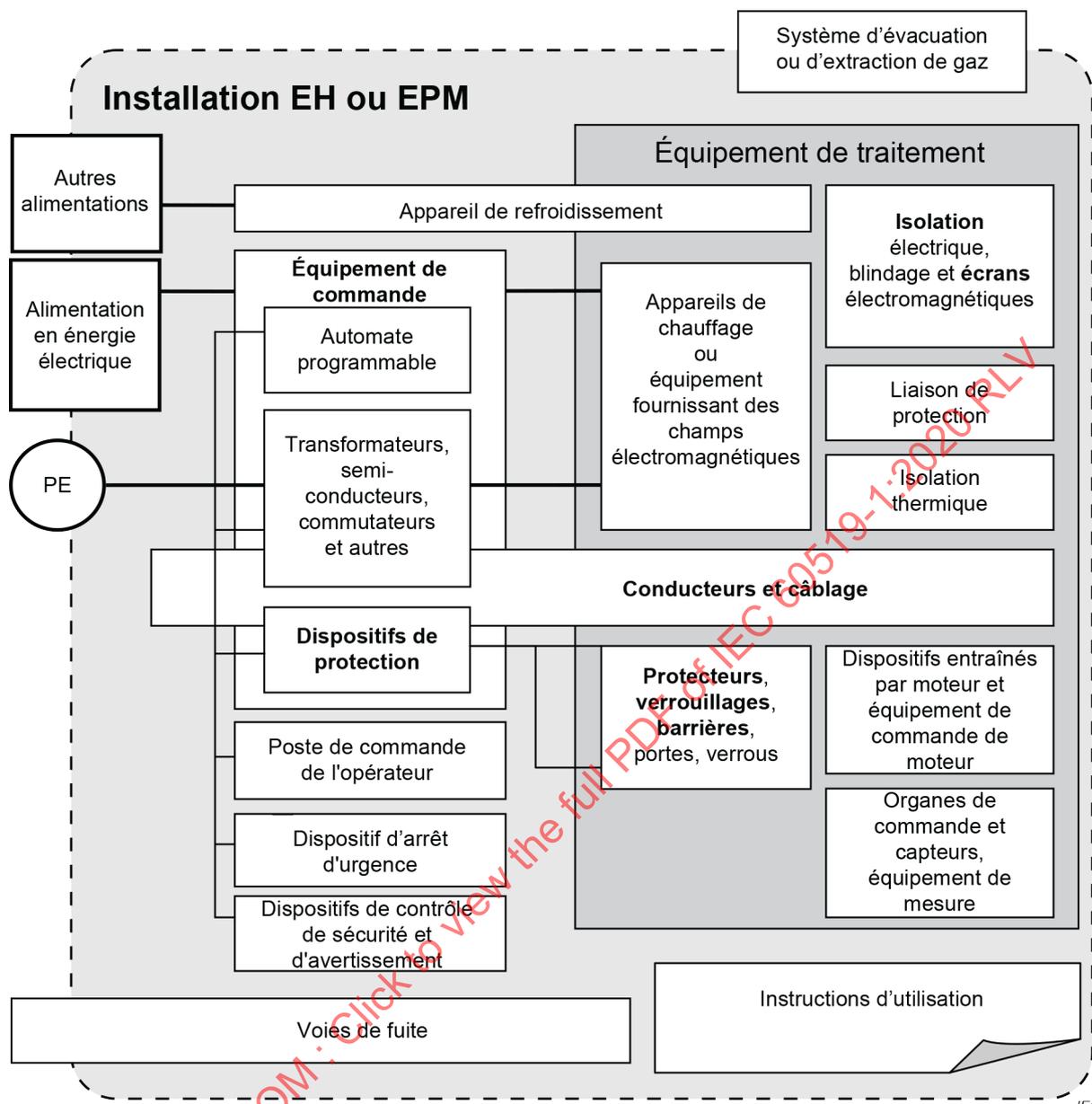


Figure 1 – Schéma de principe d'une installation EH ou EPM type

Le Tableau 2 fournit des références aux articles du présent document et d'autres normes correspondant aux pièces identifiées à la Figure 1. Les exigences relatives à l'équipement autre que l'équipement de traitement sont couvertes par les normes IEC ou ISO spécifiées dans le Tableau 2. Les sources fondamentales des dispositions de sécurité concernant l'équipement électrique des installations et équipements EH ou EPM sont l'IEC 60204-1 pour la BT et l'IEC 60204-11 pour la HT.

Les exigences de sécurité relatives à l'équipement de traitement proprement dit sont spécifiques en raison de son environnement hors norme et des conditions internes ou à proximité, dans lesquels

- a) des températures extrêmes peuvent interagir avec l'équipement,
- b) de forts **champs** électriques, magnétiques ou **électromagnétiques** peuvent interagir avec l'équipement, et
- c) l'énergie thermique ou les forces électromagnétiques peuvent menacer l'intégrité structurelle de l'équipement ou de l'**isolation** et des moyens de protection.

Tableau 2 – Installation EH ou EPM type – Liste des pièces et références

Pièce de l'installation ou de l'équipement – Voir Figure 1		Condition pour laquelle la référence est valide	Référence/source des dispositions
Pièce	Composant/élément		
Alimentation en énergie électrique		BT, ≤ 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
Mise à la terre de protection, PE			
Liaison de protection			
Alimentation en énergie électrique		HT, ≤ 200 Hz	IEC 61936-1, IEC 60071-1
Mise à la terre de protection, PE			
Liaison de protection			
Alimentation en énergie électrique		toutes autres, ≤ 36 kV	Article 7
Mise à la terre de protection, PE			
Liaison de protection			
Conducteurs et câblage dans des conditions d'environnement normalisé		< 40 °C	IEC 60228
Conducteurs et câblage exposés à des conditions d'environnement non normalisé		> 40 °C	6.4.2 et 13.2
Équipement de commande	Appareillage de commutation et de commande	BT, ≤ 200 Hz	IEC 60204-1
		HT, ≤ 36 kV, ≤ 200 Hz	IEC 60204-11
		> 36 kV, ≤ 200 Hz	Exigences particulières
		> 200 Hz	Article 7
	Automate programmable	toutes	IEC 61508-1, IEC 62061, ISO 13849-1
Dispositif de protection		toutes	IEC 61508-1, IEC 62061, ISO 13849-1
Poste de commande d'opérateur (identique à l'appareillage de commutation et de commande)		< 1 000 V, ≤ 200 Hz	IEC 60204-1
		> 1 000 V, ≤ 200 Hz	IEC 60204-11
		toutes autres	Articles 7 et 8
Dispositif d'arrêt d'urgence (identique à l'appareillage de commutation et de commande)		< 1 000 V, ≤ 200 Hz	IEC 60204-1
		> 1 000 V, ≤ 200 Hz	IEC 60204-11
		toutes autres	ISO 13850
Dispositifs de contrôle de sécurité et d'avertissement (identiques à l'appareillage de commutation et de commande)		< 1 000 V, ≤ 200 Hz	IEC 60204-1
		> 1 000 V, ≤ 200 Hz	IEC 60204-11
		toutes autres	ISO 13850
Autres fournitures – par exemple fluides, air comprimé		toutes	Article 12; ISO 13577-3
Carburants liquides ou gazeux		toutes	ISO 13577-2
Système d'extraction de fluides		toutes	Article 12; ISO 13577-1
Évacuation		toutes	ISO 13577-1
Voies de fuite		toutes	IEC 60364-4-42

Pièce de l'installation ou de l'équipement – Voir Figure 1		Condition pour laquelle la référence est valide	Référence/source des dispositions
Pièce	Composant/élément		
Équipement de traitement	Équipement électrothermique	voir 6.4	Articles 7, 8, 9, 10; Exigences particulières
	Appareils de chauffage non électriques		ISO 13577-1 ISO 13577-2
	Équipement fournissant des champs électromagnétiques		Articles 7, 8, 9, 10; Exigences particulières
	Isolation thermique		Article 10; ISO 13577-1
	Isolation électrique		Articles 7, 8, 9, 10
	Blindage électromagnétique		Articles 7, 8, 9, 10
	Organes de commande et capteurs		IEC 61310-1 IEC 61310-2 IEC 61310-3
	Équipement de mesure		IEC 61010-1 Exigences particulières
	Dispositifs entraînés par moteur et équipement de commande de moteur		IEC 60204-1
	Protecteurs, verrouillages, barrières, portes, verrous		ISO 14119 ISO 14120 Exigences particulières
Refroidissement	Articles 10 et 12		

4.3.2 Hiérarchie et structure des exigences

Les règles suivantes constituent des lignes directrices particulièrement en ce qui concerne les exigences relatives à la sécurité électromagnétique, qui comprend le choc électrique, le **choc électrique induit**, les **courants de contact** et d'autres effets des **champs électromagnétiques**.

- Pour toutes les pièces d'une installation comprises dans le domaine d'application de l'une des normes répertoriées dans le Tableau 2, la norme citée doit être utilisée.
- Pour les équipements ou pièces en dehors du domaine d'application de toutes les normes répertoriées dans le Tableau 2, les Articles 7 et 8 s'appliquent, c'est-à-dire pour les équipements dont les fréquences sont supérieures à 200 Hz ou destinés à une utilisation à des températures supérieures à 40 °C.
- L'équipement dépassant la limite de tension de 36 kV est traité dans les Exigences particulières.
- Des recommandations supplémentaires concernant les références indiquées dans le Tableau 2 sont fournies dans les articles correspondants du présent document.

4.4 Classification des dangers et des risques

4.4.1 Classification des dangers

Les dangers se différencient comme suit:

- les dangers dans lesquels les dommages sont immédiats – c'est-à-dire tout accident qui entraîne directement des dommages, et
- les dangers dans lesquels les dommages dépendent de l'**exposition**, de l'accumulation ou de la dose – par exemple de l'intensité, d'une force de champ, d'une durée d'**exposition**.

EXEMPLE 1 Des dangers immédiats sont par exemple un choc électrique, l'éjection d'objets, l'explosion, des dangers mécaniques tels que les coupures ou les chutes, des substances toxiques à des doses potentiellement mortelles.

EXEMPLE 2 Des dangers liés à l'**exposition** sont par exemple l'**exposition** à des rayonnements optiques ou d'hyperfréquences, l'**exposition** à des champs électriques ou magnétiques, l'**exposition** aux sons ou au bruit, l'**exposition** aux rayonnements ionisants ou aux substances toxiques ou radioactives.

NOTE Le contact avec des surfaces ou substances chaudes peut dépendre de la dose à basse température, ou être immédiat, par exemple dans le cas d'un contact direct avec des métaux liquides.

Les dangers se différencient selon qu'il s'agit de

- c) dangers perceptibles – c'est-à-dire de dangers créant des réactions corporelles négatives, et
- d) dangers insensibles ou imperceptibles.

EXEMPLE 3 Des dangers perceptibles sont, par exemple, la température d'un matériau ou de l'environnement, un rayonnement visible intense, les pièces en déplacement rapide, l'accélération, les vibrations ou le bruit.

EXEMPLE 4 Des dangers insensibles ou imperceptibles sont, par exemple, le rayonnement UV, le rayonnement ionisant ou les substances radioactives, les substances toxiques, les hyperfréquences, les champs magnétiques ou électriques.

4.4.2 Classification des risques

Un risque spécifique dépend de l'**émission**, de la durée, de l'intensité de l'agent, mais également de la partie du corps exposée, de la connaissance ou de la sensibilisation à l'agent, de l'expérience ou des informations sur le type de danger, et de facteurs comportementaux tels que l'aversion ou le retrait. Les risques sont traités sous forme d'un classement par catégories de niveaux de risque, les dangers imperceptibles étant classés comme exigeant des mesures de protection particulières. Le **constructeur** réduit les **émissions** d'agents potentiellement dangereux ou informe l'**utilisateur** sur les risques résiduels. Un plan de classification guide cette action. Le Tableau 3 récapitule la classification des **émissions** résiduelles utilisée dans le présent document.

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Tableau 3 – Plan de classification de sécurité pour les risques pour l’homme

Classe de risque		Restrictions et mesures de protection	Information et formation
0	exempt	Pas de restriction ni mesures de protection nécessaires	Aucune information nécessaire.
1	risque faible	Des restrictions telles qu’une limitation d’accès ou des mesures de protection peuvent être indiquées selon le résultat d’une appréciation du risque par l’ utilisateur .	Informations sur les dangers, les risques et les effets secondaires à fournir par le constructeur .
2	risque modéré	Restrictions spéciales et mesures de protection essentielles	Informations sur les dangers, les risques et les effets secondaires à fournir par le constructeur . Le constructeur doit indiquer à l’ utilisateur si une formation spécifique de l’ opérateur est nécessaire.
3a	risque élevé	Accès possible avec un équipement de protection individuelle	Informations sur les dangers, les risques et les effets secondaires à fournir par le constructeur . Le constructeur doit indiquer à l’ utilisateur la formation spécifique nécessaire de l’ opérateur et l’équipement de protection individuelle.
3	risque élevé	Aucun accès	Informations sur les dangers, les risques et les effets secondaires à fournir par le constructeur .

Chaque position spatiale ou zone de danger doit être prise en considération individuellement. Les **conditions de fonctionnement normal** et la **condition de premier défaut** doivent être prises en compte.

5 Appréciation du risque

Le présent document est fondé sur l’appréciation du risque fournie dans l’Annexe A.

Cette appréciation du risque doit être étendue et spécifiée en conséquence tout au long de l’élaboration des Exigences particulières de l’IEC 60519 (toutes les parties).

Dans l’Annexe A, l’appréciation du risque couvre un très large éventail d’équipements et d’installations; par conséquent, elle est relativement générale et peut ne pas couvrir des origines spécifiques, des situations ou événements dangereux particuliers, ou des conséquences potentielles avec le niveau de détail jugé nécessaire par le **constructeur**. Le **constructeur** doit donc ajouter à cette appréciation du risque les spécificités de sa solution technique, comme cela est spécifié dans l’ISO 12100:2010.

Si le **constructeur** a l’intention de fabriquer un équipement ou une installation qui n’est pas entièrement couvert(e) par le domaine d’application du présent document et son appréciation du risque ou si les Exigences particulières sont obsolètes et ne se réfèrent pas au présent document ou si aucune Exigence particulière n’existe, il lui est conseillé de réexaminer l’appréciation du risque de l’Annexe A. Le présent document facilite alors l’appréciation du risque et la procédure de réduction du risque telles que spécifiées dans l’ISO 12100:2010.

6 Dispositions générales

6.1 Considérations de base

6.1.1 L'installation ou l'équipement EH ou EPM doit être adapté(e) à son utilisation prévue; il doit être conçu pour être utilisé, réglé et entretenu sans exposer des personnes à des risques. La conception et la construction doivent garantir une réduction adaptée des risques dans des **conditions de fonctionnement normal** ou en **condition de premier défaut**, selon les derniers développements techniques et pendant la durée de vie prévisible de l'installation ou de l'équipement EH ou EPM.

Tout risque engendré par la **charge de travail**, lorsque celle-ci est traitée comme prévu dans l'installation EH ou EPM, et qui est prévisible par le **constructeur** doit être réduit de manière appropriée.

6.1.2 L'équipement ou l'installation EH ou EPM doit être conçu pour éviter ou réduire la possibilité d'utilisation incorrecte ou de condition de défaut.

6.1.3 L'équipement ou l'installation EH ou EPM ne doit pas présenter de risques de types immédiat ou imperceptible, à moins qu'il ne soit impossible d'atteindre autrement son but prévu. Dans ces cas, des mesures de protection, des avertissements et des instructions supplémentaires doivent être fournis.

6.1.4 Le **constructeur** doit, dans l'ordre suivant,

- a) éliminer les risques pour obtenir une installation ou un équipement intrinsèquement sûr,
- b) fournir des mesures de protection pour les risques qui ne sont pas éliminés, et
- c) fournir à l'**utilisateur** toutes les informations nécessaires sur les risques résiduels, indiquer la formation et l'équipement de protection individuelle nécessaires.

6.1.5 Les mesures de protection sont une combinaison des mesures intégrées au stade de conception et des mesures indiquées comme devant être mises en œuvre par l'**utilisateur**. Le **constructeur** doit intégrer toutes les mesures identifiées comme nécessaires selon les Articles 5 à 17 le cas échéant.

6.1.6 Si un danger spécifique est classé dans la classe de risque 1 ou 2 telle que définie dans le Tableau 3 et ne peut être davantage réduit par le **constructeur**, ce dernier doit fournir des informations détaillées à l'intention de l'**utilisateur**, notamment

- a) une description graphique ou un plan de l'installation indiquant la position et les limites des zones appartenant à la classe de risque 1 ou 2,
- b) des informations sur les dispositifs de signalisation et d'avertissement – voir 19.3,
- c) les marquages et l'avertissement écrit nécessaires – voir 19.4,
- d) l'indication des restrictions et des mesures de protection nécessaires à prendre par l'**utilisateur** – voir 19.5,
- e) l'indication des informations nécessaires à l'intention des **opérateurs** – voir 19.5, et
- f) l'indication des procédures de travail sûres ou qui réduisent le risque.

6.1.7 Si un danger spécifique est classé dans la classe de risque 3a telle que définie dans le Tableau 3 et ne peut être davantage réduit par le **constructeur**, ce dernier doit fournir des informations détaillées à l'intention de l'**utilisateur**, notamment

- a) une description graphique ou un plan de l'installation indiquant la position et les limites des zones appartenant à la classe de risque 3a,
- b) des informations sur les dispositifs de signalisation et d'avertissement – voir 19.3,
- c) les marquages et l'avertissement écrit nécessaires – voir 19.4,

- d) l'indication des restrictions et des mesures de protection nécessaires à prendre par l'**utilisateur** – voir 19.5,
- e) l'indication des informations nécessaires à l'intention des **opérateurs** – voir 19.5,
- f) l'indication de l'équipement de protection individuelle devant être porté par l'**opérateur** lorsqu'il pénètre dans la zone, et
- g) l'indication des procédures de travail sûres ou qui réduisent le risque.

6.1.8 Si un danger spécifique est classé dans la classe de risque 3 telle que définie dans le Tableau 3 et ne peut être davantage réduit par le **constructeur**, ce dernier doit fournir des informations détaillées à l'intention de l'**utilisateur**, notamment

- a) une description graphique ou un plan de l'installation indiquant la position et les limites des zones appartenant à la classe de risque 3,
- b) des informations sur les dispositifs de signalisation et d'avertissement – voir 19.3,
- c) les marquages et l'avertissement écrit nécessaires – voir 19.4, et
- d) l'indication des informations nécessaires à l'intention des **opérateurs** – voir 19.5.

6.1.9 Une réduction appropriée du risque ne doit pas être confondue avec la réduction de l'**exposition** à des niveaux proches des limites d'**exposition**. Une réduction appropriée du risque élimine un danger, ou si ce n'est pas possible, réduit l'**exposition** à la limite technique. L'utilisation appropriée des limites d'**exposition** relève de la responsabilité de l'**utilisateur**.

6.2 Dangers significatifs

Les dispositions à prendre pour la protection contre les dangers significatifs identifiés, définis dans l'Annexe A, sont spécifiées de l'Article 6 à l'Article 17. La vérification de la conformité aux dispositions du présent document doit être effectuée selon l'Article 18.

6.3 Environnement physique et conditions d'exploitation de l'installation en l'état et équipement électrique à l'extérieur de l'équipement de traitement

6.3.1 L'**installation** ou l'**équipement EH** ou **EPM** et son **équipement électrique** qui sont situés hors de l'équipement de traitement doivent être adaptés à l'environnement physique et aux conditions d'exploitation de leur but prévu.

Lorsque des conditions spéciales s'appliquent ou que les limites spécifiées dans le présent 6.3 sont dépassées, un accord entre le **constructeur** et l'**utilisateur** peut être nécessaire. Le paragraphe 4.1 de l'IEC 60204-1:2016 s'applique aux installations BT et le 4.1 de l'IEC 60204-11:2018 s'applique aux installations HT.

6.3.2 L'**installation** ou l'**équipement EH** ou **EPM** ne doit pas générer de perturbations électromagnétiques supérieures aux niveaux appropriés pour son lieu d'utilisation prévu.

6.3.3 L'**installation** ou l'**équipement EH** ou **EPM** doit être capable de fonctionner en toute sécurité à la température ambiante prévue. L'exigence minimale pour l'ensemble de l'**équipement électrique** est un fonctionnement sûr à des températures d'air comprises entre 5 °C et 40 °C.

6.3.4 L'**installation** ou l'**équipement EH** ou **EPM** doit être capable de fonctionner en toute sécurité lorsque l'humidité relative ne dépasse pas 50 % à une température maximale de 40 °C. Une humidité relative plus élevée est admise à des températures plus basses (par exemple, lorsqu'elle est inférieure à 90 % à 20 °C). L'**installation** ou l'**équipement EH** ou **EPM** doit être capable de fonctionner en toute sécurité si de la condensation se forme occasionnellement ou le **constructeur** doit éviter la condensation par la conception ou, si nécessaire, par des mesures supplémentaires (telles que des chauffages intégrés, une climatisation ou des orifices de purge).

6.3.5 L'installation ou l'équipement EH ou EPM doit être capable de fonctionner en toute sécurité à la pression d'air prévue jusqu'à 1 000 m d'altitude et dans un large éventail de climats et de conditions atmosphériques. La limite de pression ambiante inférieure doit être de 85 % de la pression atmosphérique normale au niveau de la mer, sauf accord contraire entre le **constructeur** et l'**utilisateur** et spécification dans les instructions d'utilisation.

Pour les équipements destinés à être utilisés à des altitudes plus élevées ou des pressions d'air inférieures, il est nécessaire de prendre en compte la diminution de la rigidité diélectrique, la fonctionnalité de coupure des dispositifs et la réduction du pouvoir de refroidissement de l'air provoquée par une masse volumique réduite.

6.3.6 L'équipement électrique de l'installation ou de l'équipement EH ou EPM doit être protégé de manière appropriée contre la pénétration d'éléments solides et liquides selon 11.3 de l'IEC 60204-1:2016 pour l'équipement BT. Il doit être protégé de manière appropriée contre les agents contaminants (par exemple, la poussière, les acides, les gaz corrosifs ou les sels) qui peuvent se trouver dans le lieu physique auquel l'équipement est destiné.

6.3.7 Lorsque l'installation ou l'équipement EH ou EPM ou des pièces de ceux-ci sont exposés au rayonnement (par exemple, hyperfréquences, UV, laser ou rayons X), des mesures supplémentaires doivent être prises pour éviter un dysfonctionnement de l'équipement, une détérioration accélérée de l'**isolation**, la dégradation du métal ou la corrosion due aux effets induits du rayonnement.

6.3.8 Les effets indésirables des vibrations, des chocs et des coups sur l'installation ou l'équipement EH ou EPM (y compris ceux qui proviennent de l'installation et de son matériel connexe, ainsi que ceux qui sont créés par l'environnement physique) doivent être évités par le choix du matériel approprié, en le montant à distance de l'équipement générant les vibrations ou les chocs, ou par utilisation de montages antivibrations ou antichocs.

6.3.9 Lorsque l'installation ou l'équipement EH ou EPM ou des pièces de ceux-ci sont exposés à un plasma, à des produits chimiques corrosifs ou à d'autres agents nocifs, des mesures supplémentaires doivent être prises pour éviter un dysfonctionnement, une détérioration accélérée de l'**isolation**, la dégradation du métal ou la corrosion due aux effets induits du rayonnement.

6.4 Environnement physique et conditions d'exploitation de l'équipement électrique engendrés par l'exploitation de l'équipement de traitement

6.4.1 L'équipement électrique de l'installation ou de l'équipement EH ou EPM, placé à l'intérieur ou à proximité de l'équipement de traitement, doit être adapté à l'environnement physique et aux conditions d'exploitation de son but prévu. Les conditions physiques présentes à l'intérieur ou à proximité de l'équipement de traitement couvrent un très large éventail d'environnements différents; un accord entre le **constructeur** et l'**utilisateur** peut être nécessaire concernant ces conditions.

6.4.2 L'équipement électrique doit être capable de fonctionner correctement dans des conditions de fonctionnement normal et en condition de premier défaut

- a) aux niveaux de température prévus à l'intérieur et à l'extérieur de l'équipement de traitement,
- b) aux niveaux d'humidité à l'intérieur et à l'extérieur de l'équipement de traitement (on peut attendre des niveaux d'humidité extrêmes ou une forte condensation ainsi qu'une immersion totale),
- c) aux conditions atmosphériques prévues à l'intérieur et à l'extérieur de l'équipement de traitement,
- d) sous les champs électriques et magnétiques présents à l'intérieur et à l'extérieur de l'équipement de traitement, et
- e) aux différences de pression prévues entre l'extérieur et l'intérieur de l'équipement.

6.4.3 L'**équipement électrique** doit être protégé de manière appropriée contre la pénétration d'éléments solides et liquides, en particulier contre les contaminants (tels que la poussière, les acides, les gaz corrosifs ou les sels) qui sont susceptibles d'être présents à l'intérieur et à l'extérieur de l'équipement de traitement.

6.4.4 Lorsque l'**équipement électrique** à l'intérieur de l'équipement de traitement est exposé aux rayonnements (par exemple hyperfréquences, UV, laser ou rayons X), des mesures supplémentaires doivent être prises pour éviter son dysfonctionnement ou la détérioration accélérée de son **isolation** causée par les rayonnements.

6.4.5 Les effets indésirables des vibrations, des chocs et des coups générés par l'équipement de traitement sur l'**installation** ou l'**équipement EH** ou **EPM**, ainsi que ceux qui sont créés par l'environnement physique, doivent être évités par le choix de l'**équipement électrique** approprié, en le montant à distance de l'équipement de traitement, ou par l'utilisation de montages antivibrations.

6.4.6 Lorsque l'**équipement électrique** à l'intérieur de l'équipement de traitement est exposé à un plasma, à des produits chimiques corrosifs ou à d'autres agents nocifs, des mesures supplémentaires doivent être prises pour éviter un dysfonctionnement de l'équipement, une détérioration accélérée de l'**isolation**, la dégradation du métal ou la corrosion due aux effets induits du rayonnement. Cela inclut les effets d'un amorçage d'arc sous **vide** causé par une tension dépassant localement ou temporairement la tension de claquage.

NOTE Une tension de claquage peut se produire sur une plage de pression très étendue et chaque fois que la tension dépasse la tension minimale de claquage de l'atmosphère à l'intérieur de l'équipement. Après amorçage, les arcs peuvent devenir autoentretenus.

6.5 Alimentation électrique

6.5.1 L'installation doit être conçue pour fonctionner correctement dans des **conditions de fonctionnement normal** avec les caractéristiques du réseau d'alimentation

- telles que spécifiées ci-dessous, ou
- telles que spécifiées autrement par l'**utilisateur** et visées par le **constructeur**, ou
- telles que spécifiées par le **constructeur** dans le cas d'une source d'alimentation spéciale telle qu'un générateur embarqué.

Pour les alimentations à la fréquence du réseau, les conditions suivantes, conformément à l'IEC 60204-1:2016, s'appliquent, sauf en cas d'accord contraire explicite entre le **constructeur** et l'**utilisateur**:

- a) tension permanente comprise dans la plage de 90 % à 110 % de la tension nominale;
- b) fréquence continue comprise entre 0,99 et 1,01 de la valeur nominale en régime permanent; 0,98 jusqu'à 1,02 sur une courte période (pas d'augmentation de température excessive des composants due à un courant anormal).

Pour les systèmes d'alimentation spéciaux tels que les générateurs embarqués, les limites données peuvent être dépassées à condition que l'équipement soit conçu pour fonctionner correctement dans ces conditions.

6.5.2 En cas de défaillance ou de panne de l'alimentation électrique, l'installation ou l'équipement doit

- a) passer en mode de fonctionnement sûr – il ne doit pas passer en **condition de premier défaut**, notamment ne doit pas démarrer de manière inattendue, ne doit pas être empêché de s'arrêter si la commande d'arrêt a été actionnée, ne doit pas éjecter ou laisser tomber des pièces ou une **charge de travail** à moins qu'une protection adaptée ne soit fournie,

- b) ne pas perdre le paramétrage de l'appareillage de commutation et de commande ou de l'automate programmable nécessaire à la sécurité du fonctionnement,
- c) être capable de garder tous les **dispositifs de protection** entièrement opérationnels ou leur permettre d'activer une commande d'arrêt, et
- d) être capable de refroidir sans causer de danger; cela peut exiger le fonctionnement prolongé de l'appareil de refroidissement.

6.6 Accès

6.6.1 L'installation ou l'équipement EH ou EPM doit permettre un accès sûr à toutes les zones dans lesquelles une intervention est nécessaire lors de l'exploitation ou de la maintenance. L'équipement doit être conçu et installé de façon que tous les dispositifs et composants destinés à être accessibles, observés ou vus par l'**opérateur**, soient accessibles ou visibles pour l'**opérateur**.

6.6.2 Les risques doivent être réduits en limitant ou en empêchant l'accès à tout danger ou à toute zone de danger. La limitation de l'accès aux surfaces ou aux pièces qui peuvent causer un danger ou de l'accès donnant sur une zone de danger dépend du danger proprement dit, de son type (immédiat ou dépendant de l'**exposition**) et de la force de la source de danger (par exemple, la température d'une surface ou la tension d'une **partie active**).

6.6.3 L'installation ou l'équipement EH ou EPM doit fournir une protection contre l'accès accidentel aux **parties actives dangereuses** ou contre la pénétration accidentelle dans la **zone de danger haute tension** dans tous les cas où il n'y a pas de **barrière** ni d'**enveloppe**, ou lorsque la **barrière** ou l'enveloppe doit être retirée pour accéder aux dispositifs exigeant un fonctionnement manuel ou aux composants exigeant d'être remplacés.

La voie d'accès au dispositif et l'espace nécessaire à son fonctionnement doivent prévoir une protection contre le contact accidentel avec des **parties actives dangereuses** ou contre la pénétration accidentelle dans une **zone de danger haute tension** par le maintien d'une distance appropriée.

Des **obstacles** protégeant contre le contact accidentel doivent être fournis si la voie d'accès ou l'espace est inférieur à la distance appropriée par rapport aux **parties actives dangereuses**.

6.6.4 Le niveau de protection ne doit pas être inférieur à IPXXB (également satisfait par l'IP2X) de l'IEC 60529, IEC 60529:1989/AMD1:1999 et IEC 60529:1989/AMD2:2013 depuis la direction d'approche de la **partie active dangereuse**, et ne doit pas être inférieur à IPXXA (également satisfait par l'IP1X) de l'IEC 60529, IEC 60529:1989/AMD1:1999 et IEC 60529:1989/AMD2:2013 depuis les autres directions.

6.7 Aspects ergonomiques

Les contraintes physiques et physiologiques auxquelles l'**opérateur** est confronté, lors des **conditions de fonctionnement normal** et des conditions d'environnement prévues, doivent être réduites le plus possible. À cet égard, les principaux objectifs sont les suivants:

- a) éviter une cadence de travail déterminée par l'installation uniquement;
- b) éviter une surveillance de l'installation ou de son unité de commande qui demande une concentration laborieuse;
- c) permettre la variation de la force, de la constitution ou de la taille physique des différents **opérateurs**;
- d) permettre un espace suffisant pour les mouvements de l'**opérateur**;
- e) adapter l'unité de commande et les autres interfaces à la variation prévisible des caractéristiques des **opérateurs**.

Les dispositions de l'ISO 6385:2016 s'appliquent.

6.8 Transport et stockage

6.8.1 L'installation ou l'équipement EH ou EPM doit être conçu pour résister aux effets des températures de transport et de stockage comprises entre -25 °C et 55 °C et, pendant de courtes périodes ne dépassant pas 24 h, atteignant 70 °C . Sinon, des précautions adaptées doivent être prises pour protéger l'équipement électrique de tels effets. Des moyens appropriés doivent être fournis pour éviter les dommages dus à l'humidité, aux vibrations et aux chocs.

6.8.2 L'installation ou l'équipement EH ou EPM doit être conçu pour faciliter la vidange et le remplissage des fluides de travail, si ces derniers peuvent geler ou endommager d'une autre manière l'équipement pendant le stockage ou le transport. Le constructeur doit informer l'utilisateur des procédures de vidange et de remplissage de tous les fluides de travail dans les instructions d'utilisation.

NOTE L'équipement susceptible d'être endommagé à basse température comprend les câbles isolés en PVC, certains condensateurs électrolytiques ou équipements utilisant des liquides de refroidissement pouvant geler.

6.9 Dispositions en vue de la manutention

6.9.1 L'installation ou l'équipement EH ou EPM doit pouvoir être manutentionné ou assemblé en toute sécurité.

6.9.2 Toute partie d'une installation ou d'un équipement EH ou EPM qui ne peut être déplacée à la main doit pouvoir être soulevée à l'aide d'un équipement approprié. Le constructeur doit fournir des instructions de levage ou de manutention, le cas échéant.

6.9.3 Toutes les pièces doivent s'assembler facilement par le biais de dispositions appropriées ou d'un engin de levage.

6.10 Consommables et pièces remplaçables

Les consommables ou les pièces remplaçables destinés à être remplacés par l'opérateur doivent être intégrés ou montés de façon que le remplacement soit simple et sûr, pour assurer un montage correct et clair et le branchement électrique.

7 Protection contre les dangers dus à un choc électrique

7.1 Généralités

L'Article 7 s'applique aux installations ou équipements EH ou EPM qui ne sont pas couverts par le domaine d'application de l'IEC 60204-1 ou de l'IEC 60204-11, c'est-à-dire

- a) dépassant une température ambiante de 40 °C , ou
- b) dont la fréquence de traitement électrique dépasse 200 Hz.

L'Article 7 ne s'applique ni aux équipements couverts par l'IEC 60204-1 ou l'IEC 60204-11, ni aux installations ou équipements dont la tension dépasse 36 kV, qui sont couverts par les Exigences particulières.

7.2 Règle de protection fondamentale

7.2.1 Les parties actives dangereuses ne doivent pas être accessibles et les parties conductrices accessibles ne doivent pas être actives de façon dangereuse pendant les conditions de fonctionnement normal ou en condition de premier défaut électrique.

7.2.2 Pour les installations ou équipements HT, pénétrer dans la **zone de danger haute tension** est considéré comme étant équivalent à toucher une **partie active dangereuse**.

7.2.3 Les parties non accessibles sont des **parties actives dangereuses** ou des **zones de danger haute tension** qui sont hors des limites d'atteinte – c'est-à-dire que le contact est impossible comme cela est défini dans l'ISO 13857:2008 lors des **conditions de fonctionnement normal** ou en **condition de premier défaut électrique**.

7.2.4 La protection dans des **conditions de fonctionnement normal** est assurée par la protection principale (voir 7.4), et la protection en **condition de premier défaut électrique** est assurée par la protection contre les défauts (voir 7.5). La protection par les dispositions de protection renforcées telles que définies en 5.4 de l'IEC 61140:2016 n'est pas suffisante pour des installations ou des équipements couverts par le domaine d'application du présent document.

7.3 Dispositions générales

7.3.1 Toutes les parties conductrices qui ne sont pas séparées des **parties actives dangereuses** par au moins une **isolation principale** doivent être traitées comme des **parties actives dangereuses**. Cela s'applique également aux parties conductrices qui sont séparées par une **isolation principale**, mais sont connectées à des **parties actives dangereuses** par le biais de composants, qui ne sont pas conçus pour résister à la même contrainte électrique que celle spécifiée pour l'**isolation principale**.

7.3.2 Les parties conductrices exposées de l'installation ou de l'équipement doivent être connectées à une borne de liaison de protection. Cela inclut toutes les parties enduites seulement de revêtements tels que peinture, vernis, laque et produits similaires. Les parties conductrices qui peuvent être touchées, mais sont séparées des **parties actives dangereuses** par une séparation de protection, ne sont pas incluses.

7.3.3 Si l'installation ou l'équipement n'est pas entièrement couvert quant aux pièces conductrices, les règles suivantes s'appliquent aux parties accessibles du matériau isolant. Dans les cas suivants, les surfaces accessibles des parties du matériau isolant doivent être séparées des **parties actives dangereuses**:

- si elles sont conçues pour être agrippées; ou
- si elles sont susceptibles d'entrer en contact avec des surfaces conductrices qui peuvent distribuer un potentiel dangereux; ou
- si elles peuvent entrer en contact significatif (zone supérieure à 50 mm × 50 mm) avec une partie du corps; ou
- si elles doivent être utilisées dans des zones où la pollution est hautement conductrice.

Dans ce cas, elles doivent être séparées des **parties actives dangereuses** par

- a) une double **isolation** ou une **isolation** renforcée, ou
- b) une **isolation principale** et un écran de protection, ou
- c) une combinaison des deux.

Toutes les autres surfaces accessibles des parties du matériau isolant doivent être séparées des **parties actives dangereuses** par au moins une **isolation principale**. Pour tous les équipements destinés à faire partie de l'installation, l'**isolation principale** doit être fournie pendant le montage et l'installation par le **constructeur** ou l'**utilisateur** comme cela est indiqué par le **constructeur** dans ses informations pour l'utilisation.

Les exigences sont jugées satisfaites si

- a) les parties accessibles du matériau isolant fournissent l'**isolation** exigée et leur température ne dépasse pas les limites définies dans l'Article 10, et

- b) le tableau de distribution est fabriqué en métal et les axes d'entraînement des boutons d'interruption, des poignées tournantes ou éléments similaires sont connectés efficacement au potentiel de terre à toutes les positions.

7.3.4 La conception de l'installation ou de l'équipement doit limiter l'accès aux **zones de danger haute tension**. Le besoin d'accès pour exploitation et maintenance par les **opérateurs** doit être pris en compte. Lorsque des distances de sécurité ne peuvent pas être établies, un blindage de protection permanent doit être installé. L'accès par des portes ou des **obstacles** doit être possible uniquement au moyen d'un outil.

Les étiquettes d'avertissement applicables doivent être affichées sur toutes les portes d'accès, les **protecteurs**, les **barrières** et être conformes à 19.4.

7.3.5 Si pour des raisons de fonctionnement, il n'est pas possible d'empêcher que les pièces BT suivantes soient à la fois accessibles, actives et dangereuses, elles peuvent être accessibles par un **opérateur** dans des **conditions de fonctionnement normal**:

- a) les pièces des lampes et les prises des lampes après la suppression des lampes;
- b) les pièces destinées à être remplacées et qui peuvent être actives et dangereuses lors du remplacement ou d'une autre action de l'**opérateur**, mais seulement si elles sont accessibles au moyen d'un outil et comportent un marquage d'avertissement – voir 19.4.

7.4 Protection principale

7.4.1 Toutes les installations ou tous les équipements relevant du domaine d'application du présent document doivent être équipés d'une protection principale.

- a) Pour les installations ou les équipements BT, en l'absence d'une norme spécifique répertoriée dans le Tableau 2, toute protection principale doit être conforme à l'IEC 60364-4-41:2005 et IEC 60364-4-41:2005/AMD1:2017.
- b) Pour les installations ou les équipements HT, en l'absence d'une norme spécifique répertoriée dans le Tableau 2, toute protection principale doit être conforme à 7.4.

7.4.2 La protection principale doit comprendre une ou plusieurs dispositions qui empêchent au moins le contact avec les **parties actives dangereuses** dans des **conditions de fonctionnement normal**.

7.4.3 Lorsqu'une **isolation principale** solide est employée, elle doit empêcher le contact avec les **parties actives dangereuses**.

Dans le cas des installations et équipements HT, une tension peut être présente sur la surface de l'**isolation** solide et des précautions supplémentaires peuvent être nécessaires.

Lorsque l'**isolation principale** est assurée au moyen de l'air, l'accès aux **parties actives dangereuses** ou la pénétration dans une **zone de danger haute tension** doit être empêché(e) par des **obstacles**, **barrières** ou **enveloppes** comme cela est spécifié en 7.4.4 et 7.4.5 ou en les plaçant hors de portée conformément à l'ISO 13857:2008.

Lorsqu'un **obstacle** conducteur est séparé des **parties actives dangereuses** par une **isolation principale** seulement, il s'agit d'une pièce conductrice exposée et des mesures de protection contre les défauts doivent être appliquées.

7.4.4 Les **barrières** ou **enveloppes** empêchant d'accéder aux **parties actives dangereuses** ou d'entrer dans la **zone de danger haute tension** doivent fournir un niveau de protection d'au moins IPXXB (également satisfait par l'IP2X) de l'IEC 60529:1989, IEC 60529:1989/AMD1:1999 et IEC 60529:1989/AMD2:2013.

Les **barrières** ou **enveloppes** doivent avoir une résistance mécanique, une stabilité et une durabilité suffisantes pour maintenir le niveau de protection spécifié, en tenant compte de

toutes les influences présentes provenant de l'environnement et de l'intérieur de l'**enveloppe** – l'ISO 14120:2015 doit être utilisée pour leur conception.

Lorsque la conception ou la construction permet la suppression des **barrières**, l'ouverture des **enveloppes** ou la suppression des pièces des **enveloppes**, l'accès aux **parties actives dangereuses** ou la pénétration en zone de danger doit seulement être possible

- au moyen d'une clé ou d'un outil, ou
- après le sectionnement des **parties actives dangereuses** du réseau d'alimentation dans lequel l'**enveloppe** ne fournirait plus de protection, le rétablissement de l'alimentation ne devenant possible qu'après la remise en place des **barrières** ou des pièces d'**enveloppes** ou après la fermeture des portes, ou
- lorsqu'une **barrière** intermédiaire permet de continuer à maintenir le niveau de protection exigé, cette **barrière** n'étant retirable qu'au moyen d'une clé ou d'un outil, ou
- dans le cas où aucun outil ou clé n'est exigé, si un **verrouillage**, conformément à l'ISO 14119:2013, mettant immédiatement hors circuit le danger, est installé.

Les **barrières** ou les **enveloppes** doivent être conçues ou fabriquées en un matériau ne pouvant pas générer de courants induits dangereux.

7.4.5 Dans le cas des installations et équipements HT, les inégalités importantes de champs électriques à l'intérieur ou le long d'un isolateur ou d'une **isolation** doivent être réduites au niveau de sécurité ou évitées au moyen de mesures de construction ou par le biais d'une répartition des potentiels. Cela doit empêcher l'**opérateur** d'entreprendre une action dangereuse et le protéger contre les **tensions de contact**.

NOTE La répartition des potentiels est généralement utilisée pour les installations électriques dans lesquelles des courants de terre élevés circulent.

7.4.6 À des fréquences dépassant 200 Hz, la répartition des potentiels du circuit doit être contrôlée par les moyens suivants.

- a) Si une mise à la terre est nécessaire pour des raisons inhérentes à la conception de l'équipement, aucune pièce de construction dans l'installation ne doit être utilisée. Un conducteur séparé de faible réactance pour le chemin direct entre le générateur et l'applicateur de traitement doit être fourni à la place.
- b) La chute de tension ne doit pas dépasser 5 V en valeur efficace sur une distance quelconque de l'installation pouvant être pontée par une personne, si les courants du conducteur dépassent 500 A, à moins que l'accès à l'installation ne soit empêché par des **barrières** ou **enveloppes** suffisantes (voir 7.4.4).

NOTE Cette limitation de l'étendue géométrique est due aux ondes électromagnétiques et à leur propagation qui produit une continuité de mise à la terre manquant de fiabilité à des fréquences dépassant environ 100 kHz.

7.5 Dispositions relatives à la protection en condition de premier défaut électrique

7.5.1 La protection contre les défauts doit comprendre une ou plusieurs dispositions indépendantes de celles de la protection principale et complémentaires à celles-ci. Les différentes dispositions de protection contre les défauts sont spécifiées de 7.5.2 à 7.5.8.

7.5.2 La **condition de premier défaut électrique** doit être prise en considération si elle peut avoir pour résultat

- a) qu'une **partie active** non dangereuse accessible devienne une **partie active dangereuse**, ou
- b) qu'une partie conductrice accessible qui n'est pas active en **conditions de fonctionnement normal** devienne une **partie active dangereuse**, ou
- c) qu'une **partie active dangereuse** devienne accessible.

7.5.3 Pour satisfaire à la règle fondamentale de la **condition de premier défaut électrique**, la protection contre les défauts doit être obtenue par une disposition de protection supplémentaire, indépendante de celle de la protection principale (7.4). La protection de premier défaut indépendante doit être fournie

- pour les installations ou équipements BT, en l'absence d'une norme spécifique répertoriée dans le Tableau 2, conformément à l'IEC 60364-4-41:2005 et IEC 60364-4-41:2005/AMD1:2017, et
- pour les installations ou équipements HT, en l'absence d'une norme spécifique répertoriée dans le Tableau 2, selon 7.5.

7.5.4 Chacune des deux dispositions de protection indépendantes (protection contre les défauts et protection principale) doit être conçue de façon qu'une défaillance soit peu probable dans les conditions d'environnement spécifiées en 6.3 ou 6.4 et dans des **conditions de fonctionnement normal** ou une **condition de premier défaut électrique**.

Les deux dispositions de protection indépendantes ne doivent pas avoir d'influence l'une sur l'autre.

NOTE La défaillance simultanée des deux dispositions de protection indépendantes est peu probable et n'est généralement pas prise en considération. La fiabilité repose sur le fait qu'une des deux dispositions reste effective.

7.5.5 Les exigences relatives aux liaisons équipotentielles de protection sont définies en 7.6 et s'appliquent de façon indépendante.

7.5.6 L'écran de protection doit consister en un **écran** conducteur placé entre les **parties actives dangereuses** d'une **installation** ou d'un **équipement EH** ou **EPM** et la pièce à protéger. L'**écran** de protection doit être connecté au système de liaison équipotentielle de protection de l'installation ou de l'équipement; il doit lui-même satisfaire aux exigences relatives aux liaisons équipotentielles de protection selon 7.6.

7.5.7 Une séparation simple entre un circuit et d'autres circuits ou la terre doit être obtenue par une **isolation principale** intégrale, assignée pour la plus haute tension présente.

Si un composant est connecté entre les circuits séparés, il doit résister aux contraintes électriques spécifiées pour l'**isolation** pour laquelle il réalise le circuit en pont et son impédance doit limiter le flux de courant présumé traversant le composant aux valeurs de **courant de contact** en état stationnaire indiquées à l'Annexe B.

7.5.8 L'**isolation** complémentaire doit être dimensionnée pour résister aux mêmes contraintes que pour l'**isolation principale**.

7.6 Liaison équipotentielle de protection

7.6.1 Le système de liaison équipotentielle de protection doit comprendre l'un des éléments suivants ou une combinaison appropriée de deux ou plus des éléments suivants:

- a) moyens de liaison équipotentielle de protection dans l'équipement;
- b) liaison équipotentielle de protection mise à la terre dans l'installation;
- c) conducteur de terre de protection (PE);
- d) conducteur de terre de protection, qui est également un conducteur neutre (PEN);
- e) écran de protection;
- f) point de terre de la source;
- g) électrode de terre (y compris des électrodes de terre pour la répartition des potentiels);
- h) conducteur de terre.

Des considérations spécifiques s'appliquent pour les fréquences nettement supérieures à la fréquence du réseau et sont données dans les Exigences particulières.

7.6.2 Toutes les parties des circuits de liaison de protection doivent être conçues de sorte qu'elles soient capables de résister aux contraintes thermiques et mécaniques les plus élevées pouvant être provoquées par des courants de défaut à la terre traversant toute partie des circuits de liaison de protection.

Toute partie de structure de l'installation ou de l'équipement électrique peut être utilisée en tant que partie du circuit de liaison de protection, dans le cas où un système de surveillance de défaut à la terre est installé.

7.6.3 Le système de liaison équipotentielle d'une installation ou d'un équipement HT doit être connecté à la terre en raison des risques spéciaux qui peuvent être présents, par exemple le danger d'une **tension de contact effective** et d'une tension de pas élevées et celui de parties conductrices exposées devenant actives à cause d'une décharge électrique. L'impédance par rapport à la terre de l'agencement de mise à la terre doit être assignée de façon qu'aucune **courant de contact** dangereuse ne puisse survenir (voir l'Article 18 en lien avec l'Annexe B). Les parties conductrices exposées, qui peuvent devenir actives dans des conditions de défaut, doivent être connectées à l'agencement de mise à la terre.

7.6.4 Les parties conductrices accessibles qui peuvent acquérir une **tension de contact effective** dangereuse dans le cas d'une défaillance de la protection principale, c'est-à-dire les parties conductrices exposées et tout **écran** de protection, doivent être connectées au système de liaison équipotentielle de protection.

7.6.5 Le système de liaison équipotentielle de protection doit être d'impédance suffisamment faible pour éviter une différence de potentiel dangereuse entre les parties en cas de défaillance de l'**isolation** et, si nécessaire, doit être utilisé conjointement à un **dispositif de protection** activé par le courant de défaut.

Cela peut nécessiter de prendre en considération les valeurs d'impédance relatives des différents éléments d'un système de liaison équipotentielle de protection. Il n'est pas nécessaire de prendre en considération la différence de potentiel si l'impédance du circuit limite le **courant de contact** d'état stationnaire dans le cas d'une **condition de premier défaut électrique** de sorte qu'il ne puisse pas dépasser 3,5 mA en valeur efficace pour des fréquences atteignant 100 Hz ou 10 mA pour des applications de courant continu lorsqu'elles sont mesurées selon l'Article 18. Dans certains environnements ou situations, par exemple des lieux hautement conducteurs ou des zones humides, les valeurs de limitation doivent être inférieures.

7.6.6 Toutes les parties de la liaison équipotentielle de protection doivent être dimensionnées de sorte que les contraintes thermiques et dynamiques susceptibles de se produire en raison d'un courant de défaut n'altèrent pas les caractéristiques du système de liaison équipotentielle de protection par suite d'une défaillance ou d'un chevauchement de l'**isolation principale**. Certains dommages locaux, qui ne nuisent pas à la sécurité, par exemple une tôle métallique faisant partie d'une **enveloppe**, peuvent être acceptés sur le lieu où le défaut survient.

7.6.7 Toutes les parties de la liaison équipotentielle de protection doivent être capables de résister à toutes les influences internes et externes (y compris mécaniques, thermiques et corrosives) qui peuvent se produire pendant la durée de vie attendue de l'installation.

Dans le cas où il est nécessaire de vérifier ou entretenir des pièces régulièrement, le **constructeur** doit l'indiquer dans les informations pour l'utilisation.

Les connexions conductrices mobiles, par exemple les charnières et coulisses, ne doivent pas être considérées comme faisant partie d'un système de liaison équipotentielle de protection, à moins que la conformité aux exigences du 7.6 ne soit maintenue.

Quand un composant d'une installation ou d'un équipement est destiné à être retiré, la liaison équipotentielle de protection de toute autre partie de l'installation ou de l'équipement ne doit pas être interrompue en retirant le composant, à moins de déconnecter d'abord l'alimentation électrique de l'autre partie.

Aucun élément de la liaison équipotentielle de protection ne doit contenir de dispositif dont on peut raisonnablement attendre qu'il interrompe la continuité électrique ou introduise une impédance significative, à l'exception des composants destinés à être retirés. Cette exigence peut être levée seulement temporairement pour vérifier la continuité des conducteurs de protection ou pour mesurer le courant du conducteur de protection – voir l'Article 18.

7.6.8 Lorsque les éléments de la liaison équipotentielle de protection peuvent être interrompus par le même coupleur ou dispositif de prise de courant que les conducteurs d'alimentation concernés, la liaison équipotentielle de protection ne doit pas être interrompue avant les conducteurs d'alimentation. La liaison équipotentielle de protection doit être rétablie au plus tard au moment de la reconnexion des conducteurs d'alimentation. Ces exigences ne s'appliquent pas lorsque l'interruption et la reconnexion sont seulement possibles avec l'équipement à l'état hors tension.

7.6.9 Dans les installations et les équipements HT, la liaison équipotentielle de protection ne doit pas être interrompue avant que le contact principal ait atteint une distance de sectionnement qui peut résister à la tension de tenue aux chocs assignée de l'équipement.

7.6.10 Les conducteurs de la liaison équipotentielle de protection, qu'ils soient isolés ou nus, doivent être immédiatement identifiables par leur forme, leur emplacement, le marquage ou la couleur, à l'exception des conducteurs qui ne peuvent pas être déconnectés sans destruction, par exemple dans les connexions enroulées et câblage similaire dans l'équipement électronique et les pistes sur les cartes de circuit imprimé. Si l'identification se fait par la couleur, elle doit être conforme à l'IEC 60445:2017.

7.6.11 Dans l'équipement BT, les conducteurs de protection ou la continuité du système de liaison de protection doivent être conformes à 8.2 de l'IEC 60204-1:2016. Cela inclut les exigences relatives à l'exclusion des dispositifs de coupure, des pièces qu'il n'est pas nécessaire de connecter et de l'interruption.

Les points de connexion des connecteurs de protection, la liaison de protection dans les installations comprenant un **courant de fuite** de terre qui dépasse 10 mA, et la liaison fonctionnelle doivent être conformes à 8.2 et 8.4 de l'IEC 60204-1:2016.

7.6.12 Dans l'équipement BT, les rails de roulement peuvent être utilisés comme circuit de retour sous réserve que, en cas de défaut, l'impédance de ce circuit soit suffisamment faible pour maintenir à une valeur ne dépassant pas 25 V (valeur efficace) ou 60 V (en courant continu) la tension de pas et la tension de contact entre ces rails et le sol voisin.

7.6.13 La terre, les conducteurs de protection, les gaines et les structures ne doivent pas être utilisés comme partie d'un circuit actif, sauf spécification contraire dans les Exigences particulières.

7.6.14 La mise à la terre des circuits secondaires doit être évitée à moins d'améliorer la sécurité générale de l'installation. Si les circuits secondaires sont raccordés à la terre, ils ne doivent être accessibles que si la tension du circuit secondaire est faible au point que les limites de **courant de contact** sont satisfaites – voir 7.9 pour de plus amples informations.

7.6.15 Les moyens de connexion, à l'exception des connexions de prise de courant, doivent être clairement identifiés soit à l'aide d'un symbole IEC 60417-5019:2006-08 (voir l'Annexe G), ou à l'aide des lettres PE, ou par la combinaison des deux couleurs vert et jaune. L'indication ne doit pas être apposée ou fixée au moyen de vis, de rondelles ou d'autres pièces susceptibles d'être enlevées au moment de la connexion des conducteurs.

Pour les appareils connectés par cordon, le conducteur de protection du cordon doit, en cas de défaillance du mécanisme antitraction, être le dernier conducteur à être interrompu.

7.6.16 Tous les câbles, conduits ou tubes à gaine conductrice traversant les parties d'une **enveloppe** contenant des circuits haute tension dans la bande de tension 3 doivent être mis à la terre au point où ils traversent l'**enveloppe**.

7.7 Dispositions supplémentaires pour la protection contre les défauts à des fréquences supérieures à 200 Hz

7.7.1 La protection contre les défauts doit comprendre une ou plusieurs des dispositions de 7.7.2 à 7.7.5, indépendantes de celles de la protection principale et complémentaires à celles-ci.

7.7.2 Les parties de l'**équipement électrique** fonctionnant à des fréquences supérieures à 200 Hz doivent être capables de fonctionner correctement en ce qui concerne les effets sur la peau et de proximité dans des **conditions de fonctionnement normal** et en **condition de premier défaut électrique**.

7.7.3 Toute **isolation** complémentaire doit être dimensionnée pour résister aux mêmes contraintes que pour l'**isolation principale**. En outre, les matériaux isolants doivent avoir des facteurs de perte diélectrique assez faibles à la température et à la fréquence de fonctionnement pour que l'**isolation** ne soit pas dégradée par le chauffage diélectrique des matériaux.

7.7.4 Tous les circuits haute fréquence doivent être séparés par galvanisation du système de terre à la fréquence du réseau. La défaillance de la **séparation électrique** entre le circuit et le système de terre à la fréquence du réseau qui peut charger les parties accessibles d'une **tension de contact effective** dangereuse doit être détectée par un **dispositif de protection** actionné par la tension de défaut et entraîner une déconnexion et l'absence de courant dans les circuits.

Une mise à la terre à haute fréquence peut être directement connectée au système de terre à la fréquence du réseau, si cela réduit les risques associés en comparaison à une **séparation électrique**; des informations détaillées sont fournies dans les Exigences particulières.

7.7.5 Les conducteurs séparés à faible résistance qui constituent le trajet de courant principal depuis la source de fréquence du circuit à l'applicateur de traitement ou élément similaire doivent respecter les points suivants.

- a) Ils doivent être capables de résister à toutes les influences internes et externes (notamment mécaniques, thermiques, corrosives, à décharge lumineuse) qui peuvent être attendues.
- b) Ils doivent être conformes à la tension la plus haute produite en **condition de premier défaut électrique**, si les conducteurs sont accessibles pendant la maintenance; leur **isolation** électrique et leur courant admissible doivent être tels qu'ils ne surchauffent pas pendant une **condition de premier défaut** quelconque prévisible; si des courants excessifs peuvent survenir pendant une période assez longue en **condition de premier défaut électrique** prévisible telle qu'une surchauffe se produit, un dispositif de détection du courant qui met l'équipement hors tension de façon permanente avant que les propriétés du conducteur ne soient compromises doit être installé.
- c) Ils ne doivent pas être retirables sans l'aide d'un outil.
- d) Si, pour des raisons de conception d'équipement, il est nécessaire d'inclure une déconnexion séparable du conducteur du circuit principal à des fins de maintenance, sa prise de courant doit être combinée mécaniquement à un circuit de sécurité empêchant la mise sous tension du circuit principal lors de la déconnexion et on doit intégrer un dispositif de **verrouillage** ou similaire dans le système de prise de courant, ainsi qu'une **isolation** suffisante sur l'extérieur pour assurer une déconnexion sans danger; ces

exigences ne s'appliquent pas si la séparation est nécessaire seulement lors de l'installation et de la mise à l'arrêt définitif et n'est alors possible qu'à l'aide d'outils.

- e) La connexion du conducteur de circuit séparable doit être rétablie au plus tard au moment de la reconnexion des conducteurs d'alimentation; cette exigence ne s'applique pas lorsque l'interruption et la reconnexion sont possibles seulement avec un équipement à l'état hors tension.
- f) Les connexions électriques du circuit aux extrémités doivent être séparées et donc ne pas être combinées avec une autre connexion électrique ou la liaison équipotentielle de protection d'une autre partie de l'installation ou de l'équipement.

7.8 Courants dans les conducteurs de protection

7.8.1 Des mesures doivent être prises dans l'installation ou l'équipement pour empêcher des courants excessifs dans le conducteur de protection qui dégradent la sécurité ou les **conditions de fonctionnement normal** de l'installation. La compatibilité doit être assurée pour les courants de toutes les fréquences, fournis à l'équipement et produits par lui.

7.8.2 Les limites suivantes sont applicables à l'équipement alimenté à la fréquence du réseau:

- a) pour le courant de branchement utilisant un équipement comportant une prise monophasée ou polyphasée et un système de socle de valeur assignée inférieure ou égale à 32 A: moins de 2 mA pour un courant assigné inférieur à 4 A, moins de 5 mA pour un courant assigné dépassant 10 A et 0,5 mA/A entre ces valeurs;
- b) pour le matériel d'utilisation de la connexion permanente et le matériel d'utilisation stationnaire, tous deux sans mesures spéciales pour le conducteur de protection, ou le matériel d'utilisation de branchement équipé d'une prise monophasée ou polyphasée et d'un système de socle, de valeur assignée supérieure à 32 A: moins de 3,5 mA pour un courant assigné inférieur à 7 A, moins de 10 mA pour un courant assigné dépassant 20 A et 0,5 mA/A entre ces valeurs.

Si des dispositifs à courant différentiel résiduel sont fournis dans l'installation, le courant du conducteur de protection doit être compatible avec les mesures de protection fournies.

Dans des **conditions de fonctionnement normal**, l'équipement à la fréquence du réseau ne doit pas générer de courant avec une composante de courant continu dans le conducteur de protection qui nuirait au bon fonctionnement des dispositifs à courant différentiel résiduel ou à d'autres équipements, à moins de choisir un dispositif à courant différentiel résiduel permettant un courant continu dans le circuit réseau.

7.8.3 Pour le matériel d'utilisation destiné à une connexion permanente et présentant un courant de conducteur de protection supérieur à 10 mA, une connexion sûre et fiable à la terre, telle que décrite dans l'IEC 60364-5-54:2011, doit être fournie.

7.9 Courant de contact et tension de contact effective

7.9.1 Les **courants de contact** causant des blessures doivent être évités. Aucune pièce ou surface susceptible de causer une blessure en cas de contact ne doit être accessible. Les limites des **courants de contact** maximaux admissibles en fonction de la fréquence du champ de génération sont fournies dans l'Annexe B avec les classes de risque applicables.

7.9.2 Si des **courants de contact** sont perceptibles soit dans des **conditions de fonctionnement normal** ou en **condition de premier défaut électrique**, le **constructeur** doit l'indiquer à l'**utilisateur** dans les instructions d'utilisation.

7.9.3 Dans le cas où il est nécessaire de toucher des pièces susceptibles de causer des **courants de contact** non nuisibles dans les **conditions de fonctionnement normal**, le **constructeur** doit