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TECHNICAL SPECIFICATION

colour inside

Industrial electroheating and electromagnetic processing equipment – Evaluation of hazards caused by magnetic nearfields from 1 Hz to 6 MHz

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

INDUSTRIAL ELECTROHEATING AND ELECTROMAGNETIC PROCESSING EQUIPMENT –

Evaluation of hazards caused by magnetic nearfields from 1 Hz to 6 MHz

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

IEC TS 62997, which is a technical specification, has been prepared by IEC technical committee 27: Industrial electroheating and electromagnetic processing.

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

Enquiry draft	Report on voting
27/1000A/DTS	27/1007/RVDTS

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

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

In this technical specification, the following print types are used:

- terms used throughout this specification which have been defined in Clause 3: in bold type.

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- withdrawn,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

An external alternating magnetic flux can induce electric fields inside the human body. Such induced fields constitute an important category of possible hazards. This technical specification deals with the sub-category of non-radiating magnetic nearfields in the frequency range between 1 Hz and 6 MHz being the source of the induced electric fields. The primary focus is on technical applications in industrial electroheating and electromagnetic processing installations and equipment, with the applicable safety standards in the IEC 60519 series.

IEC 62110:2009 deals with measurement procedures applicable to the characterisation of magnetic and electric field levels with regard to public exposure. IEC 62822-2:2016 provides assessments of exposure restrictions for electric arc welding equipment from 0 Hz to 300 GHz. There is, however, no other IEC standard or technical specification covering more general kinds of equipment and hazard assessments in the range of up to 6 MHz.

Magnetic field hazards are dependent on the source characteristics, including such without and with magnetic materials in the source circuit or workload. Such materials enhancing the magnetic flux density are required for creating an induced electric shock hazard below some few kHz. Static magnetic fields can cause other hazards than those by conventionally induced electric fields and are dealt with in IEC 60519-1:2015. The lower frequency limit in this technical specification is therefore 1 Hz.

NOTE A parallel IEC technical specification IEC TS 62996[1] is developed by IEC TC 27, to cover touch and contact currents and voltages in the frequency range 1 kHz to 6 MHz. It also includes measurements of capacitively coupled currents through the body. Touch and contact currents and voltages at lower frequencies are covered by IEC 61140:2016.

The upper frequency limit 6 MHz is chosen, since

- higher frequencies are not expected to be employed by internal frequency converters for DC voltage transformation in equipment;
- the free space wavelength of 6 MHz is 50 m, which results in wave phenomena that essentially do not exist in or at parts of the human body which have less than 10 % characteristic dimensions of this;
- the power penetration depth limitation by the equivalent complex permittivity of body tissues has not yet set in at 6 MHz, so the magnetic flux completely penetrates the parts of the body under study with no shielding effects, resulting in an overall simpler and linear frequency dependence of the induced electric fields;
- the equivalent complex permittivity of the parts of the body under study is typically so high in this frequency range that external electric fields are efficiently hindered from entering the part of the body and causing internal electric fields – as a consequence, the separation of capacitively coupled and induced electric fields is therefore strong;
- processing frequencies below 6 MHz are typically low impedance; higher impedance dielectric heating has its lowest ISM frequency at 6,8 MHz, being dealt with in IEC 60519-9:2005.

Electromagnetic exposure is commonly defined to occur whenever and wherever a person is subjected to electric, magnetic or electromagnetic fields, and the allowed acceptable levels of exposure are usually specified by national radiation protection or worker protection agencies in the framework of health and safety regulations addressing the user of equipment. Since different sources of information on the associated safety requirements exist and these sources tend to apply quite different safety margins, there are unfortunately significant discrepancies among their levels of the in principle pathophysiologically based so-called basic restrictions.

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1 Under preparation. Stage at the time of publication: IEC/CDTS 62996:2016.

When the source is well defined and is the basis for calculations and computations, the technical treatment of emission is preferred to the consideration of exposure. That is the case in this technical specification, also since the external magnetic nearfield is not modified by the presence of the part of the body nearby. Furthermore, the resulting induced and potentially hazardous internal electric fields depend on the size, shape and orientation of the part of the body in relation to the source, and on the spatial characteristics of the field. Since the induced electric field by magnetic nearfields is directed essentially parallel to the bodypart surface, whereas it is perpendicular for contact current fields, the hazard criteria applied in this technical specification differ from those in some standards.

This technical specification provides complete information for assessments.

The treatment of magnetic nearfields as defined in this technical specification deals with discontinuous presence of the operator in the nearfield, as well as intermittent operation. Cases which do result in shorter term higher body tissue temperature rise in very small tissue volumes are also dealt with in this technical specification. The information and requirements are thus useful for other similar cases in science and industry.

As to measurement procedures and equipment, IEC 60519-1:2015 provides an overview. IEC TC 106 has published standards which provide guidance for situations where the source of the magnetic field and the exposed person are typically further apart than in the situations addressed in this technical specification. As a consequence, those standards tend to define magnetic field sensors neither well suited for measurements very close to current-carrying conductors nor on magnetic fields which vary considerably over the region where the nearest part of the body being submitted to the emission is located.

IEC 62822-2:2016 developed by IEC TC 26 deals with the reduction of the coupling from magnetic nearfields compared with homogeneous fields, as does this technical specification, but in somewhat different ways.

Hazard estimations related to magnetic nearfields pose problems with the use of some existing exposure standards, either by an exaggerated safety margin of the so-called reference levels, or by complicated and expensive numerical modelling in applying the so-called basic restrictions. The methods in this technical specification reduce costs to industry by being simple and direct. They are also realistic, in particular since the number of reported accidents or incidents caused by magnetic nearfields as addressed in this technical specification are exceptionally few in relation to the occurrence of strong such fields in industry.

This technical specification specifies a volunteer test method for assessments of perception of immediate muscle and nerve reactions in fingers and hands at frequencies below 100 kHz. A first argument is that the test ends at the perception level when the person's finger or hand slowly approaches the current-carrying conductor without contacting it, and a distance is measured. There is no risk of harm, unlike with medical tests using volunteers, which require ethical permits, etc. A second argument is that the computational alternative in cases with intricate conductor geometries and possible magnetic materials in the source circuit or workload is highly complicated and therefore expensive, requiring numerical modelling since measurements of the magnetic nearfield is virtually impossible and the induced electric field depends on the positioning of the finger or hand. A third argument is that realistic data are immediately obtained and typically result in the safety distance in most cases being very short and therefore easy to control.

INDUSTRIAL ELECTROHEATING AND ELECTROMAGNETIC PROCESSING EQUIPMENT –

Evaluation of hazards caused by magnetic nearfields from 1 Hz to 6 MHz

1 Scope

This IEC technical specification specifies the characteristics of external magnetic nearfields, computations of and requirements on induced electric fields in body tissues in the frequency range from 1 Hz to 6 MHz with respect to induced electric shock phenomena, for electroheating (EH) based treatment technologies and for electromagnetic processing of materials (EPM). The phenomena include specific absorption rates with time integration.

NOTE The overall safety requirements for the various types of equipment and installations for electroheating or electromagnetic processing in general result from the joint application of the General Requirements specified in IEC 60519-1:2015 and Particular Requirements covering specific types of installations or equipment. This technical specification complements the General Requirements and applies to internal frequency converters for creating high or low DC voltages, and to processing frequencies.

Induced electric shock phenomena dealt with in this technical specification are caused by the alternating magnetic nearfield external to a current-carrying conductor or permeable object, inducing an electric field in a part of the body in the vicinity of the conductor.

Relaxed criteria compared with the general **basic restrictions** for exposure apply. Simplified hazard assessment procedures apply for situations when only fingers, hands and/or extremities are in the magnetic nearfield.

This technical specification does not apply to equipment within the scope of IEC 60519-9. i.e. equipment or installations for high frequency dielectric heating.

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

IEC 60519-1:2015, *Safety in installations for electroheating and electromagnetic processing – Part 1: General requirements*

3 Terms, definitions, symbols and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60519-1:2015 and the following 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.

NOTE 1 General definitions are given in IEC 60050, the International Electrotechnical Vocabulary. Terms relating to industrial electroheating are defined in IEC 60050-841.

NOTE 2 Some of the definitions in this clause differ somewhat to those in standards and guidelines, as well as between these. Definitions in this Technical Specification are bolded in the text and several of them have explanatory notes in this clause.

3.1.1
aversion
experience that is disliked but can be accepted for a short time before voluntary withdrawal

Note 1 to entry: Reactions to aversive stimuli are consciously controlled, as opposed to reactions to pain which causes harm and can normally not be controlled.

Note 2 to entry: Typical quotients of internal electric fields between **aversion** and perception in the Hz to kHz range is about 2; see IEC TS 62996:– covering touch and contact currents and voltages in the frequency range from 1 kHz to 6 MHz.

3.1.2
basic restrictions
BR
restrictions on *in situ* (i.e. internal) electric fields or specific absorption rates (**SAR**) or power densities with time and spatial averaging or integration, resulting from a part of or the whole body being subjected to an external alternating electric (E) field, magnetic (B) flux or electromagnetic field, and that are intended to be based directly on resulting established pathophysiological effects

Note 1 to entry: The term exposure is avoided since it has many, even contradictory, meanings. As a consequence, the defined term is not generally applicable outside the scope of this technical specification; see Note 3 to entry.

Note 2 to entry: **Basic restrictions** have a safety margin to harm.

Note 3 to entry: Sources of scientific and medical information on numerical values are e.g. IEEE, ICNIRP and EU. Another term for the limits is exposure limit values (ELV). Levels are different among sources; reasons within the scope of this technical specification are differences in safety factor levels, different considerations of magnetic flux curvatures and decay rates with distance from the source, body surface versus in-depth fields, **coupling values**, and measurement sensors.

Note 4 to entry: Since *in situ* electric field strength or power densities in tissues are secondary to the emitted magnetic nearfield, definitions by IEC TC 34 and TC 106 are not used in this technical specification.

Note 5 to entry: Time factors of **specific absorption rates** (**SAR**) or power densities, i.e. energy absorption versus time, are necessary for establishing criteria.

3.1.3
conductor geometry and current restrictions
CGCR
restrictions on certain combinations of conductor geometry, current, operating frequency (i.e. source properties) and distance/orientation of fingers, hands and extremities in relation to a source with no permeable material being affected, intended to be indirectly based on resulting pathophysiological effects

Note 1 to entry: **CGCR**s for complicated source properties are not considered in this technical specification.

3.1.4
coupling value
relationship between induced electric field strength maximum in a bodypart, the frequency and the inducing magnetic flux density in defined locations, under the assumption that there is no counter-induced magnetic field in the bodypart due to its resistivity

Note 1 to entry: The connection between these is $E = C \cdot f \cdot B$, where E is the electric field strength, C the coupling value, f the frequency and B the magnetic flux density. C is thus in metre.

Note 2 to entry: Examples of the defined location of the B vector flux are near the location of the maximum induced electric field strength or the centre of an induction coil.

3.1.5
electromagnetic emission
phenomenon by which electromagnetic energy is available near a source

Note 1 to entry: For industrial microwave equipment dealt with in IEC 60519-6:2011, emission rather than exposure is also applied.

Note 2 to entry: The source data used in this standard are typically expressed by conductor geometry, current and frequency in cases with no permeable or disturbing material, since magnetic nearfield flux properties are in many cases difficult or even practically impossible to measure with sufficient accuracy.

Note 3 to entry: The energy can be reactive, i.e. non-radiating (evanescent) into free space.

[SOURCE: IEC 60050-161:1990, 161-01-08, modified – The definition has been modified by replacing the words "emanates from" by "is available near" and notes to entry have been added.]

3.1.6
induced electric shock
pathophysiological effect resulting from an internal induced electric field caused by an alternating magnetic flux external to a current-carrying conductor or other flux source

Note 1 to entry: The effects in the frequency range below 100 kHz are essentially immediate, as muscle and nerve reactions. In the higher frequency range these have vanished and time-dependent local overheating constitutes the possible hazard.

Note 2 to entry: With magnetic nearfields the bodypart where the highest electric field intensity occurs is typically that nearest to a current source or the magnetic flux maximum, or a region in which the induced closed current path has a reduced cross section.

Note 3 to entry: No contact currents are supposed to be created, as with conventional electric shock dealt with in IEC TS 62996:–.

3.1.7
magnetic nearfield
magnetoquasistatic field
non-radiating alternating magnetic field existing near a current source, characterised by a field curvature and spatial decay rate at the point of investigation

Note 1 to entry: Typically, these particular influences by **magnetic nearfields** have disappeared at source distances twice the characteristic size of the bodypart.

Note 2 to entry: The field curvature is the radius R_{osc} of the osculating circle.

Note 3 to entry: Comparative calculations or computations of the **coupling value** in a homogeneous magnetic flux are valuable for approximate verifications, but such flux is not a nearfield. There are then cases where calculations and/or magnetic flux measurements are preferred.

3.1.8
pain
unpleasant experience such that it is not readily accepted a second time by the subject submitted to it

EXAMPLE A capacitor discharge corresponding to approximately 1 µF capacitance at 100 V between gripping hands, 3,5 mA AC touch current, the sting of a bee, the burn of a cigarette.

Note 1 to entry: Agents at the pain level cause harm as defined in e.g. IEC 60050-903:2013, 903-01-01.

Note 2 to entry: The examples are objective statements for standardisation purposes. Subjective experiences vary.

[SOURCE: IEC TS 60479-2:–, 3.13, modified – Note 1 has been updated and an example and Note 2 have been added.]