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Human exposure to electromagnetic fields - Low frequency (0 Hz to 10 kHz)

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Human exposure to electromagnetic fields
Low-frequency (0 Hz to 10 kHz)

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CENELEC

European Committee for Electrotechnical Standardization
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Europäisches Komitee für Elektrotechnische Normung

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Foreword

This European Prestandard has been prepared by SC 111A, Low-frequency EM radiation, of Technical Committee CENELEC TC 111, Electromagnetic fields in the human environment.

The text of the draft was voted and accepted during the combined meeting of CENELEC TC 111 and its SCs on 1994-11-30.

The following date was fixed :

- latest date of announcement of the ENV at national level (doa) 1995-03-01

Documents referred to in this Prestandard are indicated by a number between square brackets and are listed in annex D, References.

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1 Introduction

This Prestandard, which is divided into two parts, deals with the exposure of persons to electromagnetic fields and radiation at all frequencies from 0 up to 300 GHz (Part 1: 0 to 10 kHz and Part 2: 10 kHz to 300 GHz). Electromagnetic fields interact with the human body and other biological systems through a number of physical mechanisms. This Prestandard is based on well-established short-term effects, which, depending on the frequency, include the stimulation of electrically-excitable cells in nerve and muscle tissue and heating.

Basic restrictions are given to prevent any adverse consequences of these effects. They are specified in terms of biologically relevant quantities, typically induced current density and specific absorption rate. These quantities cannot be determined directly so the standard specifies a set of more-readily-measurable reference levels, in terms of external electric and magnetic field strengths and power density, derived from the basic restrictions.

Pulsed electromagnetic fields may produce other effects, such as the auditory perception of microwave pulses, in addition to those associated with continuous wave radiation. For these, restrictions in terms of specific energy absorption and energy flux density are given.

Electromagnetic fields can also interact indirectly when a person touches a conductive object in a field. If the field is sufficiently intense, the person may experience a shock or burn. To control these effects, limits are specified for the contact current.

This Prestandard has a two-tier structure in which lower levels are specified for the general public than for workers. For the general public, allowance has to be made for all likely activities and for all ages and states of health. Such persons may be unaware of some of the effects of exposure to electromagnetic fields, whereas appropriate information and training can be provided for workers.

There are reports that electromagnetic fields of lower intensity than the references levels specified in this standard may have long-term effects on health. Currently available research however has not established adverse effects and does not provide a basis for restricting exposure.

Cardiac pacemakers and other active implantable devices are designed to cope with the typical levels of electromagnetic interference encountered in daily life. However, some devices - and also some metallic prosthetic implants - may be affected below the reference levels given in this Prestandard. When necessary, advice should be sought from the manufacturer of the device and from the medical authority which implanted it. A CENELEC Standard concerning interference and implantable cardiac pacemakers is available [EN 50061:1988/A1:1995].

This Prestandard sets basic restrictions and reference levels that have been derived in a documented way. It is recognized that additional considerations may lead some countries to regard the reference levels as minimum requirements in certain frequency ranges and add further margins.

This Prestandard is issued as a prospective standard for provisional application so as to gain experience in its use. It may be modified in the light of that experience or new scientific data before conversion to a full standard, or it may be withdrawn.

The present document is regarded as a basic standard. Further standardization work should include the development of product and product family standards, based on this document, which define precisely the measurement method in each case. This additional work should be done in the coming years in parallel with the review of ENV 50166.

2 Scope

This part of the Prestandard deals with the prevention of adverse short-term effects of human exposure to static and low-frequency electric and magnetic fields in the frequency range from 0 to 10 kHz. In this region of the electromagnetic spectrum, the electric and magnetic fields must be considered separately. The rationale is set out in Annex A.

This Prestandard does not apply to the deliberate exposure of persons to electric or magnetic fields during medical research, diagnosis or treatment.

Safety hazards which may be associated with the ignition of flammable materials or the triggering of explosive devices in strong fields are not covered.

Compliance with this Prestandard may not exclude interference with or effects on some examples of implants such as cardiac pacemakers.

It is recognised that it will not always be possible to comply with the provisions of this standard under exceptional operating conditions, such as momentary short-circuit or fault currents, inherent in the technology of electrical equipment.

3 Definitions

3.1 Basic restrictions

Basic restrictions are the requirements or values specified for the quantities closely related to the biological effects to be controlled. Basic restrictions shall not be exceeded. For the frequency range covered by this part of the standard, there are basic restrictions in terms of induced current density, contact current, electric field and static magnetic field.

3.2 Reference levels

Reference levels are more-readily-measurable quantities, such as field levels, derived from the basic restrictions and given to provide a simpler means to verify compliance with the basic restrictions and to assess field effects. Their derivation includes margins based on considerations of a wide range of possible exposure situations so that, under all reasonable conditions, the basic restriction would not be exceeded if the field is below the associated reference level. In general, the reference levels may be exceeded provided the basic restrictions are not exceeded. This method of assessment may be necessary for regions of markedly non-uniform field.

3.3 Direct effects

Direct effects are those resulting from the direct coupling of an electric or magnetic field to the human body.

An electric field induces a surface charge on an exposed body, which may give rise to a tingling of the skin, vibration of body hair and small discharges, for example to clothing.

An alternating electric or magnetic field gives rise to an induced current within the body whose magnitude depends on the field strength, the frequency and the size, shape and orientation of the body. This current may stimulate nerves and muscle tissue at high current densities.

An intense static magnetic field may induce vertigo or nausea in a person moving in the field.

3.4 Indirect effects

Indirect effects are those resulting from the coupling of an electric or magnetic field to some object, such as a metallic structure, and then to a person who touches the object. Spark discharges and a continuing contact current may result which, depending on their magnitude, can cause nerve and muscle stimulation, discomfort, startle, electric shock and burns.

3.5 Workers

Employed and self-employed persons are termed workers whilst following their employment

3.6 General public

All non-workers. See 3.5 for the definition of workers.

3.7 Electric field

The electric field created in the vicinity of a charged conductor is a vector quantified by the electric field strength E. This quantity is the force exerted by an electric field on a unit charge and is measured in volts per metre (V/m). In the case of sinusoidally varying fields, the E vector either oscillates along a fixed axis (single-phase source) or rotates in a plane and describes an ellipse (polyphase or multiple synchronous sources).

Because the electric field in the vicinity of conductive objects (including persons) is generally perturbed by such objects, the value of the 'unperturbed electric field' (ie the field that would exist in the absence of movable objects and persons) shall be used to characterize exposure conditions.

3.8 Magnetic field

The magnetic field is a vector quantity. As in the case of electric fields, this vector either oscillates along a fixed axis (single-phase source) or rotates in a plane and describes an ellipse (polyphase or multiple synchronous sources). The magnetic field strength, H, is expressed in amperes per metre (A/m).

However, the magnetic flux density, B, also known as the magnetic induction, is often used to characterize magnetic fields, particularly in the context of biological effects. The magnetic flux density is defined in terms of the force exerted on a charge moving in the field and has the unit tesla (T). One tesla is equal to 1 Vs/m^2 or 1 weber per square metre (Wb/m^2).

There is an important distinction between B and H fields, particularly in magnetic materials. However, in free space, and for practical purposes in air and in biological tissue, the ratio B/H is a constant. This ratio is the magnetic permeability of free space, $\mu_0 = 4\pi \times 10^{-7}$ Vs/Am or henrys per metre (H/m). Thus in free space, air or biological tissue, a magnetic flux density of 1 mT corresponds to a magnetic field strengh of $10^4/4\pi$ A/m, or almost 800 A/m.

3.9 Effective field strength

Alternating electric and magnetic fields are, in general, elliptically polarized and can each be described in terms of time-varying sinusoidal components along three orthogonal axes. The effective (root mean square - rms) field strength is the root of the sum of the mean squares of these three components.

That is, for an electric field:

$$E_{rms} = \sqrt{(E_x^2 + E_y^2 + E_z^2)}$$

where E_x, E_y, E_z are the rms values of the three components taken over complete cycles. A similar expression applies for the magnetic field.

3.10 Current density

Current density is a vector quantity whose magnitude is equal to the charge that crosses per unit time a unit surface area perpendicular to the flow of charge. Current density is expressed in amperes per square metre (A/m^2).

3.11 Contact current

Contact current is the alternating current which flows through a human body due to contact with a conductive object coupled to an electric or magnetic field.

4 Limits

4.1 Basic restrictions

The basic restrictions given in this subclause shall not be exceeded. The effect of personal protective equipment may be taken into account.

4.1.1 Induced current density

The basic restrictions on current density induced in the head or the heart region of the trunk by continuous exposure to an external alternating field are given in the tables below.

The current density is to be averaged over a cross-section of 100 mm^2 perpendicular to the current flow in the head and heart region. The variation with frequency is shown in figure 1.

These basic restrictions are the controlling factors for the reference levels for electric field from 50/60 Hz to 10 kHz (tables 5 and 6) and for magnetic field from 0,23/1,15 Hz to 10 kHz (tables 7 and 8).

If an electric and a magnetic field of the same frequency are present simultaneously, the corresponding induced current densities should be added. If the relative directions and phases of the current flows induced are known and reasonably constant, they may be taken into account in vectorial addition before comparison with the basic restriction.
When fields of different frequencies are present simultaneously, the following formula should be used to take account of the separate contributions to the current density:

$$\Sigma_i \, J_i/J_{BR,i} \leq 1$$

where J_i is the current density induced by the i^{th} frequency, $J_{BR,i}$ is the basic restriction for that frequency and the summation is made over the i frequencies. Strictly, the current densities should again be added vectorially. Only frequencies for which $J_i/J_{max} \geq 0,3$ need be included, where J_{max} is the largest of the J_i contributions.

Table 1 : Induced current density - Workers

Frequency (f, Hz)	Induced current density (mA/m^2, rms)
0,1 - 1	40
1 - 4	40/f
4 - 1 000	10
1 000 - 10 000	f/100

Table 2 : Induced current density - General public

Frequency (f, Hz)	Induced current density (mA/m^2, rms)
0,1 - 1	16
1 - 4	16/f
4 - 1 000	4
1 000 - 10 000	f/250

4.1.2 Contact current

The basic restrictions on contact current arising from touching objects in an alternating field are given in the Tables below. The initial transient at the moment of contact is excluded from these requirements. The current is to be averaged over a period of one second. The variation with frequency is shown on Figure 1.

Compliance with these basic restrictions may be achieved through engineering procedures and administrative controls, as well as by control of the fields.

Table 3 : Contact current - Workers

Frequency (f, Hz)	Current (mA, rms)
0,1 - 10 000	3,5

Table 4 : Contact current - General public

Frequency (f, Hz)	Current (mA, rms)
0,1 - 7 500	1,5
7 500 - 10 000	$2\times10^{-4}f$

4.1.3 Electric field

The basic restriction on whole-body exposure to electric fields predominantly parallel to the body is 42 kV/m (peak) for the range 0 - 0,1 Hz and 30 kV/m (rms) above 0,1 Hz. This basic restriction is the controlling factor for the workers reference levels for electric fields up to 50 Hz. Further requirements concerning exposure to electric fields are given in 4.2.1.

4.1.4 Static magnetic field

The basic restriction on whole-body exposure to static magnetic fields is 2 T. Further requirements concerning exposure to magnetic fields are given in 4.2.2.

4.2 Reference levels

Complying with the field levels given in this subclause automatically ensures compliance with the basic restrictions on induced current density, electric field and static magnetic field. Where it can be shown that the basic restrictions on induced current density are not infringed, the associated field levels may be exceeded.

For electric fields and the general public, such exceedance shall not cause stress or annoyance because of the perception of surface charge effects. For static magnetic fields and the general public, such exceedance shall be limited to occasional access to special facilities under appropriately controlled conditions.