

© Copyright SEK. Reproduction in any form without permission is prohibited.

**Exponering för elektriska eller magnetiska fält
inom det låga och intermediära frekvensområdet –
Beräkning av strömtäthet och inre elektriska fält
inducerade i människokroppen –
Del 3-1: Exponering för elektriska fält –
Analytiska modeller och numeriska 2D-modeller**

*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 –*

*Part 3-1: Exposure to electric fields –
Analytical and 2D numerical models*

Som svensk standard gäller europastandarden EN 62226-3-1:2007. Den svenska standarden innehåller den officiella engelska språkversionen av EN 62226-3-1:2007.

Nationellt förord

Europastandarden EN 62226-3-1:2007

består av:

- **europastandardens ikraftsättningsdokument**, utarbetat inom CENELEC
- **IEC 62226-3-1, First edition, 2007 - 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 - Part 3-1: Exposure to electric fields - Analytical and 2D numerical models**

utarbetad inom International Electrotechnical Commission, IEC.

Standarden skall användas tillsammans med SS-EN 62226-1, utgåva 1, 2005.

ICS 17.220.20

Standarder underlättar utvecklingen och höjer elsäkerheten

Det finns många fördelar med att ha gemensamma tekniska regler för bl a säkerhet, prestanda, dokumentation, utförande och skötsel av elprodukter, elanläggningar och metoder. Genom att utforma sådana standarder blir säkerhetskraven tydliga och utvecklingskostnaderna rimliga samtidigt som marknadens acceptans för produkten eller tjänsten ökar.

Många standarder inom elområdet beskriver tekniska lösningar och metoder som åstadkommer den elsäkerhet som föreskrivs av svenska myndigheter och av EU.

SEK är Sveriges röst i standardiseringssarbetet inom elområdet

SEK Svensk Elstandard svarar för standardiseringen inom elområdet i Sverige och samordnar svensk medverkan i internationell och europeisk standardisering. SEK är en ideell organisation med frivilligt deltagande från svenska myndigheter, företag och organisationer som vill medverka till och påverka utformningen av tekniska regler inom elektrotekniken.

SEK samordnar svenska intressenters medverkan i SEKs tekniska kommittéer och stödjer svenska experters medverkan i internationella och europeiska projekt.

Stora delar av arbetet sker internationellt

Utdriften av standarder sker i allt väsentligt i internationellt och europeiskt samarbete. SEK är svensk nationalkommitté av International Electrotechnical Commission (IEC) och Comité Européen de Normalisation Electrotechnique (CENELEC).

Standardiseringssarbetet inom SEK är organiserat i referensgrupper bestående av ett antal tekniska kommittéer som speglar hur arbetet inom IEC och CENELEC är organiserat.

Arbetet i de tekniska kommittéerna är öppet för alla svenska organisationer, företag, institutioner, myndigheter och statliga verk. Den årliga avgiften för deltagandet och intäkter från försäljning finansierar SEKs standardiseringssverksamhet och medlemsavgift till IEC och CENELEC.

Var med och påverka!

Den som deltar i SEKs tekniska kommittéarbete har möjlighet att påverka framtidens standarder och får tidig tillgång till information och dokumentation om utvecklingen inom sitt teknikområde. Arbetet och kontakterna med kollegor, kunder och konkurrenter kan gynnsamt påverka enskilda företags affärsutveckling och bidrar till deltagarnas egen kompetensutveckling.

Du som vill dra nytta av dessa möjligheter är välkommen att kontakta SEKs kansli för mer information.

SEK Svensk Elstandard

Box 1284
164 29 Kista
Tel 08-444 14 00
www.elstandard.se

September 2007

ICS 17.220.20

English version

**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 -
Part 3-1: Exposure to electric fields -
Analytical and 2D numerical models**
(IEC 62226-3-1:2007)

Exposition aux champs électriques
ou magnétiques à basse
et moyenne fréquence -
Méthodes de calcul des densités
de courant induit et des champs électriques
induits dans le corps humain -
Partie 3-1: Exposition
à des champs électriques -
Modèles analytiques et numériques 2D
(CEI 62226-3-1:2007)

Sicherheit in elektrischen
oder magnetischen Feldern im niedrigen
und mittleren Frequenzbereich -
Verfahren zur Berechnung der induzierten
Körperstromdichte und des im menschlichen
Körpers induzierten elektrischen Feldes -
Teil 3-1: Exposition gegenüber
elektrischen Feldern -
Analytische Modelle
und numerische 2D-Modelle
(IEC 62226-3-1:2007)

This European Standard was approved by CENELEC on 2007-09-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 35, B - 1050 Brussels

Foreword

The text of document 106/125/FDIS, future edition 1 of IEC 62226-3-1, prepared by IEC TC 106, Methods for the assessment of electric, magnetic and electromagnetic fields associated with human exposure, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 62226-3-1 on 2007-09-01.

This European Standard is to be used in conjunction with EN 62226-1:2005.

The following dates were fixed:

- latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2008-06-01
 - latest date by which the national standards conflicting with the EN have to be withdrawn (dow) 2010-09-01
-

Endorsement notice

The text of the International Standard IEC 62226-3-1:2007 was approved by CENELEC as a European Standard without any modification.

CONTENTS

1 Scope	8
2 Exposure to electric field	8
3 General procedure.....	11
3.1 Shape factor.....	11
3.2 Procedure	11
4 Human body models	12
4.1 General	12
4.2 Surface area	12
4.3 Semi-spheroidal model.....	13
4.4 Axisymmetrical body model	15
5 Calculation of induced current	16
5.1 General	16
5.2 Semi-spheroid	16
5.3 Axisymmetrical models	20
5.4 Comparison of the analytical and numerical models	27
6 Influence of electrical parameters	27
6.1 General	27
6.2 Influence of permittivity	27
6.3 Influence of conductivity	28
6.4 Non-homogeneous conductivity	28
7 Measurement of currents induced by electric fields.....	28
7.1 General	28
7.2 Current flowing to the ground	28
Annex A (normative) Analytical solutions for a spheroid in a uniform electric field.....	30
Annex B (normative) Human body axisymmetrical model	33
Annex C (informative) Child body model	38
Annex D (informative) Example of use of this standard	40
Annex E (informative) Numerical calculation methods	44
Bibliography.....	52
Figure 1 – Illustration of the phenomenon of currents induced by electric field in a human body standing on the ground	10
Figure 2 – Potential lines of the electric field generated by an energised wire in the absence of any objects (all distances in metres)	10
Figure 3 – A realistic body model	12
Figure 4 – Scheme of the semi-spheroid simulating a human being standing on a zero potential plane	13
Figure 5 – Equivalent spheroid radius, R , versus height, L , and for different mass, M	15
Figure 6 – The axisymmetrical body model for the reference man (left) and woman (right).....	15

Figure 7 – Conductive spheroid exposed to electric field.....	16
Figure 8 – Calculation of the <i>shape factor for electric field</i> K_E for an spheroid exposed to an unperturbed electric field.....	17
Figure 9 – Current density J_S induced by an unperturbed electric field (1 kV/m, 50 Hz) in a spheroid versus parameter L/R (values in $\mu\text{A}/\text{m}^2$).....	18
Figure 10 – Dimensions and mesh of the semi-spheroid	19
Figure 11 – Distortion of power frequency electric field lines close to the conductive semi-spheroid	19
Figure 12 – Calculated induced current density $J_A(h)$ in the body standing in a vertical 50 Hz electric field of 1 kV/m	21
Figure 13 – Computation domain	23
Figure 14 – Mesh of the man body model and distortion of power frequency electric field lines close to model.....	23
Figure 15 – Distribution of potential lines and 50 Hz electric field magnitude (man model)	24
Figure 16 – Computation of induced currents J_A along a vertical axis, and distribution of induced currents in the man model at 50 Hz	24
Figure 17 – Mesh of the woman body model and distortion of power frequency electric field lines close to model.....	25
Figure 18 – Distribution of potential lines and 50 Hz electric field magnitude (woman model)	26
Figure 19 – Computation of induced currents J_A along a vertical axis, and distribution of induced currents in the woman model at 50 Hz	26
Figure A.1 – Conductive spheroid exposed to electric field	30
Figure B.1 – Normalised axisymmetrical models. Left: man, Right: woman	35
Figure C.1 – Computation of induced currents J_Z along a vertical axis, and distribution of induced currents in the 10 years reference child model.....	39
Figure E.1 – Spheroid model.....	45
Figure E.2 – Space potential model	46
Figure E.3 – Exemple of charge simulation method using rings.....	47
Figure E.4 – Superficial charges integral equation method, cutting of the body into N elements.....	48
Figure E.5 – Mesh of the body using finite element method	49
Figure E.6 – Impedance method	50
Figure E.7 – Yee-method: Electric and magnetic grids for spatial discretization	51
Table 1 – Data for reference man and reference woman	13
Table 2 – Values of $\arcsin(e) / e$ for different values of L/R	14
Table 3 – Derived data using spheroid model at 50 Hz	20
Table 4 – Electric field E_{BR} required to produce basic restrictions J_{BR} in the neck at 50 Hz.....	22
Table 5 – Comparison of values of the shape factor for electric field K_E and corresponding current densities for an unperturbed 50 Hz electric field of 1 kV/m	27
Table B.1 – Measures from antropomorphic survey used to construct vertical dimensions of axisymmetrical model [56]	34

Table B.2 – Measures from antropomorphic survey used to construct the radial dimensions of axisymmetrical model [56]	34
Table B.3 – Normalised model dimensions.....	36
Table B.4 – Axisymmetric model dimensions for reference man and reference woman whose mass and height are defined by ICRP [38] and are given in Table 1	37
Table C.1 – Reference values provided by ICRP for male and female children.....	38
Table C.2 – Dimensions of the reference children (in m excepted SB_R in m^2)	38
Table C.3 – Results of analytical method for the reference children	39
Table D.1 – Normalised dimensions of the women model.....	41
Table D.2 – Calculation of the dimensions for a specific person.....	42

**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 –**

**Part 3-1: Exposure to electric fields –
Analytical and 2D numerical models**

1 Scope

This part of IEC 62226 applies to the frequency range for which exposure limits are based on the induction of voltages or currents in the human body when exposed to electric fields.

This part defines in detail the coupling factor K – introduced by the IEC 62226 series to enable exposure assessment for complex exposure situations, such as non-uniform magnetic field or perturbed electric field – for the case of simple models of the human body, exposed to uniform electric fields. The coupling factor K has different physical interpretations depending on whether it relates to electric or magnetic field exposure. It is the so called “shape factor for electric field”.

This part of IEC 62226 can be used when the electric field can be considered to be uniform, for frequencies up to at least 100 kHz.

This situation of exposure to a “uniform” electric field is mostly found in the vicinity of high voltage overhead power systems. For this reason, illustrations given in this part are given for power frequencies (50 Hz and 60 Hz).

