

INTERNATIONAL STANDARD

NORME INTERNATIONALE



Electric welding equipment – Assessment of restrictions related to human exposure to electromagnetic fields (0 Hz to 300 GHz) – Part 3: Resistance welding equipment

Matériels de soudage électrique – Évaluation des restrictions relatives à l'exposition humaine aux champs électromagnétiques (0 Hz à 300 GHz) – Partie 3: Matériels de soudage par résistance



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2023 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de l'IEC ou du Comité national de l'IEC du pays du demandeur. Si vous avez des questions sur le copyright de l'IEC ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de l'IEC de votre pays de résidence.

IEC Secretariat
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, ...). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch

Discover our powerful search engine and read freely all the publications previews. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org

The world's leading online dictionary on electrotechnology, containing more than 22 300 terminological entries in English and French, with equivalent terms in 19 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

A propos de l'IEC

La Commission Electrotechnique Internationale (IEC) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications IEC

Le contenu technique des publications IEC est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

Recherche de publications IEC -

webstore.iec.ch/advsearchform

La recherche avancée permet de trouver des publications IEC en utilisant différents critères (numéro de référence, texte, comité d'études, ...). Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

IEC Just Published - webstore.iec.ch/justpublished

Restez informé sur les nouvelles publications IEC. Just Published détaille les nouvelles publications parues. Disponible en ligne et une fois par mois par email.

Service Clients - webstore.iec.ch/csc

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch

Découvrez notre puissant moteur de recherche et consultez gratuitement tous les aperçus des publications. Avec un abonnement, vous aurez toujours accès à un contenu à jour adapté à vos besoins.

Electropedia - www.electropedia.org

Le premier dictionnaire d'électrotechnologie en ligne au monde, avec plus de 22 300 articles terminologiques en anglais et en français, ainsi que les termes équivalents dans 19 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.

INTERNATIONAL STANDARD

NORME INTERNATIONALE



Electric welding equipment – Assessment of restrictions related to human exposure to electromagnetic fields (0 Hz to 300 GHz) – Part 3: Resistance welding equipment

Matériels de soudage électrique – Évaluation des restrictions relatives à l'exposition humaine aux champs électromagnétiques (0 Hz à 300 GHz) – Partie 3: Matériels de soudage par résistance

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 25.160.30

ISBN 978-2-8322-7056-1

**Warning! Make sure that you obtained this publication from an authorized distributor.
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.**

CONTENTS

FOREWORD.....	6
1 Scope.....	8
2 Normative references	8
3 Terms, definitions, quantities, units, constants and symbols	9
3.1 Terms and definitions.....	9
3.2 Quantities and units	11
3.3 Constants	11
3.4 Symbols.....	12
4 Requirements	12
5 Assessment methods.....	13
5.1 General.....	13
5.2 Methods based on reference levels.....	13
5.2.1 General	13
5.2.2 Assessment based on measured magnetic field.....	14
5.2.3 Assessment based on measured welding current.....	16
5.3 Methods based on assessment of corporal quantities (basic restrictions).....	18
5.3.1 General	18
5.3.2 Method based on coupling coefficients	19
5.3.3 Method based on the correction factor	21
5.3.4 Method based on the human model simulation.....	22
5.3.5 Result comparison	24
6 Measurement considerations	24
6.1 Measurement instruments for magnetic fields or exposure levels	24
6.1.1 General	24
6.1.2 Probe(s)	25
6.1.3 Handheld field meter	25
6.1.4 Measurement system with separate elements	25
6.2 Instruments for recording	26
6.2.1 Welding current recording.....	26
6.2.2 Magnetic field recording.....	26
6.3 Signal processing (applicable to any welding current waveform)	27
6.3.1 General	27
6.3.2 Application of the weighted peak method in the time domain	27
6.3.3 Spatial averaging.....	27
6.3.4 Time averaging.....	27
6.4 Uncertainty of assessment.....	27
7 Computational assessment methods.....	28
7.1 General.....	28
7.2 Quasi-static approximation.....	28
7.3 Human body models for simulation	28
7.4 Computational assessment against the basic restrictions.....	29
8 Source model	30
8.1 General.....	30
8.2 Source model example.....	30
9 EMF data sheet and assessment report.....	32
Annex A (informative) Example of assessment based on the individual components	34

A.1	General.....	34
A.2	Welding current generator.....	34
A.3	Coupling coefficient of welding circuit	37
A.4	Welding-system	38
Annex B	(informative) Example datasheets	40
B.1	Example current generator datasheet.....	40
B.2	Example datasheet of the welding circuit	41
B.3	Example datasheets of equipment assembly.....	42
Annex C	(informative) Coupling coefficient method	45
C.1	Principle	45
C.2	Validation of this method.....	45
C.2.1	Context.....	45
C.2.2	Basic restriction against health effects.....	46
C.2.3	Basic restriction against sensory effects	46
C.3	Conclusion.....	47
Annex D	(informative) Correction factor method.....	49
D.1	General.....	49
D.2	Principle	49
D.3	Example of correction factor finding	50
D.3.1	Context.....	50
D.3.2	Correction factor for the trunk and limbs	50
D.3.3	Correction factor for the head	50
D.4	Conclusion.....	51
Annex E	(informative) Example of exposure assessments on a welding machine	52
E.1	General.....	52
E.2	Description of the spot welding workstation.....	52
E.3	Exposure conditions.....	52
E.4	Main simulation parameters and results	54
E.4.1	Main simulation parameters	54
E.4.2	Simulation results	55
E.5	Exposure assessments	55
E.5.1	General	55
E.5.2	Method based on magnetic field calculation.....	55
E.5.3	Method based on coupling coefficients	55
E.5.4	Method based on the correction factor.....	56
E.5.5	Method based on the human model	56
E.6	Conclusion.....	57
Annex F	(informative) Computational methods	58
F.1	General.....	58
F.2	SPFD method	58
F.3	Quasi-static – Finite element method	58
F.4	Impedance method	59
F.5	Hybrid technique of FEM and SPFD method	60
F.6	Computation of the magnetic vector potential.....	60
Annex G	(informative) Averaging algorithms	62
G.1	Current density averaging over an area	62
G.1.1	General	62
G.1.2	Calculation of the current density in a Cartesian voxel.....	62

G.1.3	Calculation of the current density in a tetrahedron	63
G.1.4	Calculation of J_{avg}	63
G.2	E-field averaging in a cubical volume	64
G.3	E-field averaging along an averaging distance	64
G.3.1	General	64
G.3.2	Algorithm to construct the integration path	65
Annex H (informative)	Correspondence table between time domain and frequency domain	66
Bibliography	68
Figure 1	– Exposure measurement at the head position	15
Figure 2	– Exposure measurement at trunk position	15
Figure 3	– Exposure measurement at limb positions (hands and thigh)	16
Figure 4	– Compliance perimeters according to reference levels (action levels)	18
Figure 5	– Compliance perimeters according to basic restrictions (exposure limit values)	21
Figure 6	– Magnetic field around the human body obtained by source modelling	23
Figure 7	– Example of induced electric field in a human body exposed to a welding gun ($I = 1\text{kA}$ to 50 Hz)	24
Figure 8	– Welding current flowing in a ($a \times b$) rectangular loop configuration	31
Figure A.1	– Assessment of a complete welding system	34
Figure A.2	– Typical component based assessment	34
Figure A.3	– LF-AC (left) and MF-DC (right) current waveforms	35
Figure A.4	– Combined ELV for the sensory and health effects applicable to the head	35
Figure A.5	– Current exposure indices over the time for two welding technologies	36
Figure A.6	– Geometry of the stationary spot welding gun	37
Figure A.7	– Welding electric circuit model (in m) and one point of interest along the X axis	37
Figure A.8	– Coupling coefficient CC_{B1} along the X axis	38
Figure A.9	– Exposure index (AL) along the X axis	38
Figure A.10	– Exposure index (ELV) along the X axis	39
Figure B.1	– Example datasheet of the power source	40
Figure B.2	– Example datasheet of the electrode assembly	41
Figure B.3	– Datasheet example of the welding system	42
Figure B.4	– Example datasheet of the welding system (continuation)	43
Figure B.5	– Example datasheet of the welding system (continuation)	44
Figure C.1	– Distribution of human to disk model exposure index ratios (health effects of ELV on trunk and hands)	46
Figure C.2	– Distribution of human to disk model exposure index ratios (sensory and health effects of ELV on the head)	47
Figure D.1	– Distribution of correction factor k_E for health effects on trunk and hands	50
Figure D.2	– Distribution of correction factor k_E for effects on the head (sensory and health)	51
Figure E.1	– Welding gun and its electric circuit model (yellow dash segments)	53
Figure E.2	– Magnetic field distribution around the exposed body	53

Figure E.3 – Configuration and electric field distribution on the exposed body (for 1 kA at $f = 50$ Hz)	54
Figure E.4 – Electric field distribution on hands (for 1 kA at $f = 50$ Hz).....	54
Figure G.1 – Field components on voxel edges.....	63
Table 1 – Examples of human models to determine induced electric fields in the low frequency range.....	29
Table A.1 – Current exposure index for LF-AC technology ($I_{\text{rms}} = 11,4$ kA).....	36
Table A.2 – GP current exposure index for LF-AC technology ($I_{\text{rms}} = 11,4$ kA).....	36
Table C.1 – Representative disk radius (geometric model).....	45
Table C.2 – Coupling coefficients.....	47
Table E.1 – Coupling coefficients for the magnetic field and on human model.....	55
Table E.2 – Results based on magnetic field calculation	55
Table E.3 – Results based on coupling coefficients.....	56
Table E.4 – Results based on the correction factor	56
Table E.5 – Results based on human model	56
Table H.1 – Transcription of formulae	66

iTeh STANDARD PREVIEW
(standards.iteh.ai)

[IEC 62822-3:2023](https://standards.iteh.ai/catalog/standards/sist/0eb0188b-8619-42ad-b66f-89436aaf8303/iec-62822-3-2023)

<https://standards.iteh.ai/catalog/standards/sist/0eb0188b-8619-42ad-b66f-89436aaf8303/iec-62822-3-2023>

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTRIC WELDING EQUIPMENT – ASSESSMENT OF RESTRICTIONS RELATED TO HUMAN EXPOSURE TO ELECTROMAGNETIC FIELDS (0 HZ TO 300 GHZ) –

Part 3: Resistance welding equipment

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

IEC 62822-3 has been prepared by IEC technical committee 26: Electric welding. It is an International Standard.

This second edition cancels and replaces the first edition published in 2017. This edition constitutes a technical revision.

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

- a) inclusion of the uncertainties in the results of the assessment;
- b) simplification of the methods of exposure assessment.

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

Draft	Report on voting
26/744/FDIS	26/745/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 62822 series, published under the general title *Electric welding equipment – Assessment of restrictions related to human exposure to electromagnetic fields (0 Hz to 300 GHz)*, 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 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.

[IEC 62822-3:2023](https://standards.iteh.ai/catalog/standards/sist/0eb0188b-8619-42ad-b66f-89436aaf8303/iec-62822-3-2023)

<https://standards.iteh.ai/catalog/standards/sist/0eb0188b-8619-42ad-b66f-89436aaf8303/iec-62822-3-2023>

IMPORTANT – The "colour inside" logo on the cover page of this document 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.

ELECTRIC WELDING EQUIPMENT – ASSESSMENT OF RESTRICTIONS RELATED TO HUMAN EXPOSURE TO ELECTROMAGNETIC FIELDS (0 HZ TO 300 GHZ) –

Part 3: Resistance welding equipment

1 Scope

This part of IEC 62822 applies to equipment for resistance welding and allied processes designed for occupational use by professionals and for use by laymen.

More generally, this document covers equipment for which the welding current flows in an electrical circuit whose geometry cannot be changed and regardless of the technology of the current generator (for example LF-AC, MF-DC for spot or seam welding or capacitive discharge used for stud welding).

NOTE 1 Allied processes such as resistance hard and soft soldering or resistance heating achieved by means comparable to resistance welding equipment are included as well.

This document specifies procedures for the assessment of human exposure to magnetic fields produced by resistance welding equipment. It covers non-thermal biological effects in the frequency range from 0 Hz to 10 MHz and defines standardized test scenarios.

NOTE 2 The general term “field” is used throughout this document for “magnetic field”.

NOTE 3 For the assessment of exposure to electric fields and thermal effects, the methods specified in IEC 62311 or relevant basic standards will apply.

This document aims to propose methods for providing EMF exposure data that can be used to assist in the assessment of the workplace, especially when the conditions of use of the equipment are not known. When these are technically constrained (for example, a double hand control imposes the position and posture of the user), the data can be directly exploitable if they fall within the scope specified by the manufacturer or the integrator.

Other standards can apply to products covered by this document. In particular this document cannot be used to demonstrate electromagnetic compatibility with other equipment. It does not specify any product safety requirements other than those specifically related to human exposure to electromagnetic fields.

This document proposes several methods to assess the exposure to EMF, from simple to sophisticated, with the latter providing more precise assessment.

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 60050-851:2008, *International Electrotechnical Vocabulary (IEV) – Part 851: Electric welding* (available at www.electropedia.org)

IEC 60974-1, *Arc welding equipment – Part 1: Welding power sources*

IEC 60974-6, *Arc welding equipment – Part 6: Limited duty equipment*

IEC 61786-1, *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 62226-2-1, *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 2-1: Exposure to magnetic fields – 2D models*

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

IEC 62822-1:2016, *Electric welding equipment – Assessment of restrictions related to human exposure to electromagnetic fields (0 Hz to 300 GHz) – Part 1: Product family standard*

3 Terms, definitions, quantities, units, constants and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-851, IEC 60974-1, IEC 60974-6, and the following apply.

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

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

3.1.1

basic restriction

restriction on exposure to electric, magnetic and electromagnetic fields that is based directly on established health effects and biological considerations

Note 1 to entry: Basic restrictions are also named dosimetric reference limits (DRLs) and exposure limit values (ELVs).

3.1.2

coupling-coefficient

CC_{YX}

relation allowing to estimate Y from X

EXAMPLE CC_{EI} gives the maximum induced electric field inside a region of the human body according a unit welding current.

Note 1 to entry: Keeping in mind that the electric conductivity can be frequency dependent, a conversion between CC_{JI} and CC_{EI} or CC_{JB} and CC_{EB} is possible with the relation given in Formula (1)

$$J(j\omega) = \sigma(j\omega) \cdot E(j\omega) \quad (1)$$

where

J is the electric current density, expressed in ampere per square meter;

E is the electric field strength, expressed in volt per meter;

σ is the conductivity, expressed in siemens per meter;

ω is the angular frequency ($2 \cdot \pi \cdot f$), expressed in radians per second”.

3.1.3

exposure index

EI

result of the evaluation of exposure to (both sinusoidal and non-sinusoidal) EMF, expressed as a fraction or percentage of the permissible values

Note 1 to entry: Fractions higher than 1 (100 %) exceed the permissible values.

3.1.4

general public

individuals of all ages and of varying health conditions

3.1.5

intracorporeal

situated or occurring within the body

3.1.6

layman

operator who does not weld in the performance of his profession and may have little or no formal instruction in welding

[SOURCE: IEC 60050-851:2008, 851-11-14, modified – “arc welding” was replaced with “welding”.]

[IEC 62822-3:2023](https://standards.iteh.ai/catalog/standards/sist/0eb0188b-8619-42ad-b66f-89436aaf8303/iec-62822-3-2023)

3.1.7

non-thermal effect

stimulation of muscles, nerves or sensory organs as a result of human exposure to EMF

3.1.8

occupational exposure

exposure of workers to EMF at their workplaces, generally under known conditions, and as a result of performing their regular or assigned job activities

Note 1 to entry: A worker is any person employed by an employer, including trainees and apprentices.

3.1.9

reference level

directly measurable quantity, derived from basic restrictions, provided for practical exposure assessment purposes

Note 1 to entry: Reference levels are also named exposure reference levels (ERLs) and action levels (ALs).

Note 2 to entry: Respect of the reference levels will ensure respect of the relevant basic restriction. If the reference levels are exceeded, it does not necessarily follow that the basic restriction will be exceeded.

3.1.10

resistance welding system

combination of power source, transformer, cabling and welding circuit

3.1.11

sensory effect

transient disturbed sensory perceptions and minor change in brain functions as a result of human exposure to EMF

3.1.12**standardized configuration**

configuration reflecting the normal operator positions

3.1.13**standardized distance**

distance from the axis of a part of the welding circuit to the closest surface of the body in standardized configurations

3.1.14**welding circuit**

conductive material through which the welding current is intended to flow

Note 1 to entry: In resistance welding, the workpieces are not part of the welding circuit for the purposes of this document.

[SOURCE: IEC 60050-851:2008, 851-14-10, modified – the two notes to entry have been deleted, and a new note to entry has been added.]

3.2 Quantities and units

The internationally accepted SI units are used throughout this document.

Symbols throughout this document set in bold type are vector quantities.

Physical quantity	Symbol	Unit	Dimension
Electric conductivity	σ	Siemens per metre	S·m ⁻¹
Electric current	I	Ampere	A
Electric current density	J	Ampere per square metre	A·m ⁻²
Electric field strength	E	Volt per metre	V·m ⁻¹
Frequency	f	Hertz	Hz
Magnetic flux density	B	Tesla	T (V·s/m ²)
Magnetic permeability	μ	Henry per metre	H·m ⁻¹
Wavelength	λ	Metre	m

3.3 Constants

Physical constant	Symbol	Magnitude	Dimension
Permeability of free space	μ_0	$4 \cdot \pi \cdot 10^{-7}$	H·m ⁻¹

3.4 Symbols

Symbols used in this document are expanded hereafter.

Symbols	Meaning
*	Convolution product i.e. $B(t)*WL(t)$ means filtering $B(t)$ by $WL(t)$
t	Time
f	Frequency of a single frequency signal
$B(t)$	Magnetic flux density (magnetic field) in the time domain
$B(f)$	Magnetic flux density (magnetic field) in the frequency domain
$B_{RL}(f)$	B reference level at f
$W_{RL}(t)$	Time (impulse) response of the weighted filter according to the reference level
$W_{RL}(f)$	Frequency response of the weighted function according to the reference level
EI_{RL}	Exposure index according to the reference level
$I(t) / I$	Welding current in the time domain/frequency domain
CC_{BI}	Coupling coefficient from I to B (frequency independent)
\mathcal{F}^{-1}	Inverse Fourier transform
dB/dt	Time derivate of the magnetic flux density
R	Disk radius of 2D geometric model
E_i	Induced or internal electric field
dI/dt	Time derivate of the welding current
$W_{BR}(t)$	Time (impulse) response of the weighted filter according to the basic restriction
$W_{BR}(f)$	Frequency response of the weighted function according to the basic restriction
$CC_{EB/2D}$	Coupling coefficient from B to E_i with geometric model
$CC_{EI/HM}$	Coupling coefficient from I to E_i with human model
EI_{BR}	Exposure index according to the exposure limit value (basic restriction)
k_E	Exposure index coefficient
CEI_{BR}	Current exposure index according to the basic restrictions

4 Requirements

Equipment shall be assessed as defined in Clause 5.

If the assessment is conducted using measured or calculated external field levels, 5.2 shall be applied in conjunction with Clause 6.

If the assessment is conducted using corporal quantities, 5.3 shall be applied in conjunction with Clause 6 if measurements are performed and in conjunction of Clause 7 if a human model is applied.

The results shall be reported as specified in Clause 9.

5 Assessment methods

5.1 General

Clause 5 provides basic assessment methods considering the direct effects of electromagnetic fields [2], [3], [4], [5], [6], [7], [8]¹. Evaluations are made either against basic restrictions or against derived reference levels. In international guidelines, different limits on basic restrictions and reference levels are defined for stimulation effects which are considered for exposure to low frequency magnetic fields.

There are five methods to assess the welding equipment exposure and to demonstrate conformity or give enough information to demonstrate it with the reference levels or basic restrictions, or both. Any of the five methods can be selected, depending on which is the most relevant for the exposure assessment. If one of the first four methods does not lead to compliance, another can be chosen. The ultimate method is the fifth (dosimetry with human model).

While the evaluation based on measuring incident magnetic fields against reference levels is the easiest method (see 5.2.2), the evaluation based on computed magnetic field from the welding current can predict the exposure, and it does not require a field meter (see 5.2.3). Those methods are necessarily more conservative than the assessment of exposure according to induced quantities against basic restrictions.

Thus, the evaluation of internal (or induced) E-field or current density against basic restrictions (5.3) is performed with more realistic exposure conditions considering mainly the heterogeneity of the magnetic field.

Evaluations of induced fields against basic restrictions using simple (geometric) models are methods of intermediate complexity (see 5.3.2 and 5.3.3). As these methods have to cover a large number of situations, they are conservative most of the time and in extreme cases, they become accurate.

Lastly, evaluation of induced fields against basic restrictions with an electrical representative human body is the most rigorous and reduces uncertainties. It requires simulation after a faithful modelling of the environment (see 5.3.4).

5.2 Methods based on reference levels

5.2.1 General

The assessments are based on external (incident) magnetic fields against reference levels.

Reference levels have been derived from the basic restrictions considering the conditions which maximized the exposure (whole body exposure to a uniform field). Such an assessment is conservative under all non-uniform and local exposure conditions, which is the case in most occupational exposure situations. Therefore, this method is simple but it overestimates exposure to welding equipment most of the time.

The exposure level is determined by a comparison of the magnetic field and the relevant exposure limits applicable to the affected regions of the body.

¹ Numbers in square brackets refer to the Bibliography.