BRITISH STANDARD

BS 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)

ICS 13.280; 17.220.01; 25.160.10

National foreword

This British Standard is the UK implementation of EN 50445:2008.

The UK participation in its preparation was entrusted to Technical Committee WEE/6, Electric arc welding equipment.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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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)

Norme de famille de produit pour démontrer la conformité d'un équipement pour le soudage par résistance, le soudage à l'arc et les techniques connexes avec les restrictions de base concernant l'exposition des personnes aux champs électromagnétiques (0 Hz - 300 GHz)

Produktfamiliennorm zur Konformitätsprüfung von Einrichtungen zum Widerstandsschweißen, Lichtbogenschweißen und artverwandten Prozessen in Bezug auf die bei der Exposition durch elektromagnetische Felder anzuwendenden Basisgrenzwerte (0 Hz - 300 GHz)

This European Standard was approved by CENELEC on 2008-02-01. 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.

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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

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Foreword

This European Standard was prepared by the Technical Committee CENELEC TC 26A, Electric arc welding equipment.

The text of the draft was submitted to the formal vote and was approved by CENELEC as EN 50445 on 2008-02-01.

The following dates were fixed:

– latest date by which the EN has to be implemented at national level by p ublication of an identical national standard or by endorsement	(dop)	2009-02-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2011-02-01

This European Standard is to be read in conjunction with EN 50444 and EN 50505. The latter was prepared by the Technical Committee CENELEC TC 26B, Electric resistance welding.

This European Standard has been prepared under mandates M/305 and M/351 given to CENELEC by the European Commission and the European Free Trade Association.

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Contents

Tables

1 Scope

This product family standard applies to equipment for resistance welding, arc welding and allied processes designed for use in industrial or domestic environments, including welding power sources, wire feeders and ancillary equipment, e.g. torches, liquid cooling systems and arc striking and stabilising devices.

NOTE 1 Allied processes are for example resistance hard and soft soldering, resistance heating by means comparable to resistance welding equipment, electric arc cutting and arc spraying.

The frequency range covered is 0 Hz to 300 GHz.

This product family standard may be used to demonstrate compliance with the requirements of Directive 2006/95/EC [1] (needed for placing electric welding equipment on the European market), with regard to the limitation of human exposure to electromagnetic fields (EMF). There are additional requirements in the Directive, which are not included in this product family standard.

NOTE 2 The Directive 2006/95/EC [1], Article 2, stipulates that the Member States take all appropriate measures to ensure that electrical equipment may be placed on the market only if, having been constructed in accordance with good engineering practice in safety matters in force in the Community.

This product family standard may also be used for assessment regarding the requirements of Directive 2004/40/EC [3] on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) or Recommendation 1999/519/EC [2] on the limitation of exposure of the general public to electromagnetic fields, provided that no other relevant field sources are present in close proximity. If other relevant field sources are present, additional assessment is necessary.

NOTE 3 It should be noted that the supplier of specific equipment might not know the overall exposure environment in which the equipment is being used. This product family standard can only be used to assess human exposure from the specific equipment under evaluation when being used in accordance with the suppliers guidelines.

NOTE 4 Assessment procedures for workplaces with multiple field-sources may be found in EN 50499 [7].

Other standards may apply to products covered by this product family standard. In particular this standard can not be used to demonstrate electromagnetic compatibility with other equipment; nor does it specify any product safety requirements other than those specifically related to human exposure to electromagnetic fields.

NOTE 5 Procedures to demonstrate compliance are not specified for the whole frequency range.

2 Normative references

The following referenced documents are indispensable for the application 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.

EN 50392	Generic standard to demonstrate the compliance of electronic and electrical apparatus with the basic restrictions related to human exposure to electromagnetic fields (0 Hz – 300 GHz)
EN 50444	Basic standard for the evaluation of human exposure to electromagnetic fields from equipment for arc welding and allied processes
EN 50505	Basic standard for the evaluation of human exposure to electromagnetic fields from equipment for resistance welding and allied processes
EN 60974-1	Arc welding equipment – Part 1: Welding power sources (IEC 60974-1)
EN 60974-6	Arc welding equipment – Part 6: Limited duty manual metal arc welding power sources (IEC 60974-6)

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
action values
magnitude of directly measurable parameters at which one or more of the specified measures in Directive 2004/40/EC [3] must be undertaken

3.2
arc welding power source
equipment for supplying current and voltage and having the required characteristics suitable for arc welding and allied processes

NOTE 1 An arc welding power source may also supply services to other equipment and auxiliaries e.g. auxiliary power, cooling liquid, consumable arc welding electrode and gas to shield the arc and the welding area.

NOTE 2 In the following text, the term “welding power source” is used.

3.3
basic restrictions
exposure limit values
restrictions on exposure to electric, magnetic and electromagnetic fields that are based directly on established health effects and biological considerations

3.4
compliance boundary
spatial border outside which any point of investigation is deemed to be compliant

3.5
EMF
electric, magnetic or electromagnetic field

3.6
expert
competent person
skilled person
person who can judge the work assigned and recognize possible hazards on the basis of professional training, knowledge, experience and knowledge of the relevant equipment

NOTE Several years of practice in the relevant technical field may be taken into consideration in assessment of professional training.

3.7
induced current density (*J*)
electromagnetic field induced current per unit area inside the body

3.8
industrial and professional use
use intended only for experts or instructed persons

3.9
instructed person
person informed about the tasks assigned and about the possible hazards involved in neglectful behaviour

NOTE If necessary, the person has undergone some training.

3.10
magnetic flux density *(B)*
magnitude of a field vector that is equal to the magnetic field strength *H* multiplied by the permeability μ of the medium

$$B = \mu H$$

3.11
point of investigation (POI)
location in space at which the value of the *E*-field, *H*-field or power density is evaluated

NOTE This location is defined in cartesian, cylindrical or spherical co-ordinates relative to the reference point on the EUT.

3.12
reference levels
directly measurable quantities, derived from basic restrictions, provided for practical exposure assessment purposes

NOTE 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.

3.13
resistance welding equipment
equipment for supplying current and voltage and having the required characteristics suitable for resistance welding and allied processes

4 Compliance criteria and exposure limits

4.1 Background

Reference levels are provided for practical exposure assessment purposes to determine whether the basic restrictions are likely to be exceeded. If the measured value exceeds the reference level, it does not necessarily follow that the basic restriction will be exceeded.

In some situations, it may be necessary to show compliance with the basic restrictions directly, but it may also be possible to derive compliance criteria that allow a simple measurement or calculation to demonstrate compliance with the basic restriction. Often these compliance criteria can be derived using realistic assumptions about conditions under which exposures from a device may occur, rather than the conservative assumptions that underlie the reference levels.

NOTE 1 The limit is the basic restriction.

The exposure assessment results for the points of investigation specified in the basic standards EN 50444 and EN 50505 shall be below the relevant limits. For equipment designed exclusively for mechanized or robotic applications the points of investigation (reflecting the normal operator position for manual welding) defined in the basic standards EN 50444 and EN 50505 are not applicable. The manufacturer of this type of equipment shall define specific points of investigation.

As the highest exposure from equipment covered by the scope of this standard is to be expected in the inductive near-field, summation effects of maximum exposure levels of various pieces of equipment, e.g. in the same factory, are unlikely to be significant. However, in the presence of other strong magnetic fields (from large transformers, large electrolytic cells, etc.), in situ measurements to evaluate summation effects at medium distances (a few metres) might be appropriate. Such additional measurements are not a requirement of this standard, but may be required by other national or international regulations.

NOTE 2 Further guidance may be found in EN 50499 [7].

As there are different limits for general public or occupational exposure, the equipment documentation shall clearly state the intended use.

4.2 Equipment for use by the general public

The manufacturer shall specify if the equipment is intended to be used by the general public. Arc welding equipment built in accordance with to EN 60974-6 shall be assessed for such use. Any equipment assessed for general public use may also be used in an occupational environment.

If the environment in which the equipment is intended to be used is unknown, or not clear, the equipment shall be assessed for general public use.

The basis for assessment shall be the values of basic restrictions or reference levels from the Recommendation 1999/519/EC [2]. It must be noted that the tables of values referred to in the following sections are explained and rationalised in the text of the Recommendation 1999/519/EC [2] and the associated notes adjoining the tables. The basic restrictions on the current density only apply to central nervous system tissues in the head and trunk. These exposure limit values may permit higher current densities in body tissues other than the central nervous system under the same exposure conditions.

4.3 Equipment for occupational use

The manufacturer shall specify if the equipment is intended to be used only in an occupational environment (where the general public access is prohibited or regulated in such a way as to be similar to occupational use) by an expert or an instructed person. Arc welding equipment built in accordance with EN 60974-1 and resistance welding equipment can be assessed for such use.

The basis for assessment shall be the exposure limit values or action values from Directive 2004/40/EC [3]. It must be noted that the tables of values referred to in the following sections are explained and rationalised in the text of the Directive 2004/40/EC [3] and the associated notes adjoining the tables. The exposure limit values on the current density only apply to central nervous system tissues in the head and trunk. These exposure limit values may permit higher current densities in body tissues other than the central nervous system under the same exposure conditions.

If the limits specified above can not be complied with for some or all points of investigation, additional measures shall be defined which allow compliance (e.g. definition of a compliance boundary for occupational exposure, the use of protection devices, restrictions for manual use, etc.). If such special conditions are established, they shall be clearly stated in the instruction manual.

4.4 Equipment for occupational use in a public area

If equipment could be used under occupational conditions, but in an area where also the general public may be exposed, then the exposure shall additionally be assessed against the general public requirements under the conditions expected for that exposure situation (e.g. at usual safety distances) or, alternatively, the conditions necessary for compliance shall be established during assessment. If special conditions (such as the definition of a compliance boundary for the general public) are established, these shall be clearly stated in the instruction manual.

4.5 Exposure of persons wearing cardiac pacemakers or other medical implants

As the immunity of different types of pacemakers or other implants varies considerably, a risk assessment involving a responsible medical expert is necessary for every single case of user exposure. This risk assessment is not within the scope of this product family standard. A warning statement regarding this matter shall be included in the instruction manual.

4.6 Projectile risk

The projectile risk from ferromagnetic objects in static magnetic fields shall be considered in the instruction manual if there is a magnetic flux density greater than 3 mT.

4.7 Touch currents

The risk of touch currents generated by voltages induced in conducting structures at the workplace by electromagnetic fields due to the welding current is avoided by the application of general safety rules for electric welding, e.g. equipotential bonding and other measures, therefore no further evaluation is required.

5 Compliance assessment

5.1 General

5.1.1 Measurement and calculation

The measurements and/or calculations to demonstrate equipment compliance shall be made in accordance with the basic standards EN 50444 and EN 50505.

5.1.2 Time averaging

For occupational exposure the d.c. components of the magnetic flux density or field strength values should be averaged over a time interval of 8 h, taking into account the duty cycle of the equipment and the welding current sequence, as applicable [4].

For exposure to time-varying magnetic fields up to 10 MHz no averaging of induced current densities over time intervals is allowed.

At frequencies below 100 kHz no averaging is allowed for *H* and *B* values, at frequencies between 100 kHz and 10 GHz averaging over any six-minute period is permissible, provided that the peak restrictions given in the notes to Table 2 of Recommendation 1999/519/EC [2] and Table 2 of Directive 2004/40/EC [3] are not exceeded.

5.1.3 Spatial averaging

Generally the reference levels are intended to be spatially averaged values over the entire body of the exposed individual, but with the important proviso that the basic restrictions on localized exposure are not exceeded.

This product family standard is used to assess mainly the exposure generated from the welding circuit, creating stimulation effects. The maximum exposure is localized on the part of the body nearest to the source. In this type of situation an approach based on the spatial averaging of non uniform field distributions underestimates the exposure and is not suitable to ensure that the localized exposure does not lead to exceeding the basic restrictions for induced current densities.

Therefore spatial averaging shall not be applied to reference level based exposure assessment of stimulation effects due to fields generated by the welding circuit.

For evaluation of exposure generated from sources other than the welding circuit (for example from microprocessors, radio communication systems, ancillary equipment) and assessment of thermal effects, spatial averaging of the field may be appropriate.

For homogeneous models, induced current density values shall be averaged over any area of 1 cm^2. In the case of induced current density values obtained by numerical simulation using high resolution anatomic body models this area shall be limited to central nervous system tissues and shall not include other types of tissue. Therefore the resulting averaging area for heterogeneous models shall be smaller than or equal to 1 cm^2. For all 3D models the averaging area shall be perpendicular to the induced current flow.

5.1.4 Assessment of equipment with pulsed or non-sinusoidal welding current

Assessment shall be made in accordance with the basic standards EN 50444 and EN 50505. If summation procedures are applied, the parameters given in Table 1 shall be used, as applicable.

Table 1 – Summation parameters

	φ below f_{coc} RAD		φ above f_{coc} RAD		f_{coc} Hz		f_{sco} kHz	*b*		*d*	
	for ***B*** & ***H***	for ***J***	for ***B*** & ***H***	for ***J***	for ***B*** & ***H***	for ***J***	for ***B*** & ***H***	for ***H*** A m^{-1}	for ***B*** µT	for ***H*** A m^{-1}	for ***B*** µT
General public exposure	pi/2	0	0	-pi/2	800	1 000	150	5,2	6,25	0,73/*f*	0,92/*f*
Occupational exposure	pi/2	0	0	-pi/2	820	1 000	65	24,4	30,7	–	–

where

φ is the phase angle of the weighting function;

f_{coc} is the cut off frequency of the modelled (e.g. by RC circuit) frequency response of nervous cells;

f_{sco} is the summation cut off frequency;

b is the value to relate frequency components above f_{sco} to for stimulation considerations;

d is the value to relate frequency components below f_{sco} to for thermal considerations;

f is the frequency of the spectral component to be summed, given in MHz.

NOTE These values are taken from the Recommendation 1999/519/EC [2] and ICNIRP documents [5] and [6].

Alternatively the limits, reference levels and phases of the weighting functions for summation of spectral components can be approximated by first order filters, as specified in documents defining procedures to assess non-sinusoidal and pulsed signals [6]. Details and examples are given in the basic standards EN 50444 and EN 50505. The first order filter approach is applicable to both analytical and numerical methods as well as for field measurements.

5.1.5 Assessment of equipment with multiple welding current waveforms

This type of equipment shall be evaluated in all relevant operation modes, e.g. arc welding equipment such as a MIG standard / pulse power source with constant d.c. and pulsed output current or an a.c. / d.c. MMA power source with constant d.c. and a.c. output current. The selection of relevant operation modes, as far as applicable, and test parameters shall be made in accordance with the basic standards EN 50444 and EN 50505.

5.2 Assessment of EMF

5.2.1 General considerations

The EMF shall be assessed using one of the following methods. It is not necessary to demonstrate compliance using more than one method. However, if multiple operation modes have to be tested, different methods may be applied for these modes, e.g. measurements to show compliance with reference levels for d.c. mode and numerical simulation to show compliance with the basic restrictions for pulsed mode.

Selection criteria for appropriate application of assessment methods are given in the basic standards EN 50444 and EN 50505.

5.2.2 Electric field

In general, electric fields around electric welding equipment shall be taken into account. However, for most equipment the electric field strength can be considered to comply, without testing. This shall be verified by analysis of the technology used.

If, by this analysis, electric fields are found to be significant, tests in accordance with generic standards or to the manufacturers own specifications shall be made.

5.2.3 Magnetic field measurements to show compliance with reference levels

Measurements shall be made in accordance with the basic standards EN 50444 and EN 50505.

For general public exposure, the basis for assessment of static and time-varying fields shall be the values provided in Table 2 of Recommendation 1999/519/EC [2].

For occupational exposure, the basis for assessment of static and time-varying fields shall be the values provided in Table 2 of Directive 2004/40/EC [3].

5.2.4 Calculations to show compliance with reference levels

Analytical and numerical calculations shall be based on welding current parameters and other data (e.g. equipment configuration and geometries). Assessment shall be made in accordance with the basic standards EN 50444 and EN 50505.

For general public exposure, the basis for assessment of static and time-varying fields shall be the values provided in Table 2 of Recommendation 1999/519/EC [2].

For occupational exposure, the basis for assessment of static and time-varying fields shall be the values provided in Table 2 of Directive 2004/40/EC [3].

5.2.5 Calculations to show compliance with basic restrictions

Analytical and numerical calculations shall be based on calculated or measured field strengths. Assessment shall be made in accordance with the basic standards EN 50444 and EN 50505. The results used for induced current density assessment shall be those derived for central nervous system tissue in the head and trunk.

For general public exposure, the basis for assessment of static and time-varying fields shall be the values provided in Table 1 of Recommendation 1999/519/EC [2].

For occupational exposure, the basis for assessment of time-varying fields shall be the values provided in Table 1 of Directive 2004/40/EC [3].

NOTE The basic restrictions for static fields in Table 1 of Recommendation 1999/519/EC [2] are magnetic flux density limits, therefore evaluation may also be performed by measurement.

6 Information to be supplied with the apparatus

The manufacturer shall provide all necessary information with the product with regard to minimizing exposure. This shall include recommendations for correct installation, welding cable layout, minimum safety distances from the power source, the welding circuit, resistance welding guns and arc welding torches to the body and other relevant information such as special precautions which may be needed during maintenance and repair.

The distance from the equipment, at which the assessment was carried out shall be given in the instruction manual.

The distance from the equipment to a point beyond which the exposure value is less than 20 % of the permissible value shall be given in metres.

NOTE Standards for workplace evaluation are under consideration in CENELEC TC 106X, which may require additional information, for example exposure quotients, to be provided for the user in the future.

The instruction manual shall include general information for the user about EMF. An example is given in Annex C.

If equipment is intended for professional use only, the instruction manual shall contain a warning that this equipment shall not be used by the general public as the EMF limits for the general public might be exceeded during welding.

If there is a static magnetic flux density greater than 3 mT, a warning shall be given regarding the projectile risk from ferromagnetic objects.

Users shall be informed of specific compliance boundaries, which deviate from normal use (represented by the points of investigations defined in the basic standards EN 50444 and EN 50505) and are established during the assessment process. In this case the manufacturer shall provide a document describing these specific compliance boundaries. Information on restrictions for use shall be made available to the user prior to purchase.

7 Marking

If there is a risk that the basic restrictions could be exceeded, welding equipment shall be marked with appropriate safety symbols regarding hazards due to EMF.

8 Uncertainty of assessment

8.1 Using uncertainty for comparison with limits

The concept of “shared uncertainty budget” shall apply to the assessment (both measurements and calculations). This means that the actual measured or calculated values shall be used for comparison with the permissible values, based on the relevant exposure guidelines. Uncertainty values shall be recorded but shall not be included in the comparison, provided that the expanded assessment uncertainty is less than or equal to that specified in Table 2, or if the assessment is proven to always overestimate the exposure (i.e. conservative result).

The uncertainty of the assessment method applied shall be calculated as defined in the basic standards EN 50444 and EN 50505.

If the expanded uncertainty is higher than the value specified in Table 2 and the assessment is not proven to always overestimate the exposure, the procedure given in the generic standard EN 50392 shall be applied. This method defines uncertainty penalties for the applicable limits which are calculated in accordance with Equation (1).

$$L_{\mathrm{m}} \leq L \cdot \left(\frac{1}{1 - \frac{U_{\mathrm{p}}}{100} + \frac{U_{\mathrm{m}}}{100}} \right) \qquad (1)$$

where

L_{m} is the assessed value;

L is the applicable limit without consideration of assessment uncertainty;

U_{p} is the permissible expanded uncertainty, given in %, as defined in Table 2;

U_{m} is the expanded uncertainty of the assessment method applied, given in %.

NOTE If, for example, the permissible expanded assessment uncertainty is ± 40 % and the actual calculated expanded uncertainty of the applied assessment method is ± 50 %, the assessment results shall be compared to the applicable limits reduced by a factor of 0,91.

In all cases, the assessment shall be made based on a representative sample of the equipment.

8.2 Permissible expanded uncertainties

The expanded uncertainty of the assessment should be less than the values given in Table 2 except where it can be shown that because of the nature of the measurement environment, a higher uncertainty is appropriate. In this case the higher uncertainty shall be quoted and justified.

Table 2 – Permissible expanded uncertainties

Frequency range	Measurement	Calculation
< 10 kHz	+ 58 %, - 37 % (± 4 dB)	± 50 %
10 kHz – 1 MHz	+ 41 %, - 30 % (± 3 dB)	± 50 %
1 MHz – 30 MHz	+ 41 %, - 30 % (± 3 dB)	± 40 %
30 MHz – 1 GHz	+ 100 %, - 50 % (± 6 dB)	± 40 %
1 GHz – 30 GHz	+ 100 %, - 50 % (± 6 dB)	± 50%

When the uncertainties specified in Table 2 are asymmetric (e.g. + 58 %, - 37 %) the values for possible underestimation shall be used for comparison. For combined assessment procedures, the higher value of permissible uncertainty shall apply.

Annex A
(informative)

General public basic restrictions and reference levels

The values of basic restrictions and reference levels, as specified in the Recommendation 1999/519/EC [2], Tables 1 and 2, on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz) are given in Tables A.1 and A.2 for information.

Table A.1 – General public basic restrictions for electric, magnetic and electromagnetic fields

(0 Hz to 300 GHz)
Source: Recommendation 1999/519/EC [2], Table 1

Frequency range	Magnetic flux density	Current density r.m.s.	Whole-body average *SAR*	Localized *SAR* (head and trunk)	Localized *SAR* (limbs)	Power density *S*
	mT	mA m^{-2}	W kg^{-1}	W kg^{-1}	W kg^{-1}	W m^{-2}
0 Hz	40	–	–	–	–	–
> 0 Hz – 1 Hz	–	8	–	–	–	–
1 Hz – 4 Hz	–	8/f	–	–	–	–
4 Hz – 1 000 Hz	–	2	–	–	–	–
1 000 Hz – 100 kHz	–	f/500	–	–	–	–
100 kHz – 10 MHz	–	f/500	0,08	2	4	–
10 MHz – 10 GHz	–	–	0,08	2	4	–
10 GHz – 300 GHz	–	–	–	–	–	10

NOTE 1 f is the frequency in Hz.

NOTE 2 The basic restriction on the current density is intended to protect against acute exposure effects on central nervous system tissues in the head and trunk of the body and includes a safety factor. The basic restrictions for ELF fields are based on established adverse effects on the central nervous system. Such acute effects are essentially instantaneous and there is no scientific justification to modify the basic restrictions for exposure of short duration. However, since the basic restriction refers to adverse effects on the central nervous system, this basic restriction may permit higher current densities in body tissues other than the central nervous system under the same exposure conditions.

NOTE 3 Because of electrical inhomogeneity of the body, current densities should be averaged over a cross section of 1 cm² perpendicular to the current direction.

NOTE 4 For frequencies up to 100 kHz, peak current density values can be obtained by multiplying the r.m.s. value by $\sqrt{2}$ (~1,414). For pulses of duration t_p the equivalent frequency to apply in the basic restrictions should be calculated as $f = 1/(2t_p)$.

NOTE 5 For frequencies up to 100 kHz and for pulsed magnetic fields, the maximum current density associated with the pulses can be calculated from the rise/fall times and the maximum rate of change of magnetic flux density. The induced current density can then be compared with the appropriate basic restriction.

NOTE 6 All *SAR* values are to be averaged over any six-minute period.

NOTE 7 Localised *SAR* averaging mass is any 10 g of contiguous tissue; the maximum *SAR* so obtained should be the value used for the estimation of exposure. These 10 g of tissue are intended to be a mass of contiguous tissue with nearly homogeneous electrical properties. In specifying a contiguous mass of tissue, it is recognised that this concept can be used in computational dosimetry but may present difficulties for direct physical measurements. A simple geometry such as cubic tissue mass can be used provided that the calculated dosimetric quantities have conservative values relative to the exposure guidelines.

NOTE 8 For pulses of duration t_p the equivalent frequency to apply in the basic restrictions should be calculated as $f = 1/(2t_p)$. Additionally, for pulsed exposures, in the frequency range 0,3 GHz to 10 GHz and for localised exposure of the head, in order to limit and avoid auditory effects caused by thermoelastic expansion, an additional basic restriction is recommended. This is that the *SA* should not exceed 2 mJ kg^{-1} averaged over 10 g of tissue.

Table A.2 – General public reference levels for electric, magnetic and electromagnetic fields

(0 Hz to 300 GHz, unperturbed r.m.s. values)
Source: Recommendation 1999/519/EC [2], Table 2

Frequency range	Electric field strength E V m^{-1}	Magnetic field strength H A m^{-1}	Magnetic flux density B μT	Equivalent plane wave power density S_{eq} W m^{-2}
0 Hz – 1 Hz	–	$3{,}2 \times 10^4$	4×10^4	–
1 Hz – 8 Hz	10 000	$3{,}2 \times 10^4 / f^2$	$4 \times 10^4 / f^2$	–
8 Hz – 25 Hz	10 000	$4\,000/f$	$5\,000/f$	–
0,025 kHz – 0,8 kHz	$250/f$	$4/f$	$5/f$	–
0,8 kHz – 3 kHz	$250/f$	5	6,25	–
3 kHz – 150 kHz	87	5	6,25	–
0,15 MHz – 1 MHz	87	$0{,}73/f$	$0{,}92/f$	–
1 MHz – 10 MHz	$87/f^{1/2}$	$0{,}73/f$	$0{,}92/f$	–
10 MHz – 400 MHz	28	0,073	0,092	2
400 MHz – 2 000 MHz	$1{,}375\ f^{1/2}$	$0{,}003\ 7\ f^{1/2}$	$0{,}004\ 6\ f^{1/2}$	$f/200$
2 GHz – 300 GHz	61	0,16	0,20	10

NOTE 1 f as indicated in the frequency range column.

NOTE 2 For frequencies between 100 kHz and 10 GHz, S_{eq}, E^2, H^2, and B^2 are to be averaged over any six-minute period.

NOTE 3 For frequencies exceeding 10 GHz, S_{eq}, E^2, H^2, and B^2 are to be averaged over any $68/f^{1,05}$-minute period (f in GHz).

NOTE 4 No E-field value is provided for frequencies < 1 Hz, which are effectively static electric fields. For most people the annoying perception of surface electric charges will not occur at field strengths less than 25 kV m^{-1}. Spark discharges causing stress or annoyance should be avoided.

NOTE 1 No higher reference levels on exposure to ELF fields are provided when exposures are of short duration (see Note 2 of Table A.1). In many cases, where the measured values exceed the reference level, it does not necessarily follow that the basic restriction will be exceeded. Provided that adverse health impacts of indirect effects of exposure (such as micro shocks) can be avoided, it is recognised that the general public reference levels can be exceeded provided that the basic restriction on the current density is not surpassed. In many practical exposure situations external ELF fields at the reference levels will induce current densities in central nervous-system tissues that are below the basic restrictions. Also it is recognised that a number of common devices emit localised fields in excess of the reference levels. However, this generally occurs under conditions of exposure where the basic restrictions are not exceeded because of weak coupling between the field and the body.

NOTE 2 For peak values, the following reference levels apply to the E-field strength (V m^{-1}), H-field strength (A m^{-1}) and the B-field (μT):

– for frequencies up to 100 kHz, peak reference values are obtained by multiplying the corresponding r.m.s. values by $\sqrt{2}$ (= 1,414). For pulses of duration t_p the equivalent frequency to apply should be calculated as $f = 1/(2t_p)$;

– for frequencies between 100 kHz and 10 MHz peak reference values are obtained by multiplying the corresponding r.m.s. values by 10^a, where $a = (0{,}665 \log(f/10^5) + 0{,}176)$, f in Hz;

– for frequencies between 10 MHz and 300 GHz peak reference values are obtained by multiplying the corresponding r.m.s. values by 32.

NOTE 3 Generally, with regard to pulsed and/or transient fields at low frequencies, there are frequency-dependent basic restrictions and reference levels from which a hazard assessment and exposure guidelines on pulsed and/or transient sources can be derived. A conservative approach involves representing a pulsed or transient EMF signal as a Fourier spectrum of its components in each frequency range, which can then be compared with the reference levels for those frequencies. The summation formulae for simultaneous exposure to multiple frequency fields can also be applied for the purposes of determining compliance with the basic restrictions. Although little information is available on the relation between biological effects and peak values of pulsed fields, it is suggested that, for frequencies exceeding 10 MHz, S_{eq} as averaged over the pulse width should not exceed 1 000 times the reference levels or that field strengths should not exceed 32 times the fields strength reference levels. For frequencies between about 0,3 GHz and several GHz and for localised exposure of the head, in order to limit or avoid auditory effects caused by thermoelastic expansion, the specific absorption from pulses must be limited. In this frequency range, the threshold SA of 4 mJ kg^{-1} – 16 mJ kg^{-1} for producing this effect corresponds, for 30 μs pulses, to peak SAR values of 130 W kg^{-1} - 520 W kg^{-1} in the brain. Between 100 kHz and 10 MHz, peak values for the fields strengths are obtained by interpolation from the 1,5-fold peak at 100 kHz to the 32-fold peak at 10 MHz.

Annex B
(informative)

Occupational basic restrictions and reference levels

The values of basic restrictions and reference levels, as specified in Table 1 (exposure limit values) and Table 2 (action values) of Directive 2004/40/EC [3] on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) are given in Tables B.1 and B.2 for information.

Table B.1 – Occupational basic restrictions for electric, magnetic and electromagnetic fields

(0 Hz to 300 GHz, all conditions to be satisfied)
Source: Directive 2004/40/EC [3], Table 1, "Exposure limit values"

Frequency range	**r.m.s. current density for head and trunk *J***	**Whole body average *SAR***	**Localised (head and trunk) *SAR***	**Localised (limbs) *SAR***	**Power density *S***
	mA m^{-2}	W kg^{-1}	W kg^{-1}	W kg^{-1}	W m^{-2}
Up to 1 Hz	40	–	–	–	–
1 Hz – 4 Hz	$40/f$	–	–	–	–
4 Hz – 1 000 Hz	10	–	–	–	–
1 000 Hz – 100 kHz	$f/100$	–	–	–	–
100 kHz – 10 MHz	$f/100$	0,4	10	20	–
10 MHz – 10 GHz	–	0,4	10	20	–
10 GHz – 300 GHz	–	–	–	–	50

NOTE 1 f is the frequency in Hz.

NOTE 2 The exposure limit values on the current density are intended to protect against acute exposure effects on central nervous system tissues in the head and trunk of the body. The exposure limit values in the frequency range 1 Hz to 10 MHz are based on established adverse effects on the central nervous system. Such acute effects are essentially instantaneous and there is no scientific justification to modify the exposure limit values for exposure of short duration. However, since the exposure limit values refer to adverse effects on the central nervous system, these exposure limit values may permit higher current densities in body tissues other than the central nervous system under the same exposure conditions.

NOTE 3 Because of the electrical inhomogeneity of the body, current densities should be calculated as averages over a cross-section of 1 cm² perpendicular to the current direction.

NOTE 4 For frequencies up to 100 kHz, peak current density values can be obtained by multiplying the r.m.s. value by $2^{½}$.

NOTE 5 For frequencies up to 100 kHz and for pulsed magnetic fields, the maximum current density associated with the pulses can be calculated from the rise/fall times and the maximum rate of change of magnetic flux density. The induced current density can then be compared with the appropriate exposure limit value. For pulses of duration t_p, the equivalent frequency to apply for the exposure limit values should be calculated as $f = 1/(2t_p)$.

NOTE 6 All *SAR* values are to be averaged over any six-minute period.

NOTE 7 Localised *SAR* averaging mass is any 10 g of contiguous tissue; the maximum *SAR* so obtained should be the value used for estimating exposure. These 10 g of tissue are intended to be a mass of contiguous tissue with nearly homogeneous electrical properties. In specifying a contiguous mass of tissue, it is recognised that this concept can be used in computational dosimetry but may present difficulties for direct physical measurements. A simple geometry such as cubic tissue mass can be used provided that the calculated dosimetric quantities have conservative values relative to the exposure guidelines.

NOTE 8 For pulsed exposures in the frequency range 0,3 GHz to 10 GHz and for localised exposure of the head, in order to limit and avoid auditory effects caused by thermoelastic expansion, an additional exposure limit value is recommended. This is that the *SA* should not exceed 10 mJ kg^{-1} averaged over 10 g of tissue.

NOTE 9 Power densities are to be averaged over any 20 cm² of exposed area and any $68/f^{1,05}$-minute period (where f is in GHz) to compensate for progressively shorter penetration depth as the frequency increases. Spatial maximum power densities averaged over 1 cm² should not exceed 20 times the value of 50 W m^{-2}.

NOTE 10 With regard to pulsed or transient electromagnetic fields, or generally with regard to simultaneous exposure to multiple frequency fields, appropriate methods of assessment, measurement and/or calculation capable of analysing the characteristics of the waveforms and nature of biological interactions have to be applied, taking account of European harmonised Standards developed by CENELEC.

Table B.2 – Occupational reference levels for time varying electric and magnetic fields

(0 Hz to 300 GHz, unperturbed r.m.s. values)
Source: Directive 2004/40/EC [3], Table 2, "Action values"

Frequency range	Electric field strength E V m^{-1}	Magnetic field strength H A m^{-1}	Magnetic flux density B μT	Equivalent plane wave power density S_{eq} W m^{-2}	Contact current I_C mA	Limb induced current I_L mA
0 Hz –1 Hz	–	$1{,}63 \times 10^5$	2×10^5	–	1,0	–
1 Hz – 8 Hz	20 000	$1{,}63 \times 10^5/f^2$	$2 \times 10^5/f^2$	–	1,0	–
8 Hz – 25 Hz	20 000	$2 \times 10^4/f$	$2{,}5 \times 10^4/f$	–	1,0	–
0,025 kHz – 0,82 kHz	$500/f$	$20/f$	$25/f$	–	1,0	–
0,82 kHz – 2,5 kHz	610	24,4	30,7	–	1,0	–
2,5 kHz – 65 kHz	610	24,4	30,7	–	$0{,}4/f$	–
65 kHz – 100 kHz	610	$1\,600/f$	$2\,000/f$	–	$0{,}4/f$	–
0,1 MHz – 1 MHz	610	$1{,}6/f$	$2/f$	–	40	–
1 MHz – 10 MHz	$610/f$	$1{,}6/f$	$2/f$	–	40	–
10 MHz – 110 MHz	61	0,16	0,2	10	40	100
110 MHz – 400 MHz	61	0,16	0,2	10	–	–
400 MHz – 2 000 MHz	$3\,f^{1/2}$	$0{,}008\,f^{1/2}$	$0{,}01\,f^{1/2}$	$f/40$	–	–
2 GHz – 300 GHz	137	0,36	0,45	50	–	–

NOTE 1 f is the frequency in the units indicated in the frequency range column.

NOTE 2 For frequencies between 100 kHz and 10 GHz, S_{eq}, E^2, H^2, B^2 and $I_L{}^2$ are to be averaged over any six-minute period.

NOTE 3 For frequencies exceeding 10 GHz, S_{eq}, E^2, H^2 and B^2 are to be averaged over any $68/f^{1{,}05}$-minute period (f in GHz).

NOTE 4 For frequencies up to 100 kHz, peak action values for the field strengths can be obtained by multiplying the r.m.s. value by $2^{½}$. For pulses of duration t_p, the equivalent frequency to apply for the action values should be calculated as $f = 1/(2t_p)$.

For frequencies between 100 kHz and 10 MHz, peak action values for the field strengths are calculated by multiplying the relevant r.m.s. values by 10^a, where $a = (0{,}665 \log (f/10^5) + 0{,}176)$, f in Hz.

For frequencies between 10 MHz and 300 GHz, peak action values are calculated by multiplying the corresponding r.m.s. values by 32 for the field strengths and by 1 000 for the equivalent plane wave power density.

NOTE 5 With regard to pulsed or transient electromagnetic fields, or generally with regard to simultaneous exposure to multiple frequency fields, appropriate methods of assessment, measurement and/or calculation capable of analysing the characteristics of the waveforms and nature of biological interactions have to be applied, taking account of harmonised European Standards developed by CENELEC.

NOTE 6 For peak values of pulsed modulated electromagnetic fields, it is also suggested that, for carrier frequencies exceeding 10 MHz, S_{eq} as averaged over the pulse width should not exceed 1 000 times the S_{eq} action values or that the field strength should not exceed 32 times the field strength action values for the carrier frequency.

Annex C
(informative)

Example for general EMF information

The instruction manual should include general information for the user about EMF as given below:

Electric current flowing through any conductor causes localized electric and magnetic fields (EMF). Welding current creates an EMF field around the welding circuit and welding equipment.

EMF fields may interfere with some medical implants, e.g. pacemakers. Protective measures for persons wearing medical implants have to be taken. For example, access restrictions for passers-by or individual risk assessment for welders.

All welders should use the following procedures in order to minimize exposure to EMF fields from the welding circuit:

– route the welding cables together – secure them with tape when possible;

– place your torso and head as far away as possible from the welding circuit;

– never coil welding cables around your body;

– do not place your body between welding cables. Keep both welding cables on the same side of your body;

– connect the return cable to the work piece as close as possible to the area being welded;

– do not work next to, sit or lean on the welding power source;

– do not weld whilst carrying the welding power source or wire feeder.

Bibliography

[1] Directive 2006/95/EC of the European Parliament and of the Council of 12 December 2006 on the harmonisation of the laws of Member States relating to electrical equipment designed for use within certain voltage limits (codified version), Official Journal L 374, 27.12.2006, p. 10-19

[2] Council Recommendation 1999/519/EC of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz), Official Journal L 199, 30.07.1999, p. 59-70

[3] Directive 2004/40/EC of the European Parliament and of the Council of 29 April 2004 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) (18th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC), Official Journal L 159, 30.4.2004, p. 1-26

[4] International Commission on Non-Ionising Radiation Protection, Guidelines on Limits of Exposure to Static Magnetic Fields, Health Physics, Volume 66, Number 1, 1994, p. 113-122

[5] International Commission on Non-Ionising Radiation Protection, Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic and Electromagnetic Fields (up to 300 GHz), Health Physics, Volume 74, Number 4, April 1998, p. 494-522

[6] International Commission on Non-Ionising Radiation Protection, Guidance on Determining Compliance of Exposure to Pulsed and Complex Non-Sinusoidal Waveforms below 100 kHz with ICNIRP Guidelines, Health Physics, Volume 84, Number 3, March 2003, p. 383-387

[7] EN 50499 [1)], Determination of workers exposure to electromagnetic fields

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1) At draft stage.

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