“New European Limits and Standards for EMF exposure in welding”

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European Limits on the EMF Exposure and Welding

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ENTE MORALE

Basics on EMF, reference units

- The electromagnetic field is a physical field that is produced by electrically charged objects and which affects the behaviour of charged objects in the vicinity of the field.
- The electromagnetic field extends indefinitely throughout space and describes the electromagnetic interaction, one of the four fundamental forces of nature.
- The field can be viewed as the combination of:
  - **Electric field**, produced by stationary charges
  - **Magnetic field** produced by moving charges (currents)

Source: Wikipedia

Basics on EMF, reference units

- The electric field **E** exerts forces on an electric charge and is expressed in volt per meter (V m^{-1}).
- A magnetic field can be specified in two ways:
  - magnetic flux density, **B**, expressed in tesla (T),
  - as magnetic field strength, **H**, expressed in ampere per meter (A m^{-1})
  - **B** = μ**H**, where μ is the magnetic permeability;
- In the **far-field region**, the *plane-wave model* is a good approximation of the electromagnetic field propagation:
  - The wave fronts have a planar geometry;
  - The **E** and **H** vectors and the direction of propagation are mutually perpendicular, with the relation E/H= 377 ohm.
  - The Energy Density can be evaluated as **S** = **EH** = $E^2/377 = 377H^2$.
- In the **near-field region**, the electromagnetic field structure may be *highly inhomogeneous*
  - Exposures in the near field are more difficult to evaluate, because both E and H fields must be measured and because the field patterns are more complicated.

Interaction of EMF to the Human Body: coupling mechanisms

- **Coupling** to **low-frequency electric fields**
  - Electric fields external to the body induce a surface charge on the body resulting in **induced currents**
- **Coupling** to **low-frequency magnetic fields**
  - Induced electric fields and **circulating electric currents**.
- **Absorption** of energy from **electromagnetic fields (f > 100Hz):**
  - The absorption is significant and leads to **temperature increases**;
    - frequencies from about 100 kHz to less than about 20 MHz, at which **absorption in the trunk decreases rapidly with decreasing frequency, and significant absorption may occur in the neck and legs;**
    - frequencies in the range from about 20 MHz to 300 MHz, at which relatively high absorption can occur in the whole body, and to even higher values if partial body (e.g., head) resonances are considered;
    - frequencies in the range from about 300 MHz to several GHz, at which significant local, nonuniform absorption occurs
    - frequencies above about 10 GHz, at which energy absorption occurs primarily at the body surface

Reference units for the evaluation of EMF exposure

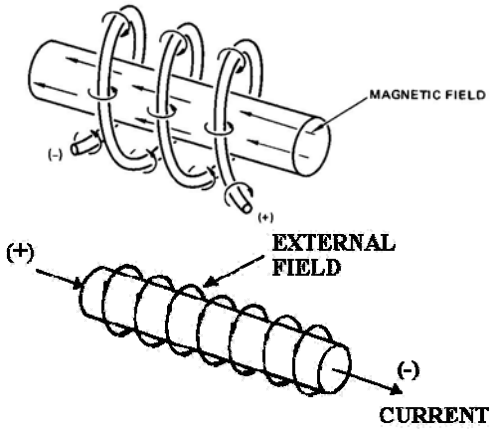
- The mostly commonly used dosimetric units are:
  - **Current density J** in the frequency range up to10MHz;
  - **Current I** in the frequency range up to 110MHz;
  - **Specific energy absorption rate SAR** ,in the frequency range 100kHz–10GHz;
  - **Specific energy absorption, SA**, for pulsed fields in the frequency range 300MHz–10GHz;
  - **Power density S** in the frequency range 10–300GHz.

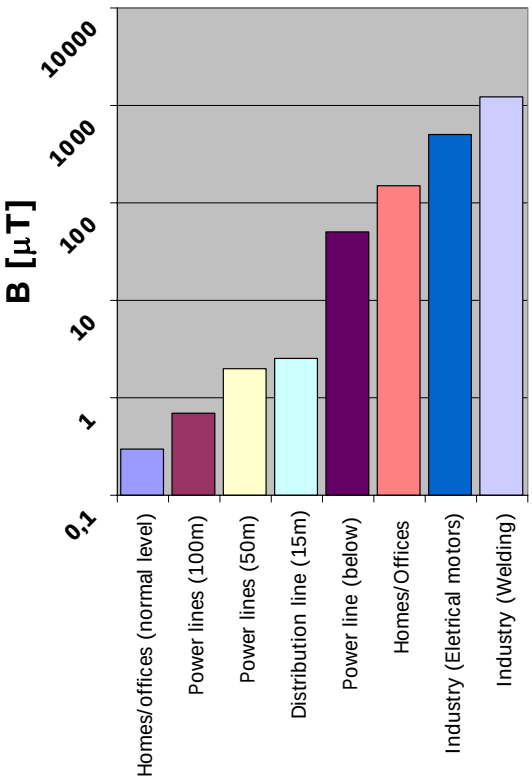
Quantity	Symbol	Unit
Conductivity	σ	siemens per meter (S m^{-1})
Current	I	ampere (A)
Current density	J	ampere per square meter (A m^{-2})
Frequency	f	hertz (Hz)
Electric field strength	E	volt per meter (V m^{-1})
Magnetic field strength	H	ampere per meter (A m^{-1})
Magnetic flux density	B	tesla (T)
Magnetic permeability	μ	henry per meter (H m^{-1})
Permittivity	ϵ	farad per meter (F m^{-1})
Power density	S	watt per square meter (W m^{-2})
Specific energy absorption	SA	joule per kilogram (J kg^{-1})
Specific energy absorption rate	SAR	watt per kilogram (W kg^{-1})

ELECTRIC, MAGNETIC, ELECTROMAGNETIC, AND DOSIMETRIC QUANTITIES AND CORRESPONDING SI UNITS.

The case of welders and EMF

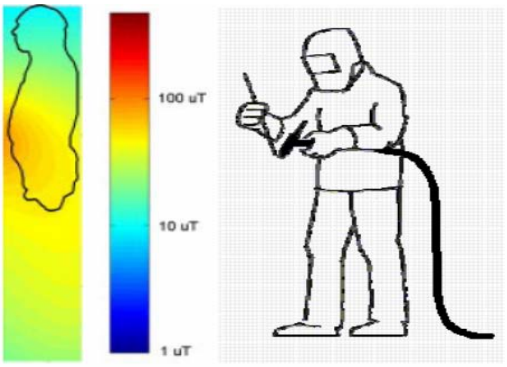
- Welding operations with electric appliances can give rise to high energy density Magnetic Fields, which can be directly related to the Current used (ranging form 0,1A to several kA)
- Frequency ranges from 50 Hz to KHz.



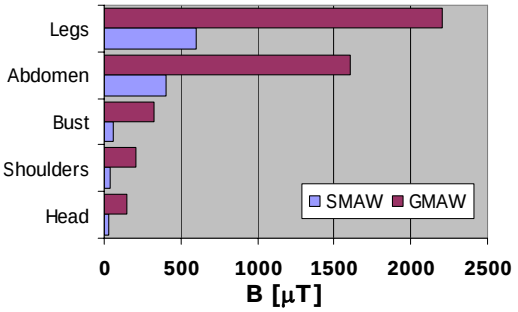


Arc welding processes

- The welders exposure depends on the following factors:
  - Current intensity (and welding process)
  - Waveform and type of power source.
  - Workshop design
  - Position of welding cables with respect to the body and its relevant parts
- Gas Metal Arc Welding might be assumed as giving rise to the highest exposing process.



Evaluated EMF in TIG welding



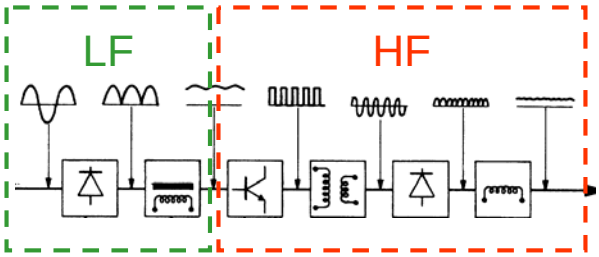
Evaluated EMF in SMAW and GMAW

Resistance welding

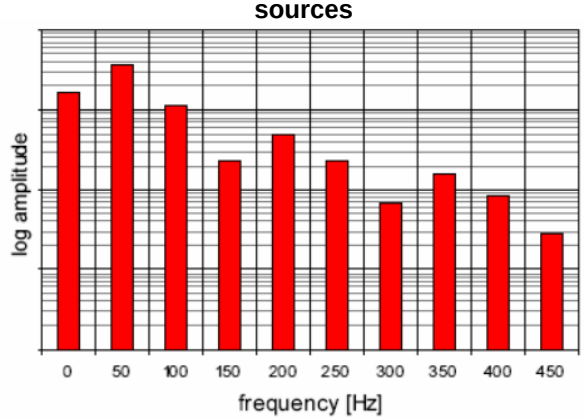
- In resistance welding, current can reach 10^4 A, namely in alternating current (50Hz or 60 Hz) or rectified current.
  - Cables are running through the workshop and near to the welders chest;
  - The highest magnetic field is generated in the welding torch (a coil)
  - The use of high frequency power source is growing:
    - advantages in reduction of EMF intensity
    - disadvantages as for the absorption of energy (increase in frequencies and flickering)

Use of electronically switched power sources

- The need for higher electrical efficiency, productivity and quality and the development of high power electronics, is leading to the growing use of electronically switched power sources (based on the inverter technology)
- The result is a current wave form which is composed as superimposed currents of different waveforms with both Low and High Frequency.



Simplified scheme of Electronic power sources



Amplitude-frequency distribution in alternating square waveform

Relation between EMF and chronic diseases

- The following adverse effect on health are considered as related to occupational and residence exposure to EMF:
  - Adult and childhood leukemia
  - Adult and childhood brain cancer
  - Male and female breast cancer
  - EMF as a “broad spectrum” carcinogen for all cancers
  - Miscarriage (or *spontaneous abortion*)
  - Other reproductive and developmental conditions
  - Amyotrophic lateral sclerosis (Lou Gehrig’s Disease)
  - Alzheimer’s disease
  - Acute myocardial infarction
  - Suicide
  - Other adverse non-cancer health outcomes (depression, electrical sensitivity)

Biological effects and epidemiological studies (up to 100 kHz)

- With the possible exception of mammary tumors, there is currently **no convincing evidence for carcinogenic effects** of these fields.
- Laboratory studies on cellular and animal systems that **high levels of induced current density** (10–100 mA m^{-2}), **significant tissue effects have been consistently observed**, such as functional changes in the nervous system and other tissue effects.
- Data on cancer risk associated with exposure to ELF fields among **individuals living close to power lines** are apparently consistent in indicating a slightly higher risk of leukemia among children, although more recent studies question the previously observed weak association. **The basis for the hypothetical link between childhood leukemia and residence in close proximity to power lines is unknown**; however there is **a lack of support from laboratory studies** leading to the conclusion that the epidemiological data can be considered still insufficient.

Biological effects and epidemiological studies (up to 100 kHz)

- There have been reports of an increased **risk of certain types of cancer**, such as leukemia, nervous tissue tumors, and, to a limited extent, breast cancer, **among electrical workers**. In most studies, job titles were used to classify subjects according to presumed levels of magnetic field exposure. A few more recent studies, however, have used more sophisticated methods of exposure assessment; overall, these studies suggested an increased risk of leukemia or brain tumors but were largely inconsistent with regard to the type of cancer for which risk is increased.
- In a large number of **epidemiological studies**, **no consistent evidence** of adverse **reproductive effects** have been provided.

Biological effects and epidemiological studies (up to 100 kHz)

- Measurement of **biological responses in laboratory** studies and in **volunteers** has provided little indication of adverse effects of low-frequency fields at levels to which people are commonly exposed. **A threshold current density of 10 mA m-2 at frequencies up to 1 kHz has been estimated for minor effects in nervous system functions.**
- Among **volunteers**, the most consistent effects of exposure are the appearance of **visual phosphenes** and a **minor reduction in heart rate** during or immediately after exposure to ELF fields, but there is **no evidence that these transient effects are associated with any long-term health risk**.
- A **reduction in nocturnal pineal melatonin synthesis** has been observed in several **rodent species** following exposure to weak ELF electric and magnetic fields, but **no consistent effect has been reported in humans exposed to ELF fields under controlled conditions**.
- Studies involving exposures to 60-Hz magnetic fields up to 20 mT have not reported reliable effects on melatonin levels in blood.

Biological effects and Epidemiological Studies (100 kHz – 30 GHz)

- Available experimental evidence indicates that the exposure of **resting humans and animals** for approximately 30 min to EMF producing a **whole-body SAR of 1 to 4 W kg^{-1} results in a body temperature increase of less than 1 °C.**
- **Exposure to more intense fields**, producing SAR values in excess of 4 W kg^{-1}, can **overwhelm the thermoregulatory capacity of the body** and produce harmful levels of tissue heating.

Biological effects and Epidemiological Studies (100 kHz – 30 GHz)

- Data on human responses to high-frequency EMF that produce detectable heating have been obtained from **controlled exposure of volunteers** and from **epidemiological studies on workers** exposed to sources such as radar, medical diathermy equipment, and heat sealers
  - no **major health effects** associated with typical exposure environments
  - no **convincing evidence that typical exposure levels lead to adverse reproductive outcomes or an increased cancer risk in** exposed individuals.
- This is consistent with the results of **laboratory research on cellular and animal models**, which have demonstrated neither teratogenic nor carcinogenic effects of exposure to athermal levels of high-frequency EMF.

ICNIRP review on the Epidemiological Literature on EMF and Health

- **Exposure assessment is a particular difficulty of EMF epidemiology**, in several respects:
  a) The exposure is imperceptible, ubiquitous, has multiple sources, and can vary greatly over time and short distances.
  b) The exposure period of relevance is before the date at which measurements can realistically be obtained and of unknown duration and induction period.
  c) The appropriate exposure metric is not known and there are no biological data from which to impute it.
- Also **in the field of Radio Frequencies** (100kHz to 300Hz) a key concern across all studies is the **quality of assessment of RF exposure**, including the question of whether such exposure was present at all. Despite the rapid growth of new technologies using RFs, little is known about population exposure from these and other RF sources and even less about the relative importance of different sources.

ICNIRP review on the Epidemiological Literature on EMF and Health

- "In the absence of experimental evidence from cellular or animal studies, and given the methodological uncertainties in the epidemiologic literature, there is no chronic disease for which an etiological relation to EMF can be regarded as established."
- In the field of RFs, a key element in improving future studies would be the use of a meter that monitors individual exposure, even if in the absence of information on what biologic mechanism is relevant, if any, it is unclear what aspect of exposure needs to be captured in epidemiologic studies.

ICNIRP guidelines: Basic restrictions

- Different scientific bases were used in the development of basic exposure restrictions for various frequency ranges:
  - Between **1 Hz and 10 MHz**, basic restrictions are provided on current density to prevent effects on nervous system functions;
  - Between **100 kHz and 10 GHz**, basic restrictions on SAR are provided to prevent whole-body heat stress and excessive localized tissue heating;
  - In the **100 kHz–10 MHz range**, restrictions are provided on both current density and SAR;
  - Between **10 and 300 GHz**, basic restrictions are provided on power density to prevent excessive heating in tissue at or near the body surface.

ICNIRP: Basic restrictions

Exposure characteristics	Frequency range	Current density for head and trunk (mA m^{-2}) (rms)	Whole-body average SAR (W kg^{-1})	Localized SAR (head and trunk) (W kg^{-1})	Localized SAR (limbs) (W kg^{-1})
Occupational exposure	up to 1 Hz	40	—	—	—
	1–4 Hz	40/*f*	—	—	—
	4 Hz–1 kHz	10	—	—	—
	1–100 kHz	*f*/100	—	—	—
	100 kHz–10 MHz	*f*/100	0.4	10	20
	10 MHz–10 GHz	—	0.4	10	20
General public exposure	up to 1 Hz	8	—	—	—
	1–4 Hz	8/*f*	—	—	—
	4 Hz–1 kHz	2	—	—	—
	1–100 kHz	*f*/500	—	—	—
	100 kHz–10 MHz	*f*/500	0.08	2	4
	10 MHz–10 GHz	—	0.08	2	4

[a] Note:

1. f is the frequency in hertz.
2. Because of electrical inhomogeneity of the body, current densities should be averaged over a cross-section of 1 cm^2 perpendicular to the current direction.
3. For frequencies up to 100 kHz, peak current density values can be obtained by multiplying the rms 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 $f = 1/(2t_p)$.
4. 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.
5. All SAR values are to be averaged over any 6-min period.
6. Localized 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.
7. 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 to 10 GHz and for localized exposure of the head, in order to limit or avoid auditory effects caused by thermoelastic expansion, an additional basic restriction is recommended. This is that the SA should not exceed 10 mJ kg^{-1} for workers and 2mJ kg^{-1} for the general public, averaged over 10 g tissue.

ICNIRP: Reference levels

- Where appropriate, the reference levels are obtained from the basic restrictions by mathematical modelling and by extrapolation from the results of laboratory investigations at specific frequencies.
- They are given for the condition of maximum coupling of the field to the exposed individual, thereby providing maximum protection.
  - For purposes of demonstrating compliance with the basic restrictions, the reference levels for the electric and magnetic fields should be considered separately and not additively.
  - For the specific case of occupational exposures at frequencies up to 100 kHz, the derived electric fields can be increased by a factor of 2 under conditions in which adverse indirect effects from contact with electrically charged conductors can be excluded.

ICNIRP Reference levels for occupational exposure

Frequency range	E-field strength (V m^{-1})	H-field strength (A m^{-1})	B-field (μT)	Equivalent plane wave power density S_{eq} (W m^{-2})
up to 1 Hz	—	1.63×10^5	2×10^5	—
1–8 Hz	20,000	$1.63 \times 10^5/f^2$	$2 \times 10^5/f^2$	—
8–25 Hz	20,000	$2 \times 10^4/f$	$2.5 \times 10^4/f$	—
0.025–0.82 kHz	$500/f$	$20/f$	$25/f$	—
0.82–65 kHz	610	24.4	30.7	—
0.065–1 MHz	610	$1.6/f$	$2.0/f$	—
1–10 MHz	$610/f$	$1.6/f$	$2.0/f$	—
10–400 MHz	61	0.16	0.2	10
400–2,000 MHz	$3f^{1/2}$	$0.008f^{1/2}$	$0.01f^{1/2}$	$f/40$
2–300 GHz	137	0.36	0.45	50

[a] Note:
1. f as indicated in the frequency range column.
2. Provided that basic restrictions are met and adverse indirect effects can be excluded, field strength values can be exceeded.
3. For frequencies between 100 kHz and 10 GHz, S_{eq}, E^2, H^2, and B^2 are to be averaged over any 6-min period.
4. For peak values at frequencies up to 100 kHz see Table 4, note 3.
5. For peak values at frequencies exceeding 100 kHz see Figs. 1 and 2. Between 100 kHz and 10 MHz, peak values for the field strengths are obtained by interpolation from the 1.5-fold peak at 100 kHz to the 32-fold peak at 10 MHz. For frequencies exceeding 10 MHz it is suggested that the peak equivalent plane wave power density, as averaged over the pulse width, does not exceed 1,000 times the S_{eq} restrictions, or that the field strength does not exceed 32 times the field strength exposure levels given in the table.
6. For frequencies exceeding 10 GHz, S_{eq}, E^2, H^2, and B^2 are to be averaged over any $68/f^{1.05}$-min period (f in GHz).
7. No E-field value is provided for frequencies <1 Hz, which are effectively static electric fields. Electric shock from low impedance sources is prevented by established electrical safety procedures for such equipment.

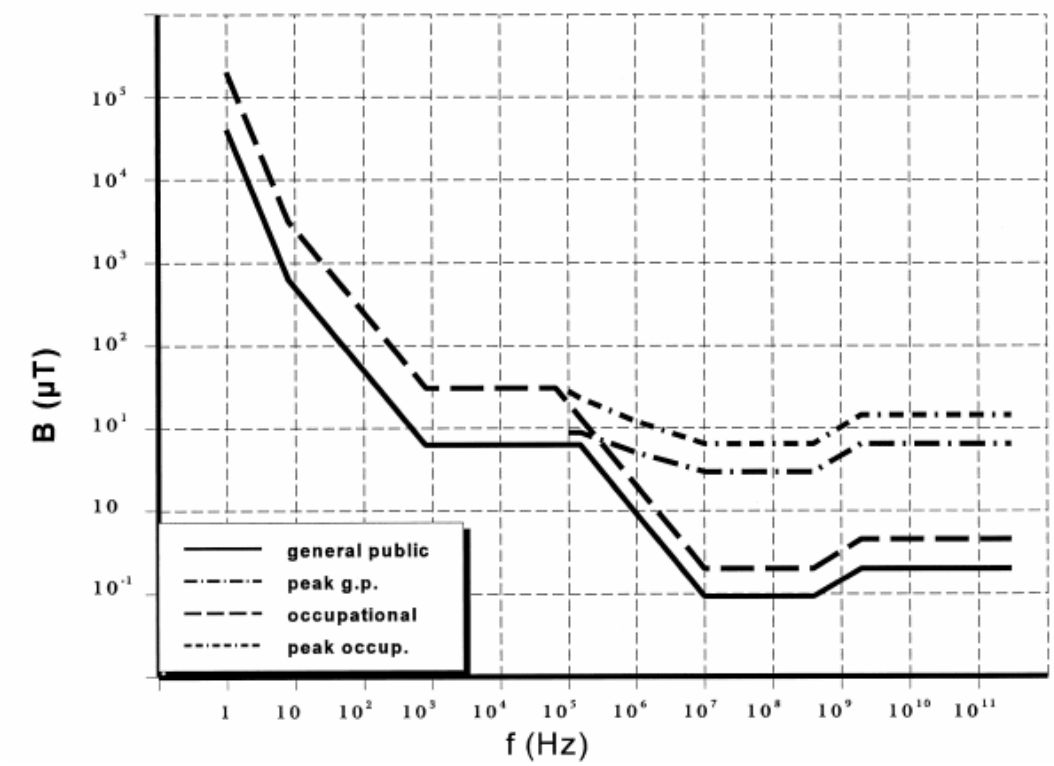
doc. VIII 2042-07

ICNIRP Reference levels for public exposure

Frequency range	E-field strength (V m^{-1})	H-field strength (A m^{-1})	B-field (μT)	Equivalent plane wave power density S_{eq} (W m^{-2})
up to 1 Hz	—	3.2×10^4	4×10^4	—
1–8 Hz	10,000	$3.2 \times 10^4/f^2$	$4 \times 10^4/f^2$	—
8–25 Hz	10,000	$4{,}000/f$	$5{,}000/f$	—
0.025–0.8 kHz	$250/f$	$4/f$	$5/f$	—
0.8–3 kHz	$250/f$	5	6.25	—
3–150 kHz	87	5	6.25	—
0.15–1 MHz	87	$0.73/f$	$0.92/f$	—
1–10 MHz	$87/f^{1/2}$	$0.73/f$	$0.92/f$	—
10–400 MHz	28	0.073	0.092	2
400–2,000 MHz	$1.375f^{1/2}$	$0.0037f^{1/2}$	$0.0046f^{1/2}$	$f/200$
2–300 GHz	61	0.16	0.20	10

[a] Note:
1. f as indicated in the frequency range column.
2. Provided that basic restrictions are met and adverse indirect effects can be excluded, field strength values can be exceeded.
3. For frequencies between 100 kHz and 10 GHz, S_{eq}, E^2, H^2, and B^2 are to averaged over any 6-min period.
4. For peak values at frequencies up to 100 kHz see Table 4, note 3.
5. For peak values at frequencies exceeding 100 kHz see Figs. 1 and 2. Between 100 kHz and 10 MHz, peak values for the field strengths are obtained by interpolation from the 1.5-fold peak at 100 kHz to the 32-fold peak at 10 MHz. For frequencies exceeding 10 MHz it is suggested that the peak equivalent plane wave power density, as averaged over the pulse width does not exceed 1,000 times the S_{eq} restrictions, or that the field strength does not exceed 32 times the field strength exposure levels given in the table.
6. For frequencies exceeding 10 GHz, S_{eq}, E^2, H^2, and B^2 are to be averaged over any $68/f^{1.05}$-min period (f in GHz).
7. No E-field value is provided for frequencies <1 Hz, which are effectively static electric fields. perception of surface electric charges will not occur at field strengths less than 25 kVm^{-1}. Spark discharges causing stress or annoyance should be avoided.

ICNIRP reference levels



Simultaneous exposure to multiple frequency fields

- It is important to determine whether, in situations of simultaneous exposure to fields of different frequencies, these exposures are additive in their effects. **Additivity should be examined separately for the effects of thermal and electrical stimulation**.
  - Formulae are provided, considering the cumulative effects in specific frequency ranges, assuming worst-case conditions among the fields from the multiple sources.
  - As a result, typical exposure situations may in practice require less restrictive exposure levels than indicated by the relevant formulae for the reference levels.

For electrical stimulation, relevant for frequencies up to 10 MHz, induced current densities should be added according to

$$\sum_{i=1\ \mathrm{Hz}}^{10\ \mathrm{MHz}} \frac{J_i}{J_{L,i}} \leq 1. \qquad (5)$$

For thermal effects, relevant above 100 kHz, SAR and power density values should be added according to:

$$\sum_{i=100\ \mathrm{kHz}}^{10\ \mathrm{GHz}} \frac{SAR_i}{SAR_L} + \sum_{i>10\ \mathrm{GHz}}^{300\ \mathrm{GHz}} \frac{S_i}{S_L} \leq 1, \qquad (6)$$

where

J_i = the current density induced at frequency i;
$J_{L,i}$ = the induced current density restriction at frequency i as given in Table 4;
SAR_i = the SAR caused by exposure at frequency i;
SAR_L = the SAR limit given in Table 4;
S_L = the power density limit given in Table 5; and
S_i = the power density at frequency i.

European Directive 2004/40/CE

- The Directive lays down **minimum requirements for the protection of workers from risks to their health and safety** arising or likely to arise from exposure to electromagnetic fields (0 Hz to 300 GHz) during their work.
  - The Directive refers to the risk to the health and safety of workers due to **known short-term adverse effects in the human body** caused by the circulation of induced currents and by energy absorption as well as by contact currents.
  - The Directive does **not** address suggested **long-term effects**.
  - The Directive does not address the **risks resulting from contact with live conductors**.

European Directive 2004/40/CE

- "*The employer shall assess and, if necessary, measure and/or calculate the levels of electromagnetic fields to which workers are exposed.*"
- *"Assessment, measurement and calculation may, until harmonised European **standards from Cenelec** cover all relevant assessment, measurement and calculation situations, be carried out in accordance with the scientifically-based standards and guidelines referred to in Article 3[*] and, when relevant, by taking into account the emission levels provided by the manufacturers of the equipment when it is covered by the relevant Community Directives."*

- *[*] Article 3* refers to ICNIRP guidelines and relevant reference levels.

European Directive 2004/40/CE. Exposure Limits

Exposure limit values (Article 3(1)). All conditions to be satisfied

Frequency range	Current density for head and trunk J (mA/m²) (rms)	Whole body average SAR (W/kg)	Localised SAR (head and trunk) (W/kg)	Localised SAR (limbs) (W/kg)	Power density S (W/m²)
Up to 1 Hz	40	—	—	—	—
1 — 4 Hz	40/f	—	—	—	—
4 — 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 — 300 GHz	—	—	—	—	50

doc. VIII 2042-07

European Directive 2004/40/CE. Action Limits

Action values (Article 3(2)) (unperturbed rms values)

Frequency range	Electric field strength, E (V/m)	Magnetic field strength, H (A/m)	Magnetic flux density, B (μT)	Equivalent plane wave power density, S_{eq} (W/m²)	Contact current, I_C (mA)	Limb induced current, I_L (mA)
0 — 1Hz	—	$1,63x10^5$	$2x10^5$	—	1,0	—
1 — 8 Hz	20 000	$1,63x10^5/f^2$	$2x10^5/f^2$	—	1,0	—
8 — 25 Hz	20 000	$2x10^4/f$	$2,5x10^4/f$	—	1,0	—
0,025 — 0,82kHz	500/f	20/f	25/f	—	1,0	—
0,82 — 2,5 kHz	610	24,4	30,7	—	1,0	—
2,5 — 65 kHz	610	24,4	30,7	—	0,4 f	—
65 — 100 kHz	610	1 600/f	2 000/f	—	0,4 f	—
0,1 — 1 MHz	610	1,6/f	2/f	—	40	—
1 — 10 MHz	610/f	1,6/f	2/f	—	40	—
10 — 110 MHz	61	0,16	0,2	10	40	100
110 — 400 MHz	61	0,16	0,2	10	—	—
400 — 2 000 MHz	$3f^{½}$	$0,008f^{½}$	$0,01f^{½}$	f/40	—	—
2 — 300 GHz	137	0,36	0,45	50	—	—

Approach to EMF from the standardisation viewpoint

- The International Electrotechnical Commission (IEC) started dealing with the matter considering the welding equipment
  - Emission limits are designed to reduce the probability of interference with other equipment
  - Immunity requirements and test methods for continuous and transient, conducted and radiated disturbances including electrostatic discharges.

EN 50240 Electromagnetic compatibility (EMC) Product standard for resistance welding equipment

EN 60974-10 Arc welding equipment – electromagnetic compatibility (EMC) requirements

Table 1 – Immunity levels – Enclosure

Phenomena		Units	Test specification	Basic standard and test set-up	Remarks	Performance criteria
Radio-frequency EM field, amplitude modulated		MHz V/m (unmod. r.m.s.) % AM (1 kHz)	80 – 1 000 3 80	IEC 61000-4-3	This test level specified is prior to modulation	A
Electrostatic discharge	Contact discharge	kV (charge voltage)	±4	IEC 61000-4-2	See basic standard for applicability of contact and/or air discharge test. See note	B
	Air discharge	kV (charge voltage)	±8			B
NOTE Testing is not required at lower levels than those specified.						

Approach to EMF from the standardisation viewpoint

- A further step has been the development of international standards considering
  - the effects on the human body based on the ICNIRP reference values
  - Test methods and criteria for the evaluation of reference levels

EN 50xx3 Basic standard for the evaluation of human exposure to electromagnetic fields from equipment for resistance welding and allied processes

EN 50444 Basic standard for the evaluation of human exposure to electromagnetic fields from equipment for arc welding and allied processes

EN 50445 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)

References

- 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)
- Review of the epidemiologic literature on EMF and health, ICNIRP (international commission for non-ionizing radiation protection) standing committee on epidemiology, Environmental health perspectives, Volume 109 | supplement 6 | December 2001,
- Council recommendation of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz) (1999/519/EC)
- Epidemiology of health effects of radiofrequency exposure, ICNIRP (international commission for non-ionizing radiation protection) standing committee on epidemiology, Environmental health perspectives, Volume 112 | Number 17 | December 2004

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