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Related information on human exposure to electromagnetic fields (EMF)

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1. Introduction

At the Quebec meeting, I introduced two CENELEC standards on electromagnetic field for resistance welding equipment.
One is:
prEN 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)
The other is:
prEN 50505 Basic standard for the evaluation of human exposure to electromagnetic fields from equipment for resistance welding and allied processes

The former standard specifies the compliance criteria and exposure limits, the latter defined the assessment methods. The evaluation of exposure limit is decided based on Directive 2004/40/EC. The values of basic restriction and reference levels brought from the European Council Recommendation 1999/519/EC.

Those documents were circulated for the draft enquiry by CENELEC members last year, and the reviews were closed this February.

The guideline including reference levels was recommended by ICNIRP (International Commission on Non-Ionizing Radiation Protection) and International EMF Project by WHO. In order to consider welding equipment, especially resistance welding equipment, ELF EMF (Extremely Low Frequency Electromagnetic Field) is most important target.

According to the WHO EMF project, however, only point out

2. Reference levels of EMF exposure by the new draft IEC

prEN/CDV 50445 required the EMF limit values based on the European Directives as shown in Table 1 and 2 for the occupational persons.

However, the limit values were not agreed with other countries and other societies yet. According to the Federal-Provincial-Territorial Radiation Protection Committee of Canada, there are many threshold values this moment in the world. Table 3 indicates this difference among many organizations related to the regulation on this EMF. Moreover, nobody has not concrete evidence of that the EMF, especially ELF EMF (Extremely Low Frequency Electro Magnetic Field) is harm on the occupational persons who are adult.

Note: The EU directives were decided based on the ICNIRP. (International Commission on Non-Ionizing Radiation Protection) Guidelines.

Table 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 mA m^{-2}	Whole body average SAR W kg^{-1}	Localised (head and trunk) SAR W kg^{-1}	Localised (limbs) SAR W kg^{-1}	Power density S W m^{-2}
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

NOTE 1 f is the frequency in Hertz.

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 cm^2 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 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 cm^2 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 cm^2 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 .2 - Occupational reference levels for 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 –1) Hz	–	$1{,}63 \times 10^5$	2×10^5	–	1,0	–
(1 – 8) Hz	20 000	$1{,}63 \times 10^5/f^2$	$2 \times 10^5/f^2$	–	1,0	–
(8 – 25) Hz	20 000	$2 \times 10^4/f$	$2{,}5 \times 10^4/f$	–	1,0	–
(0,025 – 0,82) kHz	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	$3f^{1/2}$	$0{,}008f^{1/2}$	$0{,}01f^{1/2}$	*f*/40	–	–
(2 – 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.

Table 3 Reference levels for occupational exposure and exposure of the general public to electric and magnetic fields at power frequencies

	Electric Field Strength, rms (kV/m)		Magnetic Flux Density, rms (μT)	
Standard	**Public**	**Occupational**	**Public**	**Occupational**
ACGIH (2003) (60 Hz)		25		1000
ICNIRP (1998) (60 Hz)	4.17	8.33	83.33	416.67
IEEE (2002) (60 Hz)	5 10*	20	900	2710
Australia (1989)(50/60 Hz)	5	10	100	500
Bulgaria (1999) (50 Hz)		5		1200
Japan (2001) (50/60 Hz)	3	3		
Russia (1999) (50 Hz)	0.5 1†	5	10 50†	100

*Intermediate electric field exception within power transmission line rights-of-way
†Living areas outside buildings

Although the long time research efforts more than thirty years by many researchers and many organizations including WHO's EMF project, WHO announced only that only Childhood leukemia may link to the ELF EMF last month in this June. (See Annex A as the reference)

According to the Federal-Provincial-Territorial Radiation Protection Committee of Canada, they has not found any evidence to regulate the electro magnetic field for the occupational persons. Their statement is shown as Annex B.

The limit value was come from experimental results on acute change in central nervous system by conductive current in it. The paragraph described in the "Guidelines for limiting exposure to time varying electric, magnetic and electromagnetic fields (Up to 300 GHz)" by ICNIRP is shown below.

> In the frequency range from a few Hz to 1 kHz, for levels of induced current density above 100 mA m^{-2}, the thresholds for acute changes in central nervous system excitability and other acute effects such as reversal of the visually evoked potential are exceeded. In view of the safety considerations above, it was decided that, for frequencies in the range 4 Hz to 1 kHz, occupational exposure should be limited to fields that induce current densities less than 10 mA m^{-2}, i.e., to use a safety factor of 10. For the general public an additional factor of 5 is applied, giving a basic exposure restriction of 2 mA m^{-2}. Below 4 Hz and above 1 kHz, the basic restriction on induced current density increases progressively, corresponding to the increase in the threshold for nerve stimulation for these frequency ranges.

However, the IRPA/INIRC Guidelines said "No adverse health effects are expected from exposures of the head and/or trunk to magnetic flux densities up to 2 T, or from exposure of the limbs to magnetic flux densities up to 5 T." Then, the ICNIRP stated other limit values for the occupational persons. The Guidelines on limits of exposure to static magnetic fields is shown in Table 4.

Table 4

Table 3. Limits of exposure to static magnetic field.[a,b,c,d]

Exposure characteristics	Magnetic flux density
Occupational	
Whole working day (time-weighted average)	200 mT
Ceiling value	2 T
Limbs	5 T
General public	
Continuous exposure	40 mT

[a] Caution: People with cardiac pacemakers and other implanted electrically activated devices, or with ferromagnetic implants, may not be adequately protected by the limits given here. The majority of cardiac pacemakers are unlikely to be affected from exposure to fields below 0.5 mT. People with some ferromagnetic implants or electrically activated devices (other than cardiac pacemakers) may be affected by fields above a few mT.
[b] When magnetic flux densities exceed 3 mT, precautions should be taken to prevent hazards from flying metallic objects.
[c] Analog watches, credit cards, magnetic tapes, computer disks, etc. may be adversely affected by exposures to 1 mT but this is not a safety concern for humans.
[d] General public. Occasional access of members of the public to special facilities where magnetic flux densities exceed 40 mT can be allowed under appropriately controlled conditions provided that the appropriate occupational exposure limit is not exceeded.

In this guideline, they permit higher threshold values in the conditions.

The new standards required only to refer the EU Directives, but the values were not agreed with other countries, and it seems that there is no concrete scientific evidence to accept the EU Directive's values yet.

We believe the prEN standards on EMF are going to be published as IEC standards. If so, the words "values in Table 1 of Directive 2004/40/EC/Table 2 of EC Recommendation 1999/519/Ec" described in the draft prEN50445 shall be read with 'values specified by the each national standard or national law"

Furthermore, the limit values should be decided depend on the working category of equipment line EMC standard (See CISPR 11. The example is show in Annex C)

Annex A

Large study links power lines to childhood cancer

- 00:01 03 June 2005
- NewScientist.com news service
- Gaia Vince

Children living near overhead power lines may have an increased risk of leukemia but the association may not be causal, UK researchers say.

The confusing message, which comes from the largest study to date - of over 29,000 children with cancer - is that since "there is no biological mechanism to explain the higher risk", the results, "although statistically significant, may be due to chance".

The study – a collaboration between the Childhood Cancer Research Group at the University of Oxford and National Grid owners, Transco – looked at cancer data in England and Wales between 1962 and 1995, for children aged up to 15 years old.

They were able to map how far each child lived from a high voltage overhead power line. Comparing the children who had cancer with a control group of 29,000 children without cancer but who lived in comparable districts, found that children whose birth address was within 200 metres of an overhead power line had a 70% increased risk of leukemia. Children living 200 to 600 m away from power lines had a 20% increased risk.

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"We don't think it is possible that a magnetic field of these low magnitudes could have a causative effect on childhood leukemia," Draper says.

The increase in leukemia risk for those living at distances greater than 60 m was "difficult to interpret, but is most unlikely to be due to any residual electromagnetic field, or other exposures related to the power line", says David Grant, scientific director of Leukemia Research. "It cannot be excluded that it is a statistical artefact."

But given the statistical significance of their results, the researchers had considered other theories. One established link with the disease is low exposure to infection soon after birth - an effect seen most commonly in babies born to higher income, middle-class families, where early social mixing between infants is rarer. Draper's group looked at the population characteristics in areas immediately surrounding power lines.

Journal reference: *British Medical Journal* (vol 330, p 1290)

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Annex B
Statements Federal-Provincial-Territorial Radiation Protection Committee of Canada,

14. POSITION STATEMENT FOR THE GENERAL PUBLIC ON THE HEALTHEFFECTS OF POWER-FREQUENCY (60 Hz) ELECTRIC AND MAGNETICFIELDS

1. Electric and magnetic fields (EMFs) are produced by the generation, transmission, distribution and use of electrical energy at power frequencies (60 Hz in Canada).People are exposed to these fields while in close proximity to power lines and other electrical facilities, as well as electrical wiring, equipment and appliances in homes, schools and workplaces.

2. Studies to investigate the health effects of these fields have taken place around the world for more than thirty years. These studies include laboratory research into effects on cells and animals, as well as epidemiological (human health) studies looking at possible associations between exposures and diseases in the population. Short- and long-term scientific investigations have been conducted and are continuing.

3. Laboratory research has shown that power-frequency EMFs can interact with biological systems; however, results to date have not provided conclusive evidence that these fields cause adverse health effects, such as cancer. Epidemiological studies have not established an association between exposure to power-frequency EMFs and the development of cancer in adults. The evidence associating cancer in children with exposure to power-frequency EMFs remains in conclusive.

4. After a recent evaluation of the scientific data, the International Agency for Research on Cancer classified extremely-low-frequency (ELF) magnetic fields as "possibly carcinogenic to humans" based on studies of childhood cancer(http://monographs.iarc.fr). "Possibly carcinogenic to humans" is a classification used to denote an agent for which there is limited evidence of carcinogenicity in humans and less than sufficient evidence for carcinogenicity in experimental animals. In the case of ELF fields, the evidence is not strong enough to conclude that they definitely cause cancer in children. More studies are needed to draw firm conclusions.

5. Immediate biological effects can result from direct exposure but only at field strength levels well above those typically found in living environments. Peripheral nerve and muscle stimulation can be caused by intense magnetic fields and hair stimulation by intense electric fields. Minor shocks may be caused by touching poorly-grounded, conducting (metallic) objects located under some high voltage lines, as a result of electrical charge induced by high intensity electric or magnetic fields.

Annex C
EMC standard has some classes for the regulation

Regulated Equipment Defined by Category (CISPR 11)

Group 1 ISM equipment is equipment containing intentionally generated and/or used conductively coupled radio-frequency energy that is necessary for the internal functioning of the equipment itself.

Group 2 ISM equipment is equipment in which radio-frequency energy is intentionally generated and/or used in the form of electromagnetic radiation for the treatment of material, as well as spark-erosion equipment.

Within each group:

Class A equipment is equipment suitable for use in all establishments other than domestic and those directly connected to a low-voltage power supply network which supplies buildings used for domestic purposes.

Class B equipment is equipment suitable for use in
domestic establishments and in establishments directly connected to a low-voltage power supply network that supplies buildings used for domestic purposes.

Table A.1 – Mains terminal disturbance voltage limits, idle state

Frequency band	Class B dBµV		Class A dBµV	
MHz	Quasi-peak	Average	Quasi-peak	Average
0,15 – 0,50	66 Decreasing linearly with logarithm of frequency to 56	56 Decreasing linearly with logarithm of frequency to 46	79	66
0,50 – 30	56	46	73	60

Table A.2 – Mains terminal disturbance voltage limits, load conditions

Frequency band	Class B dBµV		Class A dBµV		Class A > 100 A [a] dBµV	
MHz	Quasi-peak	Average	Quasi-peak	Average	Quasi-peak	Average
0,15 – 0,50	66 Decreasing linearly with logarithm of frequency to 56	56 Decreasing linearly with logarithm of frequency to 46	100	90	130	120
0,50 – 5	56	46	86	76	125	115
5 – 30	60	50	90 Decreasing linearly with logarithm of frequency to 70	80 Decreasing linearly with logarithm of frequency to 60	115	105

[a] Applicable to equipment with mains supply currents I_{1cc} in excess of 100 A per phase.

End of text