

Extra low frequency magnetic fields of welding machines and personal safety

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The article is focused on the determination of the amplitude and the frequency parameters of the extra low frequency (ELF) field, created by the use of electro-technical devices.

Keywords: safety, health protection, ELF magnetic fields, welding machine

1 Introduction

ELF (Extremely Low Frequency) is a name for a field with extremely low frequencies in range 0 - 300 Hz. The fields with frequency 50/60 Hz are used in ordinary conditions. Some of the sources use the frequencies below 50 Hz, but there are processes that produce the frequencies below 50 Hz, such as demagnetization, welding, and special drivers and so on. The sources of the ELF fields are described and summarized in Tab. 1.

The standards for exposition to the ELF fields and the safety limits are discussed in article. The ELF fields are fields with frequencies in range from 0 Hz to 300 Hz. Most of the electro-technical devices are operated by the 50 Hz or 60 Hz frequency. The operating devices produce the effects with lower frequencies than their own supply frequency. The brain frequencies around 0.5 Hz were discovered during the past years and called the epsilon level. The article describes the exploration of the ELF fields during the process of arc welding by different

kinds of arc welding machines. All of the tested welding machines produce strong magnetic fields around the 5 Hz frequency with no dependence on the welding machine type. The ELF radiation of the welding machines connecting wires and electric arc are discussed in the article. The results of the measurements are compared to actual standards for non-ionizing radiation. The recommendations for reduction of the impact of the ELF fields during the use of welding machines are described at the end of the article.

2 Influences on human health

Further research of different brain waves, associated with different states of consciousness, brings the discovery of new frequency ranges, respectively consciousness levels. Some kinds of deep meditations, ecstasy, inspirations or extracorporeal perceptions show the frequencies lower than 0.5 Hz. This frequency range was named the

Table 1. Sources of ELF [1, 2]

Group	Effect	B (T)	f (Hz)	Notes
Transformers and convertors	275 and 400 kV	1×10^{-5}	50	¹⁾ 1.5 m
Devices using induction	Inductive heating injection press	1×10^{-5}	50	¹⁾ > 1 m
	Inductive heating	6×10^{-2}	< 50	¹⁾ < 1 m
	Demagnetisation coils	1×10^{-4}	< 50	2)
Arc welding	welding (3×400 V)	1×10^{-4}	< 50	3)
	welding CO ₂	1×10^{-5}	< 100	3)
	welding invertor	1×10^{-6}	< 100	3)

¹⁾ distance from transformer

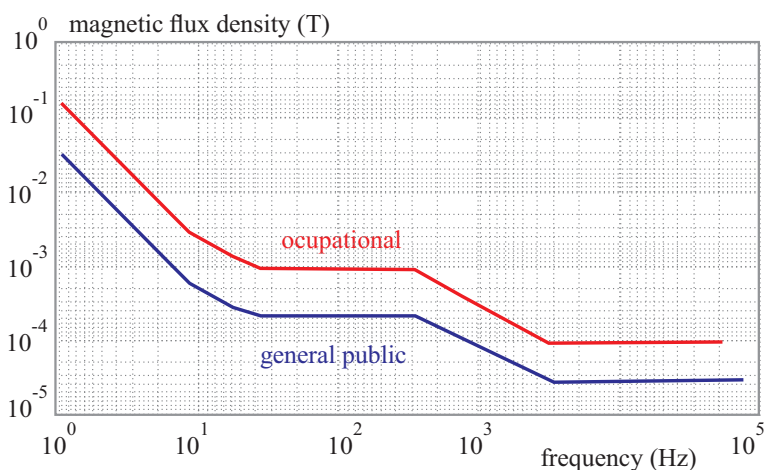
²⁾ according to the coil principle

³⁾ according to the machine type

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Table 2. Sources of EMG and their influence to the organism and organism biochemistry [4 - 13]

Group	Effect	Magnetic flux density (T)	Frequency (Hz)	Notes
Natural fields	Magnetic storm	2.10×10^{-5}	$> 10^{-5}$	Hurbanovo 5/2000
	Earth EMG pulsing	1.00×10^{-7}	0.002-5	-
	Magnetosphere resonance cavity	5.00×10^{-5}	550	-
	Lightings atmosphere distortions	5.00×10^{-5}	< 2000	-
	Natural background (Slovakia)	4.60×10^{-5}	1.00×10^{-5}	-
Cell structures	Isolated cells	1.00×10^{-3}	0-100	Isolated cells
	Nerve stimulation	1.50×10^{-5}	15-25	experiments
Organs	Retina	5.00×10^{-3}	20	-
	Recognition	2.00×10^{-5}	50	$20 \mu\text{T} - 1.26 \text{ mT}$
Functions	Decreased accuracy of numerical exercises	6.00×10^{-4}	50	-
	Cardiovascular system decreasing of cardio arrhythmia	2.00×10^{-5}	60	-
	Immunity system. increasing of oxidation reactions monocytes	2.00×10^{-3}	50-600	-
	Reproduction (gnawers)	3.00×10^{-2}	50	smaller skeleton augment
	CNS changes of hippocampus opioid receptors norepinephrine	1.00×10^{-4}	50	-

**Fig. 1.** The attention should be taken to the highlighted frequency ranges [16]

Epsilon level. It was necessary to adjust the EEG devices for measuring of such ultra-slow brain frequencies. Ankermüller [3] demonstrated the connection between the brain Alfa waves frequency and the Schumann resonance. König demonstrated the correlation between the Schumann resonance and the brain rhythm in 1979. He compared the human EEG with the natural environment EMG and discovered that the Schumann frequency is very close to the Alpha rhythm frequency.

Magnetism is used also as a healing instrument. Magnetotherapy is based on sensitivity of a person to mag-

netic fields. Human exposed to the impact of magnetic fields reacts by the tissue receptors [14]. The reactions of radicals and ion exchange are known, mainly Ca^{2+} , which activates vasodilatation, analgesic, stimulate healing, myorelaxation of the soft tissue and so on. Electrical voltages induced by magnetic fields are lower than the membrane voltage of cells, but presumable are enough to influence the membrane receptors and initiate the biochemical reactions in cells. Magneto mechanical influences are observed in the strong magnetic field intensity, when free radicals arise, activate antioxidation systems and initiate

Table 3. Sources of ELF - different arc welding machines

Welding machine	Position	B(T)			Welding current
		X-axis	Y-axis	Z-axis	
Triodyn (3x400) transformer	1	$8 \times 10^{-6}/50$ Hz $2.6 \times 10^{-6}/150$ Hz	$6.0 \times 10^{-6}/50$ Hz	$1.3 \times 10^{-5}/50$ Hz $2.2 \times 10^{-6}/150$ Hz	70 A
	2	$2.0 \times 10^{-6}/5$ Hz $9 \times 10^{-6}/100$ Hz	$1.0 \times 10^{-6}/5$ Hz $5 \times 10^{-6}/100$ Hz	$9.8 \times 10^{-6}/100$ Hz	
	3	$2.0 \times 10^{-5}/5$ Hz	$1.8 \times 10^{-5}/5$ Hz	$2.7 \times 10^{-5}/5$ Hz	
MIG (CO2 OMI 166)	1	$8.4 \times 10^{-7}/50$ Hz $2 \times 10^{-7}/150$ Hz	$3.4 \times 10^{-7}/50$ Hz $8.0 \times 10^{-8}/150$ Hz	$1.3 \times 10^{-7}/50$ Hz $5.0 \times 10^{-8}/150$ Hz $4.2 \times 10^{-5}/100$ Hz	70 A
	2	$1.0 \times 10^{-5}/10$ Hz $2.4 \times 10^{-5}/100$ Hz	$4.0 \times 10^{-6}/100$ Hz	$1.4 \times 10^{-5}/200$ Hz $0.9 \times 10^{-5}/300$ Hz	
	3	$4.9 \times 10^{-6}/4$ Hz $4.8 \times 10^{-6}/100$ Hz	$2.8 \times 10^{-6}/4$ Hz $2.6 \times 10^{-6}/100$ Hz	$1.0 \times 10^{-6}/4$ Hz $0.7 \times 10^{-6}/100$ Hz	
Invertor (ARC 120)	1	$2.4 \times 10^{-8}/100$ Hz $3.0 \times 10^{-8}/125$ Hz $5.0 \times 10^{-8}/250$ Hz	$9.4 \times 10^{-8}/50$ Hz $5.3 \times 10^{-8}/150$ Hz $2.6 \times 10^{-8}/250$ Hz	$1.0 \times 10^{-7}/50$ Hz $1.2 \times 10^{-7}/125$ Hz $5.2 \times 10^{-8}/150$ Hz	80 A
	2	$8.6 \times 10^{-7}/5$ Hz	$4.4 \times 10^{-7}/5$ Hz $4.0 \times 10^{-8}/50$ Hz	$6.6 \times 10^{-7}/5$ Hz	
	3	$2.2 \times 10^{-7}/5$ Hz $1.0 \times 10^{-7}/50$ Hz	$3.2 \times 10^{-7}/5$ Hz $1.5 \times 10^{-7}/50$ Hz	$1.0 \times 10^{-7}/5$ Hz $0.5 \times 10^{-7}/50$ Hz	

many biochemical reactions. Magnetic fields with low frequency increase the excitability of CNS and decrease the blood flow in larger diameter vessel. The limiting values of the exposure levels are presented on Fig. 1., according to the ICNIRP [15]. Frequency ranges highlighted by the red colour needs further attention.

The ICNIRP handbook does not take into consideration the studies about functionalities based on the changes of chemistry in inner organs, the CNS for example, during individual reactions initialized by ELF. It is mainly the production of free radicals initialized by the ELF. It is a fact that the ICNIRP handbook and other extracts (directive 35/2013/EU) of the WHO (World Health Organisation) studies made a comment in caption about the fact that these documents do not consider the chronic impacts. The magnetic flux density value for range 1 - 8 Hz is too high in comparison to the values in Tab. 2. This would lead to the changes in a health condition. The psychology knowledge describes the effects in range of the Alpha, Beta and Epsilon levels [16, 17]. The studies indicate the effects in the range 1 - 25 Hz, shown at a lower magnetic flux density level than is the limit value for the range 1 - 8 Hz. The ICNIRP dealt with the vector fundamentals of ELF in 2014. The factor dB/dt is used and the effect of speed of its change is taken into account [18]. The directive 2013/35/EU follows the ICNIRP in a large extent. The WHO accepts the ICNIRP in exposition of humans by EMI and non-ionizing radiation. The differences

in the limits prepared by ICNIRP, CENELEC (The European Committee for Electrotechnical Standardization) ENV 50166/95 and ACGH (The American Conference of Governmental Industrial Hygienists) are minor, but do not take into consideration the results in the publications of the WHO.

3 Experiments and results

The measurements were performed on two types or arc welding machines, transformer and MIG (CO₂). The magnetic flux density for each machine was measured in three positions with respect to the welding machine. The first position (1) was measured with a sensor placed on the top of the welding machine while turned on, without welding. The second position (2) was measured with a sensor placed between the connecting wires from the welding machine to the hand grip. The third position (3) was measured 40 cm from the welding point. This distance is equivalent to the distance of a workers head. The measurement was performed by the VEMA 041 magnetometer designed for measurements of the vector stationary and the low-frequency magnetic field. The magnetometer operates with a constant sampling rate of 1 kHz at a sensitivity ≥ 2 nT. The magnetometer allows measuring, recording and analysing of the magnetic field in a time and a frequency domain.

The vector character of the generated magnetic field is apparent from the realized measurements, however the recommendations are given in scalar values that do not respect the rotation (change) of the magnetic field vector in space and time. The knowledge of the magnetic field vector placement and its magnitude allow us to place the worker outside the area with over limit values.

4 Conclusion

The measurements prove that the source of the EMG field is welding arc, not the device itself. The second major source of the EMG can be the connecting cables from the welding machine to the hand grip. These properties should be taken into account during the using of the welding machine. The ICNIRP handbook deals with the vector fundamental of the ELF field, but within the measurement principles still use inadequate tools. The use of the scalar quantity does not allow studying the time and the space displacement of the workstation and the worker position. The dynamics of the magnetic field are not taken into account. The difference can be observed mainly in the magnetic field intensity and the direction with respect to the source and the monitored area. The difference between these two vectors can bring the information about the absolute limiting values and the equivalent dose.

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REFERENCES

[1] P. Chadwick and F. Lowes, "Magnetic fields on British trains", *Ann Occup Hyg.*, 42(5):331-335, (1998).

- [2] M. Oravec *et al.*, "Experimental measurements of low-frequency magnetic fields terms of safety", http://www.mmsscience.eu/content/ile/archives/MM_Science.201640.pdf.
- [3] N. Begich and J. Manning, "Angels Don't Play This Haarp", *Advances Tesla Technology*, ISBN: 0009648812.
- [4] <http://stara.suh.sk/obs/slnsem/15css/prigan1/prigan1.htm>.
- [5] 10.1016/S0006-3495(98)77669-6.
- [6] 10.1201/9781420041569.ch2.
- [7] J. P. Reilly, *Health Phys.*, 83 (3), 341-355.9 (2002).
- [8] Y. Kurokawa *et al.*, "No influence of short-term exposure to 50-Hz magnetic fields on cognitive performance function human", *Int. Arch. Occup. Environ. Health*, 76(6):437-442, (2003).
- [9] A. W. Preece, K. A. Wesnes and G. R. Iwi, "The effect of a 50-Hz magnetic field on cognitive function humans", *Int. J. Radiat. Biol.*, 74(4):463-470, (1998).
- [10] A. Sastre, M. R. Cook and C. Graham, "Nocturnal exposure to intermittent 60 Hz magnetic fields alters human cardiac rhythm", *Bioelectromagnetics*, 19(2):98-106, (1998).
- [11] H. Tuschl *et al.*, "Occupational exposure to static, ELF, VF and VLF magnetic fields and immune parameters", *Int. J. Occup. Med. Environ. Health*, 13(1):39-50, (2000).
- [12] IARC Working Group on the Evaluation of Carcinogenic Risks to Humans, Non-ionizing radiation, Part 1: Static and extremely low-frequency (ELF) electric and magnetic fields. Lyon, IARC, (2002).
- [13] L. Zecca *et al.*, "Biological effects of prolonged exposure to ELF electromagnetic fields rats: III. 50 Hz electromagnetic fields", *Bioelectromagnetics*, 19(1):57-66, (1998).
- [14] <http://www.who.int/peh-emf/publications/elfehc/en/>.
- [15] M. Šostronek and Z. Kus, "Ochrana zdravia pred neionizujúcim žiarením", , Akadémia ozbrojených síl gen.M.R.Štefánika.
- [16] ICNIRP Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields (1Hz -100kHz), *Health Physics* 99(6):818-836, (2010).
- [17] "Neurofeedback EEG alfa a theta rytmov, Teória a prax, Indikácie klinické a neklínické, efektívita a inštrumentácia" PhDr Pavel Krivulka.
- [18] http://dubravaska.sk/wp-content/uploads/2013/11/dizertacna_praca_final_verzia.pdf.
- [19] http://www.icnirp.org/cms/upload/publications/ICNIRP_mvt-gdl.2014.pdf.
- [20] Smernica európskeho parlamentu a rady 2013/35/EÚ o minimálnych zdravotných a bezpečnostných požiadavkách týkajúcich sa vystavq enia pracovníkov rizikám vyplývajúcim z fyzikálnych činností.

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