WORKSHOP HANDBOOK

ELECTROMAGNETICAL FIELDS OF WELDING EQUIPMENT IN THE FRAMEWORK OF THE DIRECTIVE 2004/40/EC

International workshop organized by VITO nv
April 6 2006

PROGRAMME

Chairman
Gilbert Decat, VITO (Belgium)

08:30	**Arrival, registration & coffee**
09:00	**Welcome and VITO in a nutshell** *Roger Dijkmans, VITO (Belgium)*
9:15	**Workshop Introduction** *Gilbert Decat, VITO (Belgium)*
9:20	**EMF-NET in short** *Paolo Ravazanni, CNR (Italy)*
9:30	**Electromagnetic fields: public and workers protection in the European Union** *Georges Herbillon, European Commission*
10:00	**Coffee break - posters - exhibition**
10:30	**Welding Technology: an overview of frequently used welding processes in industry** *Bart Verstraeten, BIL (Belgium)*
11:00	**Limit values and action values of electromagnetic fields'directive related to welders exposure** *Tommi Alanko, FIOH (Finland)*
11:30	**Biological effects of electromagnetic fields related to welding** *Luc Verschaeve, VITO (Belgium)*
12:00	**Standardization of EMF measurements of welding equipment** *Geoff Melton, TWI Ltd (UK)*
12:30	**Lunch – posters – exhibition** *Chairman: Kjell Hanson Mild, NIWL (Sweden)*
13:30	**Electromagnetic fields associated with Arc Welding – examples of measurements for compliance** *Monica Sandström, NIWL (Sweden)*
14:00	**General techniques for numerical calculations for compliance** *Paolo Rossi & Rosaria Falsaperla, ISPESL (Italy)*
14:30	**EMF associated with Spot Welding - examples of measurements and calculations for compliance** *Jolanta Karpowicz & Krzysztof Gryz , CIOP-PIB (Poland)*

15:00	**Coffee break – posters – exhibition**
15:30	**Future EU Directive on Optical Radiation related to welding processes** *Georges Herbillon, European Commission*
16:00	**Laser welding – biological effects and safety aspects** *Agnieszka Wolska, CIOP-PIB (Poland)*
16:30	**Occupational health consideration about welding associated EMF emissions** *Maurits De Ridder , Univ. Ghent (Belgium)*
17:00	**Panel discussion** *Chairs: Kjell Hansson Mild & Gilbert Decat*
17:30	**Workshop close**

LIST OF PARTICIPATION

Decat	Gilbert	Belgium	VITO	gilbert.decat@vito.be	Chair
Hansson Mild	Kjell	Sweden	National Institute for Working Life	mild@niwl.se	Chair
Rossi	Paolo	Italy	National Institute of Occupational Safety and Prevention (ISPESL)-Italy	paolo.rossi@ispesl.it	Speaker
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Gryz	Krzysztof	Poland	Central Institute for Labour Protection	krgry@ciop.pl	Speaker
Karpowicz	Jolanta	Poland	Central Institute for Labour Protection	jokar@ciop.pl	Speaker
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Alanko	Tommi	Finland	Finnish Institute of Occupational Health	tommi.alanko@ttl.fi	Speaker
Sandström	Monica	Sweden	NationalInstitute for Working Life	monica.sandstrom@arbetslivsinstitutet.se	Speaker
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	Jose				
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Van Mieghem	Eric	Belgium	SCK-CEN	evmieghem@sckcen.be	Participant
Cosac	Andreea	Romania	National Institute of Research and development for Electrical Engineering ICPE-CA	andreea_cosac@icpe-ca.ro	Participant
Figueroa Karlström	Eduardo	Sweden	Konsult Firma Vascaia	eduardo.figueroa@chello.se	Participant
Stockbroeckx	Benoit	Belgium	CEO	info@mic6.com	Participant

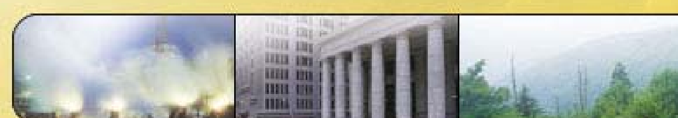
VITO IN A NUTSHELL

Roger Dijkmans
VITO, Belgium

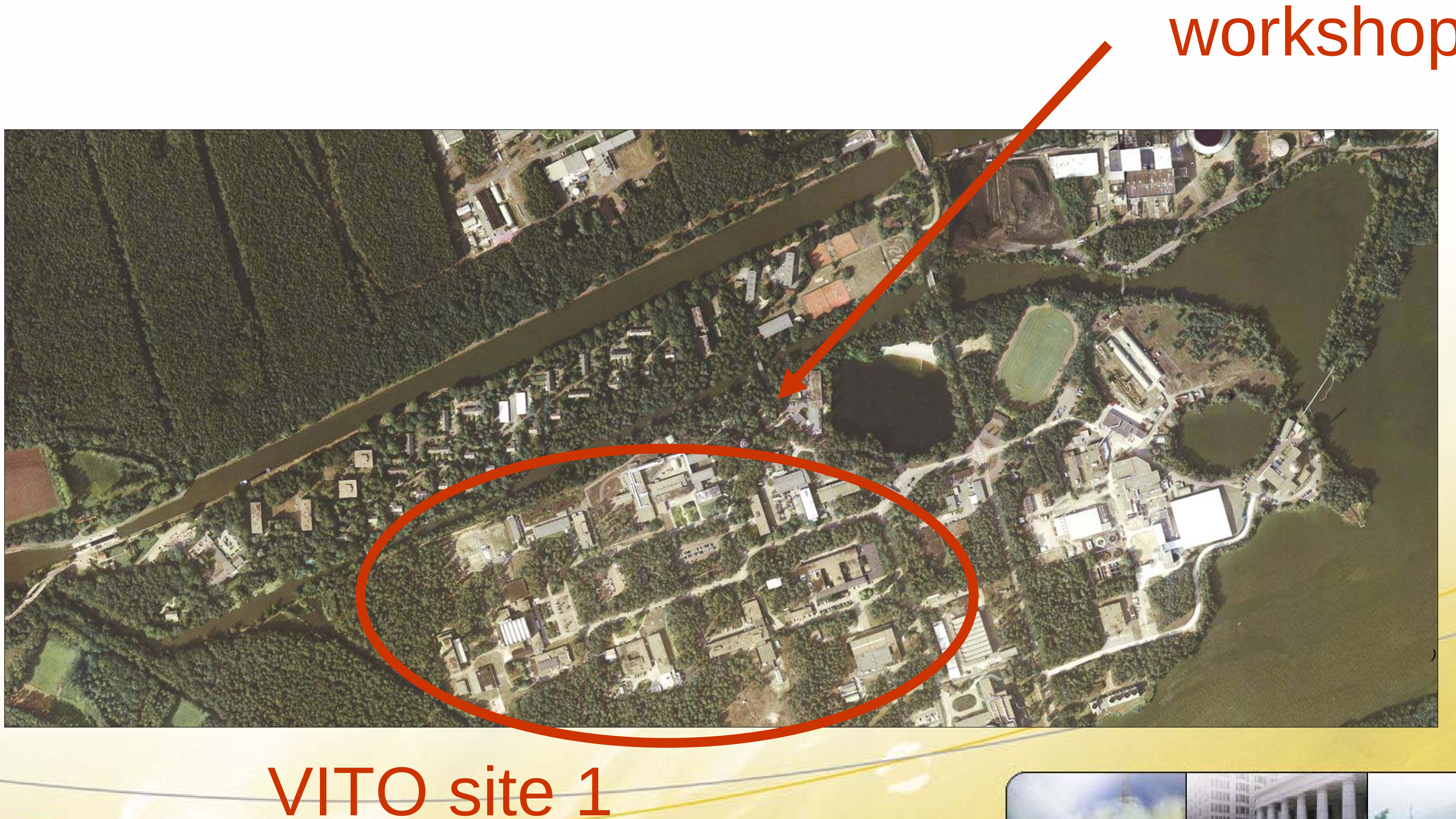
Welcome
VITO in a nutshell

Roger Dijkmans,

April 6, 2006

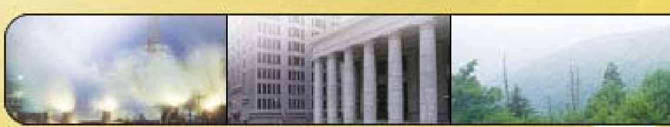


Welcome at VITO



VITO (Flemish institute for technological research)

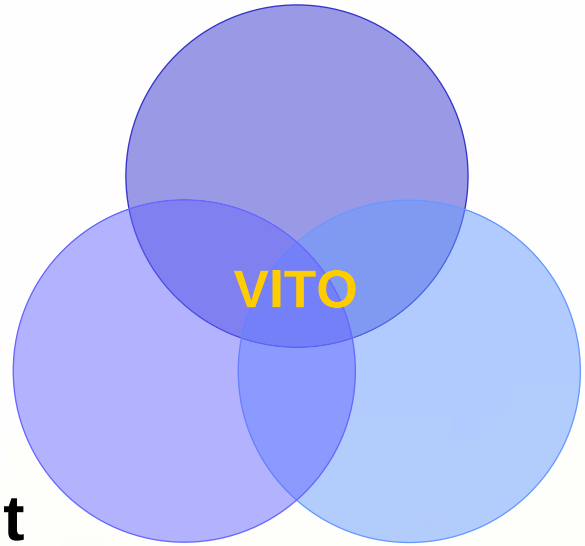
- Established in 1991
- From Belgian Nuclear Research Centre
- Autonomous public research company (Flemish government)



Activities

Scientific world

→ strategic research
→ PhD students
→ diffusion of knowledge

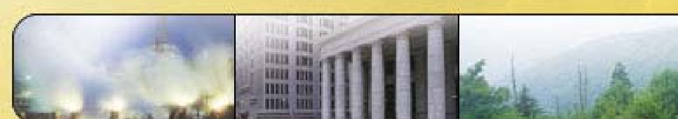


Government

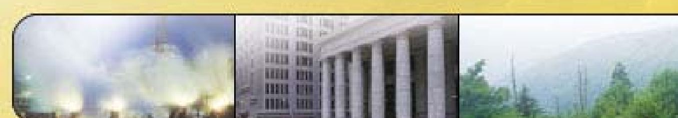
→ policy supporting research
→ contract research
→ reference centres

Industry

→ contract research
→ consultancy
→ technology transfer

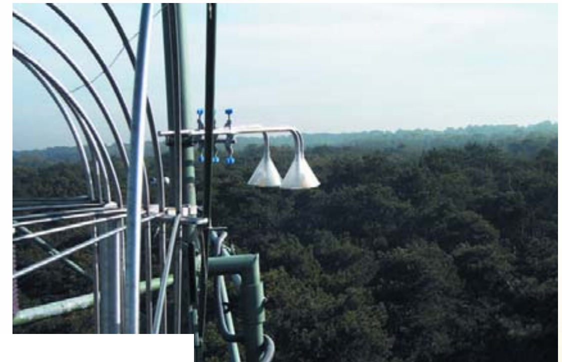


- 460 people – 7 centres of expertise
- Environment: measurements, toxicology, remote sensing, models
- Technology testing/development: environment, energy and materials

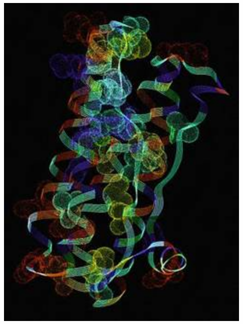


Environmental measurements

- Reference laboratory
- Advanced analytical equipment

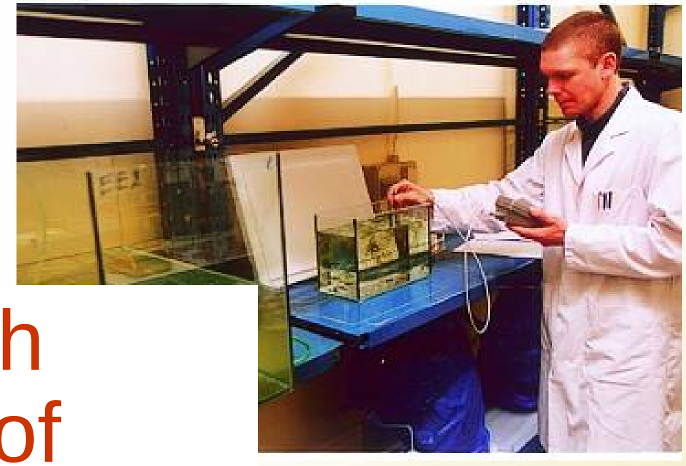


related: measurement
of electromagnetic fields

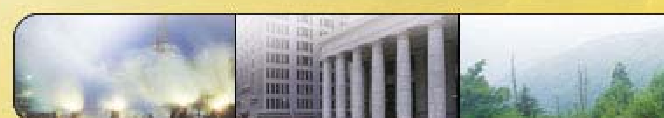


Environmental toxicology

Environment and health

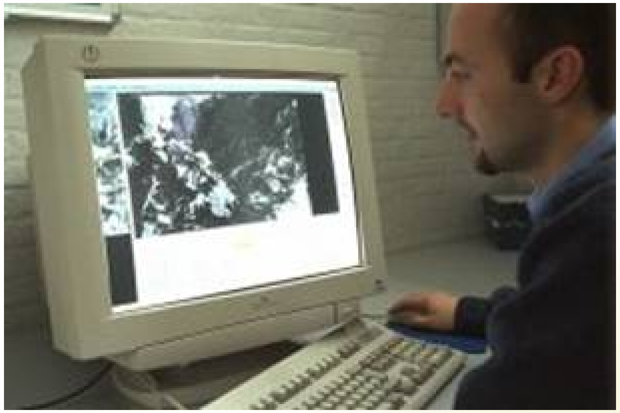


related: health assessment of electromagnetic fields



Remote sensing

Remote sensing and image processing



Environmental models: center for integrated envronmental studies

sustainable development

Questions policy makers

Public agencies industry

Evaluation models

Include electromagnetic fields

Environmental data (measurements, surveys, industry experts, literature, …)

Expertise in environmental sciences, industrial processes, economics

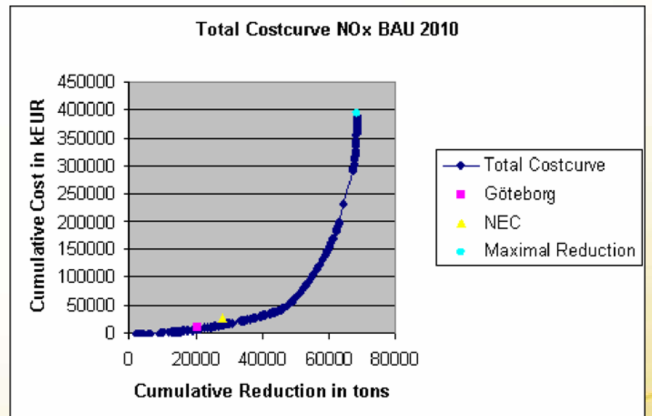
Models: integrated environmental studies

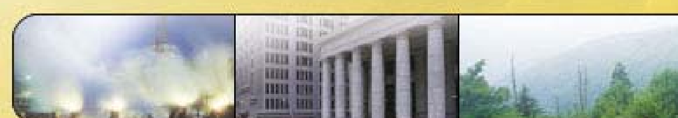
- Product and technology studies
- BAT and EMIS
- Risk evaluation and environmental damage costs
- Emission reduction strategies
- Water and soil pollution
- Electromagnetic environmental pollution
- Atmospheric processes

Emis

www.emis.vito.be

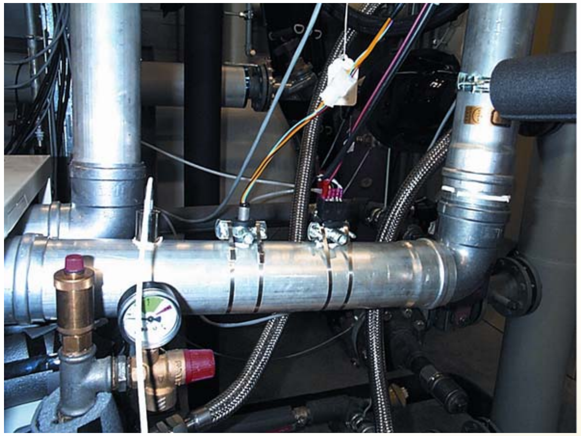
HET ENERGIE EN MILIEU INFORMATIESYSTEEM VOOR HET VLAAMSE GEWEST

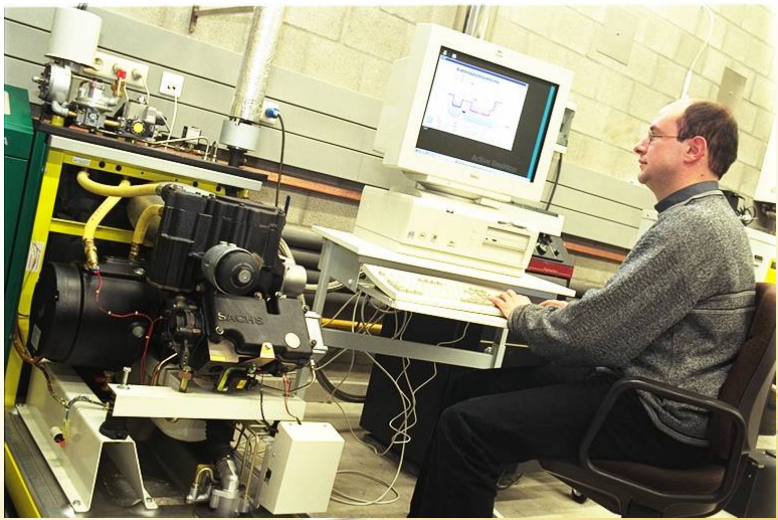




Energy technology

sustainable energy technologies



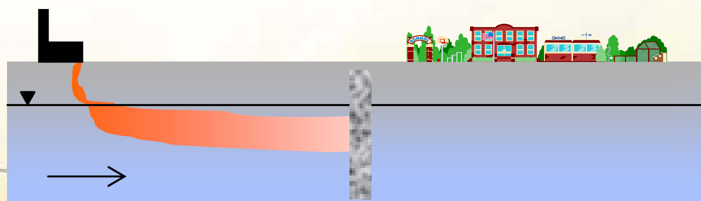


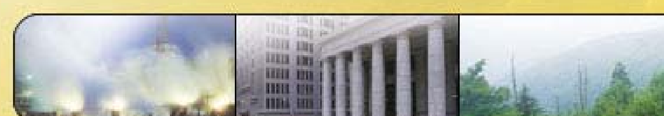
Environmental and process technology

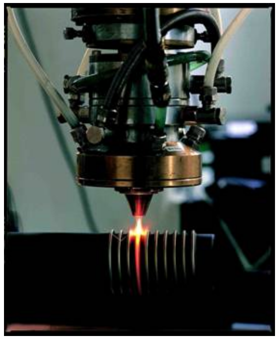
- water / soil / waste /
  air /

- end-of-pipe / in process

- special SME program



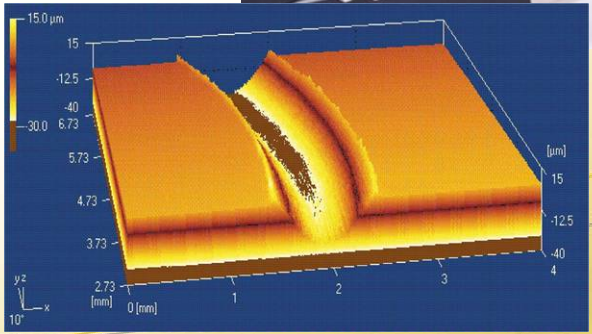


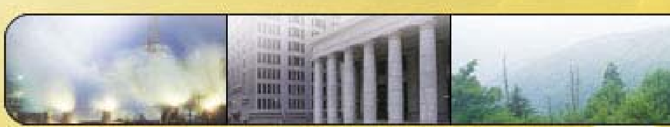


Material technology

- Plasmatechnology
- Ceramic materials and powder metallurgy
- …
- Laser Centre Flanders

Include technical support laser welding





Ear implant

Question:

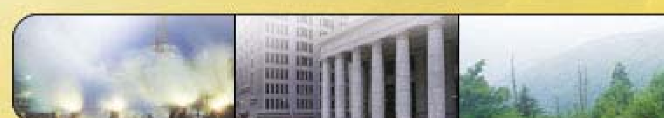
- The client develops ear implants of all kinds.
- To develop the technology to weld together the different parts of the implant.

Offered solution:

- Pulsed Nd-YAG lasers were used to weld parts of which some only 50µm in thickness.
- Tests were done to determine the optimized welding parameters and input was given for the weld design.
- A method to test the density of the connections was also developped
- Prototypes were welded for validation.

VITO - electromagnetic fields - welding

- 460 people – 7 centres of expertise
- Environment: **measurements**, **toxicology**, remote sensing, **models**)
- Technology testing/development : environment, energy and **materials**



WELCOME – WORKSHOP

Gilbert Decat- workshop Organizer
VITO – Belgium

On behalf of the EMF-NET /MT-2 WORKEN team we are pleased to welcome you to VITO (www.vito.be) for the first international workshop on Electromagnetic Fields (EMF) of Welding Equipment in the framework of the Directive 2004/40/EC.

The forum of the invited EMF experts will lead us to exchange ideas and experience about the new European Directives, the exposure assessment, the dosimetry, and the safety aspects of electrical and laser welding.

On the 29th of April 2004 the European Parliament/Council launched the Directive 2004/40/EC on the minimum health and safety requirements regarding the exposure of workers to the risks arising from Electromagnetic Fields (EMF's). Since the Member States must transpose the provisions of the directive into a national legislation within 4 years, occupational decision makers are often asking which EMF sources the directive provisions could be problematic for? While standardization bodies like CENELEC (www.cenelec.org) are dealing with the details of the protocols of exposure assessment, dosimetry calculations and risk aspects the MT-2 WORKEN activities are mainly focused on offering scientific support to decision makers who are dealing with these issues. Because electrical welding produces strong EMF's from which the assessment of the exposure, the dose and the risk is associated with many gaps and uncertainties, MT-2 WORKEN is challenging this topic as a model for other complex occupational EMF sources.
Though the lectures of the workshop cover mainly electrical welding, some speakers will give an overview on the very new European Directive on optical radiation (publication is expected end April or early May) and the safety aspects of laser welding, too. In this respect it is interesting to notice that the applications of laser welding are steady expanding and that VITO (www.vito.be) is responsible for the 'Laser centre Flanders (www.lcv.be)'.
The workshop is organized in the framework of the Coordination Action EMF-NET (www.jrc.cec.eu.int/emf-net/) "Effect of the Exposure to Electromagnetic Fields: from Science to Public Health and Safer Workplace" (European Commission FP6 Coordination Action, Thematic Priority 8, Policy support and anticipating scientific and technological needs, Contract N° SSPE-CT-2004-502173, 2004-2008).

Enjoy the workshop.

Contact:

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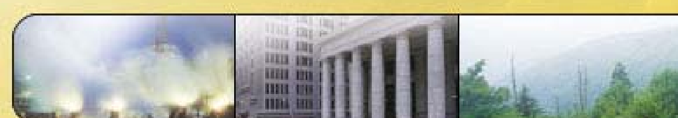
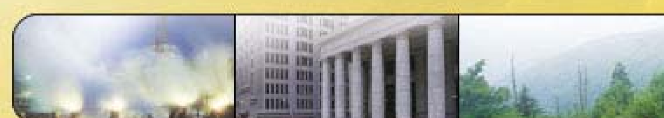
Workshop Introduction

Gilbert Decat,

(gilbert;decat@vito.be)



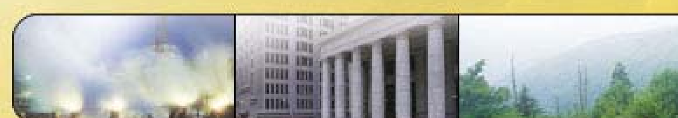
We have an excellent panel of experts who will give us the opportunity to discuss the complexity of the exposure, dosimetry and risks of EMF related to welding and perhaps to other sources



- **Dr Paolo Ravazzani is excused**

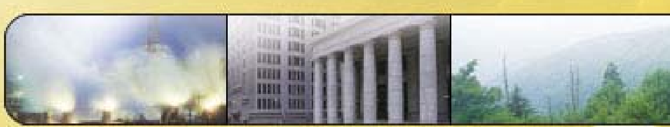
- **Exhibition and poster session**

- **Optional visit to the “Flanders Laser Centre” after the workshop.**



The workshop is organized under the umbrella of

ENJOY it



EMF NET IN SHORT

Paolo Ravazinni
CNR, Italy

EC EMF-NET Coordination Action

Activities and main issues

Paolo Ravazanni

Electromagnetic Fields of Welding
Equipment in the framework of the
Directive 2004/ 40/ EC

April 6, 2006
Vito Mol

EMF-NET is a Coordination Action that aims to coordinate the results of the research activities related to the biological effects of electromagnetic fields.
It considers also the potential risks related to exposure in the working environment.
The consortium involves 41 participants.

- EMF-NET HOME PAGE: http://www.jrc.cec.eu.int/emf-net/

Workplan

- MT1: Scientifi
  on EMF health
  - Laboratory
    applications
  - Epidemiolog
- MT3: Improve
  research on E
- MT4: Risk per
- MT5: Observa
  - Monitoring
  - Monitoring
  - Coordinatio

Main Task	*Main Task Coordinators*
MT1	**Jukka Juutilainen** **Joschen Buschmann**
	Elisabeth Cardis **Maria Feychting**
MT2	**Jolanta Karpowicz**
MT3	**Theo Samaras**
MT4	**Demosthenes Papamelethiou**
MT5	**Norbert Leitgeb**
	Bernard Veyret
	Gyorgy Thuroczy

Recent Interpretation Reports

- Report on research needs AUG 2005
- Report on ELF laboratory JAN 2006
- Report on RF and cancer-related projects NOV 2005
- Report on IF effects JAN 2006
- Report on use of EMF in clinical practice (expected by APR 2006)
- Survey on THz exposure at occupational site (expected by APR 2006)
- Report on EMF Hypersensitivity (expected by APR 2006)
- Report on genotoxicity end EMF (expected by APR 2006)
- Report on EMF and health lesson learned (expected by APR 2006)
- Report on medical implants and workers (expected by MAY 2006)

Other Outputs

- Organization/co-organization of workshops/events
- Collaboration with EC Services
- Books and Special Issues
- Info on the activities of European Projects
- EMF-NET Website: **http://emf-net.isib.cnr.it**
- Newsletters

ELECTROMAGNETIC FIELDS:
PUBLIC AND WORKERS PROTECTION IN THE EUROPEAN UNION

Georges Herbillon
European Commission

Protection of the public

On 12 July 1999, the Council adopted a Recommendation (1999/519/EEC[1]) limiting the exposure of the general public to electromagnetic fields in a view of protecting human health against well-known acute health effects. This was decided following a European Parliament resolution of 1994, which called the Commission to propose legislative measures to reduce the exposure of workers and public to electromagnetic fields (EMF). The adoption of a more binding legal act such as a directive was not possible for the general public due to the limitations fixed in article 152 of the Treaty. Nevertheless, it is worth noting that the Amsterdam Treaty in 1999 expanded the scope of EU activities in public health. Due to the fact that *"A high level of human health protection shall be ensured in all Commission policies and activities"*, there is a possibility in the future to use this statement to achieve a certain harmonisation through the binding "product legislation".

The Recommendation of 1999 was adopted after endorsement of a scientific steering committee composed of independent, highly qualified experts. The Recommendation covers all the range of frequencies till 300 GHz; this means that it's technology neutral and applies for all devices emitting electromagnetic fields. The annexes of the Recommendation specify some "exposure limits": *basic restrictions* that are based directly on established health effects and which should not be exceeded; *reference levels* which are expressed in more directly measurable variables than the *basic restrictions*. These *reference levels* are provided for practical assessment purposes and compliance with them will always ensure compliance with the relevant *basic restrictions*. This exposure limitation system derives from the ICNIRP[2] guidelines and is based on established health effects. It also takes into account a precautionary approach to long-term possible carcinogenic effects by the introduction of safety margins in the exposure.

As the name says, Recommendation 1999/519/EEC is not a binding document. However, Member States are strongly encouraged to take its provisions into account and many of them have already done so. It is the basis of a sound protection system based on directly established health effects. It also promotes further research and appropriate dissemination of information.

Occupational exposure: protection of the workers

For workers, the situation developed differently: Article 137 of the EU Treaty provides for a much stronger legal framework and enables the Commission to develop proposals for directives i.e. for *binding European legislation* related to health and safety at work.

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[1] O.J. L199 of 30.7.1999, p.59
[2] International Commission for Non Ionizing Radiation Protection

In 1992 already, within the framework established by the Single Act of 1987 and encouraged by the European Parliament, the Commission tabled a first proposal covering different physical agents: vibrations, noise, electromagnetic fields and optical radiation. A slightly amended proposal was published in 1994 after the first reading in the European Parliament. Subsequently, the discussions of the proposal only started in the Council in 1999, after the decision had been taken to split the proposal into four parts and to discuss each component separately. This boosted the process and a first directive was adopted by the Council and the Parliament in 2002 on "vibrations" and a second one in 2003 on "noise" at work. The discussions on the third component "EMF" started in 2002 and a related binding directive (2004/40/EC)[3] was adopted on 29 of April 2004.

What is the philosophy of the EMF directive (2004/40/EC)?

In a nutshell we can say that the EMF directive is "prevention" oriented and is built upon the same principles as the so-called *framework directive* 89/391/EC[4] *on the introduction of measures to encourage improvements in the safety and health of workers at work*. The principles laid down there can be summarized as follows: in his enterprise the employer is responsible for the health and safety of the workers working for him directly or under a subcontracting agreement. He is responsible for the determination and assessment of risks; he must put in place provisions aiming at avoiding or reducing the risks, giving priority to collective protective measures before personal ones. He must also ensure appropriate and timely information and training of workers, foresee consultation and participation of them, and guarantee appropriate health surveillance in line with the national rules and practices.

The EMF directive explains, in some details for the specific case of occupational exposure to electromagnetic fields (introducing exposure limits etc.), the obligations of the employers which were already made compulsory in the *framework directive*. Article 12 also imposes on the Member States that the provisions of the directive, considered as minimal requirements against occupational risks due to exposure to electromagnetic fields, be transposed in national legislation within 4 years. The provisions of the EMF directive shall thus be "operational" by 30 April 2008.

What does directive 2004/40/EC actually cover?

This directive covers the same frequency range as the recommendation for the public referred to above (up to 300 GHz) and introduces binding *Exposure Limit Values* (ELVs) but also *Action Values*, i.e. values the magnitude of which is directly measurable and above which the employers are obliged to implement measures as specified in the directive. Moreover, compliance with the *Action Values* will ensure compliance with the relevant exposure limit values. Exceeding the *Action Values* is not forbidden but obliges the employer to apply one or more provisions laid down in the directive. In practice, the employer will be obliged to remeasure or recalculate the actual ELVs and reassess the working conditions in order to ensure that the relevant *Exposure Limit Values* are not exceeded.

Long term effects have been excluded from the scope of the directive because it was considered at the time that there was not sufficient consistent scientific evidence. For

[3] O.J. L184 of 24.5.2004, p.1
[4] O.J. L183 of 29.6.1989, p.1

the same reason no *Exposure Limit Value* was set for static magnetic fields. Only an *Action Value* has been fixed which should act as an alarm bell indicating to the employer that the working conditions for the staff need to be carefully established and regularly reviewed (cognitive deficits may be observed).

On the other hand*, the provisions of the directives apply to all sectors* without exception!

It is worth noting that the measurement or calculation of workers' exposure to electromagnetic fields is difficult in many situations. This has been recognized by the Council and the European Parliament in the text of the directive itself (Article 3, paragraph 3). In line with this provision, the Commission has therefore asked the relevant European Standard Organisation CENELEC to develop a standard specifically dedicated to that issue. This standard should be available by 30 April 2008.

Moreover, subsequently to several requests from Member States and Members of the European Parliament, the European Commission is currently preparing a non binding "good practice" guide at the intention of the employers and other interested parties in order to facilitate the interpretation and the implementation of the provisions of the EMF directive and its technical annex.

Contact:

European Commission,
DG Employment, Social Affairs and Equal Opportunitie,
Unit Health, Safety and Hygiene at Work
EUFO 2177
L-2920 Luxembourg.

georges.herbillon@cec.eu.int

Electromagnetic Fields:

Public and Workers Protection in the European Union

Georges HERBILLON
European Commission (DG EMPL/D4)

Electromagnetic Fields:

EMF Protection in the EU

Public: *Council Recommendation* (1999)

(non binding)

&

Workers: *Council Directive* 2004/40/EC

(binding)

Council Recommendation 1999/519/EC of 12 July 1999

- **Legal Basis :<u>Article 152 of Amsterdam Treaty</u> :**
  - ***"A high level of human health protection shall be ensured in the definition and implementation of all Community policies and activities"***
  - **<u>But limits through:</u>**

    "... excluding any harmonization of the laws and regulations of the Member States".

Council Recommendation 1999/519/EC of 12th July

- Adoption in 1999 after endorsement of the ICNIRP guidelines by the Scientific Steering Committee of the Commission in 1998
- covers O Hz to 300 GHz
- applies to the general public

  (not workers)
- provides minimum requirements for protection

Council Recommendation 1999/519/EC of 12th July

Technical annexes:

- Minimum requirements for protection are made of a series of maximum exposure levels (basic restrictions & reference levels)
- limits are based on established health effects + safety factor
- Precautionary approach
- Subsidiarity & proportionality principles
- Based on scientific opinions

Member States Responsibilities
(1/2)

- Member States to adopt basic restrictions and reference levels used in the technical annexes but are free to adopt more restrictive regulations

  But if so, they should consider a risk/benefit analysis

Member States Responsibilities
(2/2)

- Member States must report to the Commission on implementation progress after a period of three years following the adoption of the Recommendation

- Member States should promote:
  - the dissemination of information and rules of practice in this field to obtain recommended levels of exposure
  - relevant research in the context of their national research programs

Health & Safety at Work

Directive 2004/40/EC of the European Parliament and of the Council of 29 April 2004 on the minimum H & S requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields)

Published in OJ L 184 of 24 May 2004 (corrected version)

- Workplaces
- Work Equipment, Scaffolding
- Personal Protective Equipment
- Display Screen Equipment
- Safety Signs

- Carcinogens
- Biological Agents
- Chemical Agents
- <u>Physical Agents</u>:
  - Noise (2003/10/EC)
  - Vibrations (2002/44/EC)
  - EMF(2004/40/EC)
  - *Optical Radiation (2006)*
- Manual Handling of Loads
- Asbestos

- Pregnant Women
- Young People

- Construction Sites
- Mineral-extracting Industries
- Drilling in Mineral-extracting Industries
- Fishing Vessels
- Explosive Atmospheres

Framework Directive 89/391/EEC

to encourage improvements in health and safety at work

Health & Safety at Work

General philosophy of the EU legislation

“Framework” directive 89/391/EEC

- ***Scope (+responsibility of employers)***
- ***Identification & assessment of (all) risks***
- ***Elimination or reduction of risks***
- ***Priority for collective measures, otherwise use personal protective measures/equipment***
- ***Training and information of workers***
- ***Consultation of workers***
- ***Appropriate medical surveillance***

Health & Safety at Work

Some historical background...

- ***Draft Proposal adopted by the Commission on 23 December 1992 [COM(92) 560 final], included 4 physical agents: Noise, Vibrations, EMF and Optical radiation***

- ***Amended proposal after the opinion of the E.P. on 20 April 1994 was published on 19 August 1994***

Health & Safety at Work

- ***Discussions started at Council level in 1999 during German Presidency. Initial proposal was split in 4 directives.***

- ***Two first directives “Vibrations” and “Noise” were adopted by the E.P. and the Council in 2002 and 2003.***

Health & Safety at Work

- *The Danish Presidency and the Commission services (EMPL D/4) organised a Seminar in September 2002 to update knowledge on EMF.*
- *Discussions started in the Social Questions Working Party level (Council)*
- *Political agreement was adopted by the Employment, Social Policy, Health and Consumer Affairs Council the 20th October 2003*
- *Formal adoption on 29 April 2004*

EMF Directive
General Provisions :

- ***<u>Article 1</u>: “Aim and Scope”***
  - ***Risks from exposure to electromagnetic fields - EMF (0 Hz to 300 GHz)***
  - ***Risks due to known short-term adverse effects in the human body***
  - ***It does not address the long-term effects***
  - ***It does not address the risks resulting from contact with live conductors***
  - ***Directive 89/391/EEC fully applies***

EMF Directive
General Provisions :

- ***Article 2*: "Definitions"**
  - ***Electromagnetic fields*:** *static magnetic and time-varying electric, magnetic and electromagnetic fields with frequencies up to 300 GHz*
  - ***Exposure Limit Values*:** *limits on exposure to EMF which are based directly on established health effects and biological considerations.*
  - ***Action Values*:** *the magnitude of directly measurable parameters at which one or more of the specified measures in this Directive must be undertaken. Compliance with these values will ensure compliance with the relevant exposure limit values.*

EMF Directive
General Provisions :

- ***<u>Article 3</u>: "Exposure limit values and action values"***
  - *"For the assessment, measurement and/or calculation of workers' exposure to EMF, until harmonised European standards from the CENELEC cover all relevant assessment, measurement and calculation situations, Member States may employ other scientifically-based standards or guidelines".*

EMF Directive
Obligations of Employers :

- ***Article 4*: "Determination of exposure and assessment of risks"** *(1/3)*
  - ***The employer shall assess and, if necessary measure and calculate the level of EMF to which workers are exposed***
  - ***On the basis of the assessment, if the Action Values are exceeded, the employer shall assess and calculate whether the exposure Limit Values are exceeded***

EMF Directive
Obligations of Employers :

- ***Article 4*: "Determination of exposure and assessment of risks"** ***(2/3)***
  - *The assessment, measurement and calculations may not be carried out in workplaces open to the public provided that an evaluation has been undertaken in accordance with 1999/519/EC Council Recommendation*
  - ***The assessment, measurement and calculations shall be planned and carried out at suitable intervals. Data shall be preserved***

EMF Directive
Obligations of Employers :

- ***<u>Article 4</u>: "Determination of exposure and assessment of risks"* (3/3)**
  - ***The employer shall give particular attention to:***
    - ✓ The level, frequency spectrum, duration and type of exposure
    - ✓ The Exposure Limit Values and Action Values
    - ✓ Any effects concerning the health and safety of workers
    - ✓ Any indirect effects such as: interference with medical electronic devices; projectile ferromagnetic objects in static magnetic fields; initiation of electro-explosive devices; ignition of flammable material by sparks caused by induced fields and/or contact currents or spark discharges
    - ✓ The existence of replacement equipment to reduce the levels of exposure
    - ✓ Appropriate information obtained from health surveillance
    - ✓ Multiple sources of exposure, and simultaneous exposure to multiple frequency fields

EMF Directive
Obligations of Employers :

- ***<u>Article 5</u>*: *"Provisions aimed at avoiding or reducing risks"*** *(1/2)*

  - *The risk shall be controlled at the source, eliminated or reduced to a minimum*

  - *If the <u>Action Values</u> are exceeded and unless it is demonstrated that the <u>Exposure Limit Values</u> are not exceeded, the employer shall devise and implement an action plan to prevent exposure exceeding the Limit Values, taking into account:*

EMF Directive

Obligations of Employers :

- ***Article 5*: "Provisions aimed at avoiding or reducing risks"** *(2/2)*

  - ✓ *Other working methods that entail less exposure*
  - ✓ *The choice of equipment emitting less EMF*
  - ✓ *Technical measures to reduce the emission including the use of interlocks*
  - ✓ *Appropriate maintenance programmes*
  - ✓ *The design and layout of workplaces*
  - ✓ *Limitation of the duration and intensity of the exposure*
  - ✓ *The availability of adequate PPE (personal protective equipment)*

EMF Directive
Obligations of Employers :

- ***<u>Article 6</u>: "Workers' information and training"***

  - ***The employer shall ensure that workers who are exposed to EMF receive any necessary information and training***

EMF Directive
Obligations of Employers :

- ***Article 7**: “Consultation and participation of workers”*

To be done:

In accordance with Article 11 of Directive 89/391/EEC (framework directive)

EMF Directive
Miscellaneous Provisions :

***Article 8**: "Health surveillance"*

Appropriate health surveillance shall be carried out according to Articles 14 and 15 of Directive 89/391/EEC (framework directive)

***Article 9:** "Sanctions"*

must be effective, proportionate and dissuasive

EMF Directive
Miscellaneous Provisions :

Article 10: "Technical amendments"

- *Modifications of exposure Limit Values and Action Values to be done in accordance with* Article *137(2) of the EU Treaty*
- *Amendments to the Annex of a strictly technical nature, can be done in accordance with procedure in Article 11 of the Directive*

Article 11: "Committee"

- *The Commission shall be assisted by the Committee referred to In Article 17 of the Directive 89/391/EEC (framework directive)*

EMF Directive
Final Provisions :

- ***<u>Article 12</u>*: "Reports"**

  By Member States, every five years
  The Commission to report to Council and EP
  Special attention as regards exposure to static magnetic fields

- ***<u>Article 13</u>*: "Transposition"**

  Not later than 4 years after the entry into force

  (30 April 2008)

EMF Directive
Annex of the directive:

1) ***Exposure Limit Values :***

Table 1 : all conditions to be satisfied

2) Exposure Action Values:

Table 2: Compliance with these values will ensure compliance to exposure Limit Values

EMF Directive
for occupational exposure

Thank you
for
your attention

Bedankt voor
uw aandacht

WELDING TECHNOLOGY :
AN OVERVIEW OF FREQUENTLY USED WELDING PROCESSES IN INDUSTRY

Bart Verstraeten
BIL – Belgium

Introduction

Welding is an industrial process with a big economical relevance. In Belgium there are 27000 welders and the selling of welding consumables and welding equipment is good for over 90000 k€. Yet welding has a certain duality. It's seen as an attractive and dynamic process but also as unhealthy and a 'dirty job'. This is one of the reasons why good welders are difficult to find. Creating a better welding environment and making welding healthier, can only be seen as a step in the good direction. Welding as a process is used in almost every construction, household equipment, process installation … and in almost every industrial sector. When we talk about welding processes we must realize that there are about 100 different welding processes. A brief introduction in the most used welding processes in industry can therefore be useful in the context of a seminar about the health risks involved with EMF during welding.

Welding

Welding is uniting material in the welding zone, with heat and/or pressure, with or without filler metal, the heat or energy required is supplied from outside sources.
The most used 'outside sources' are electrical machines. They supply the necessary heat through an electrical arc (arc welding) or through an electrical current (resistance welding).

Arc welding processes

The majority of welding in industry is done with arc welding processes. The base for this is an electrical arc between an electrode and a work piece. The energy necessary for this electrical arc is supplied by a power source. This power source will transform the primary power, with a high voltage to a secondary power with a low voltage, but with the possibility to provide a high current. Depending on the welding process the supplied secondary welding current will be AC or DC.

The most used arc welding process is MIG/MAG welding or Gas Metal Arc Welding. With this process the arc is established between a continuously fed solid wire consumable electrode and the work piece. The molten pool or weld bead must be protected against the air for metallurgical reasons and is realized by a shielding gas. The current type is DC or pulsed DC or DC with a special waveform, the upper limit of the current is 500 A. Recently AC MIG welding was invented, but this process is still very rare in industry. Applications are e.g. general construction, automotive industry, ship building…

Another arc welding process that is used a lot in industry is Shielded Metal Arc Welding or manual metal arc welding. The arc is established between a consumable covered electrode and a work piece. The molten pool or weld bead is protected against the air by gasses from the covering of the electrode. The current type can be AC or DC and can raise up to 360 A. Applications are e.g. general construction, repair welding, field welds…

A third much used arc welding process is TIG welding. The electrical arc is established between a non-consumable electrode and the work piece. The protection of the weld bead against the negative influence of the air is done by an inert gas. The current type can be AC, DC or pulsed DC, with a maximum current up to 400 A. Applications are e.g. also general construction but the process is used where 'precision' or high quality welds are needed.

Another arc welding process that is used a lot in industry is Submerged Arc Welding (SAW). This is an automated process, where the arc is established between a continuously fed wire electrode and the work piece. The difference with MIG/MAG welding is the fact that the protection of the weld bead against the air is done by a powder covering around the arc. The current type is AC or DC and can be up to 1000 A. Applications are mainly heavy constructions.

Resistance welding processes

The most important resistance welding process is spot welding. Spot welding is based on a (very) high current which runs through two or more plates pressed between two copper electrodes. The heat is generated by the Joule effect (Heat = $R.I^2.t$). The most used type of current is AC, 50 Hz, but recent developments brought 1000 Hz DC machines on the market. The current can be very high; (ten) thousands of amperes are not an exception. The welding time on the other hand is usually very short (< 1 sec). Applications are there e.g. in the automotive industries, steel furniture, household devices…

This is only a very brief overview of the most used welding processes in industry, but it gives an idea about the process fundamentals and the type of current used for this processes, which is of course important in relation to EMF.

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LIMIT VALUES AND ACTION VALUES OF ELECTROMAGNETIC FIELDS' DIRECTIVE RELATED TO WELDERS EXPOSURE

Tommi Alanko
FIOH – Finland

The EU directive 2004/40/EC gives the minimum health and safety requirements regarding the exposure of workers to the risks arising from electromagnetic fields [1]. The directive refers to the risk to the health and safety of workers due to known short-term adverse effects in the human body.

These effects can be caused by the circulation of induced currents and by energy absorption as well as by contact currents. Proposed long-term effects or risks resulting from contact with live conductors are not addressed in the directive. The exposure limit values and the action values are based on the guidelines on limiting exposure to non-ionising radiation by the International Commission on Non-Ionising Radiation Protection (ICNIRP) [2].

The directive obligates the employer to assess and, if necessary, measure or calculate the levels of electromagnetic fields to which workers are exposed. The assessment or calculations need not be carried out if the assessment for the exposure of the general public to electromagnetic fields has been done according to the Council Recommendation 1999/519/EC [3] and the restrictions as specified therein are respected for workers and safety risks are excluded. The assessments, measurements and calculations must be planned and carried out by competent persons at suitable intervals. The data from the assessments, measurements and calculations have to be stored in suitable form for future reference. The legislation of the EU member states should comply with the directive no later than 30 April 2008.

Two classes of limits are given by the directive, called *exposure limit values* and *action values*. The quantity used to specify the exposure limit values at frequency range relevant to welding is current density and in some cases, at higher frequencies (> 100 kHz), specific absorption rate (SAR).

Exposure limit values are based directly on established health effects and biological considerations. The workers must not be exposed above exposure limit values in any situation. Workers exposed to electromagnetic fields are protected from all known adverse health effects when the limit values are followed. The exposure limit values at frequency ranges related to welders exposure are presented in Table 1.

Table 1. Exposure limit values at frequency ranges related to welders exposure

Frequency range	Current density vor 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)
Up to 1 Hz	40	-	-	-
1 – 4 Hz	40/f	-	-	-
4 – 1000 Hz	10	-	-	-
1000 Hz – 100 KHz	f/100	-	-	-
100 KHz – 10 MHz	f/100	0.4	10	20

At frequencies up to 1 Hz the exposure limit values are provided for current density to prevent effects on the cardiovascular and central nervous system. Between 1 Hz and 10 MHz current density limits are set to prevent effects on the central nervous system functions. From 100 kHz upwards the exposure limit values on SAR are provided to prevent the whole body stress and excessive localised heating of tissue. The current density limit values are intended to protect against acute effects on central nervous system tissues in the head and trunk of the body so the measurements are not averaged over time. However, all SAR values are to be averaged over any six-minute period.

The action values are provided for comparison with measured values of physical quantities. In general, compliance with action values ensures compliance with the exposure limit values. If the measured values are higher than action values, it does not necessarily follow that the exposure limit values are exceeded, but more detailed analysis is required to ensure compliance. The directly measurable physical quantities used to specify the exposure limit values at frequency range relevant to welding are electric field strength (E), magnetic field strength (H) and magnetic flux density (B). The action values at frequency ranges related to welders exposure are presented in Table 2.

Table 2. Action values at frequency ranges related to welders exposure (unperturbed rms values)

Frequency range	Electric field Strenght E (V/m)	Magnetic field Strenght H (A/m)	Magnetic Flux density B (µT)	Contact current, I_c (mA)
0 – 1 Hz	-	1.63×10^5	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	0.4f
65 – 100 KHz	610	1600/f	2000/f	0.4f
0.1 – 1MHz	610	1.6/f	2/f	40

f *is the frequency in the units indicated in the frequency range column.*

For the frequencies up to 100 kHz the peak action values is obtained by multiplying the rms values by 2½. For pulses of duration t the equivalent frequency to apply for the action values (and exposure
limit values) is f = 1/(2×t). For complicated pulses compliance with guidelines must be confirmed with more demanding methods [4]. For frequencies over 100 kHz the measured quantities are to be averaged over any six-minute period.

[1] DIRECTIVE 2004/40/EC of The European Parliament and of the Council on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields), 2004.
[2] 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 74(4):494-522, 1998.
[3] Council of European Union. Council Recommendation on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz). (1999/519/EC). Off J Eur Commun, L199, 59-70.
[4] 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 84(3):383-387, 2003.

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Limit values and action values of electromagnetic fields directive related welders exposure

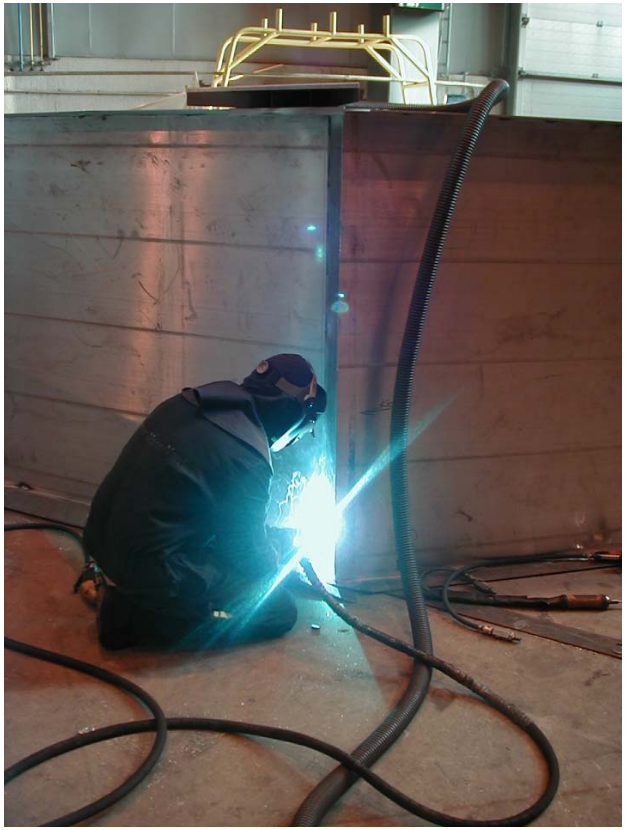
EMF-NET/EMF-WORKEN Workshop on:

Electromagnetic fields of welding in the framework of the Directive 2004/40/EC

Tommi Alanko, PhD

Contents

- What are electromagnetic fields?
- ELF field interaction
- Directive – Aim & scope
- Exposure limit values and action values
  - values
  - determination
  - multiple frequency fields



Electric field

- Electric fields are associated with voltage (V)
- Electric field strength (E) is expressed in the unit of volts per meter (V/m)
- Example: 240V generator connected to parallel metal plates separated by a distance of 1 m=> E = 240 V/m

Magnetic fields

- associated with electric current
- exist when electric charges are in motion
- two quantities generally used
  - magnetic field strength (H) - ampere per meter (A/ m)
  - magnetic flux density (B) - tesla (T)

$B = \mu H$, μ is permebility of the medium

- 1 microtesla (μT) = 0.8 amperes per meter (A/m)

Current density

- Current density (J) is expressed in ampere per square meter (A/m^2) is proportional to E

$$J = \sigma E$$

where σ is the conductivity of the medium in siemens per meter (S /m)

ELF fields (1 Hz - 100 kHz)

- ELF magnetic fields induce electric fields and circulating electric currents in the body
- ELF fields and currents may cause electric stimulation of the nervous system tissue and muscle cells without significant warming
- Internal current density correlates with the rate of change of the external magnetic flux density and the radius of the inductive current loop

ELF fields (1 Hz – 100 kHz)

- The magnitude of currents inside the body increase proportionally with frequency. Hence at the lowest ELF frequencies, strong external fields are required to cause neural or cardiac stimulation.

- Interaction of induced currents with exitable cells in the retina can cause flickering sensations in the eyes, called magnetophosphenes. The threshold current density to induce the phosphenes is about 10 mA/m^2 at 20 Hz
  - At lower and higher frequencies higher currents are needed to produce the visual phenomena
  - Volunteers have experienced these phenomena during exposure to ELF magnetic fields above 3-5 mT

ICNIRP – EU directive

ICNIRP guidelines (0-300 GHz)		Directive 2004/40/EC
Basic restrictions	=	Exposure limit values
Reference levels	=	Action values

Recommendation and Directive

- 1999/519/EC
  - Council Recommendation on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz)
  - 30.7.1999

- 2004/40/EC
  - Directive on the minimum health and safety requirements regarding the exposure of workers to the risks arising from electromagnetic fields (0 Hz to 300 GHz)
  - 29.4.2004

Directive

- Minimum requirements for the protection of workers

- Short-term adverse effects in the human body
  - circulation of induced currents
  - energy absorption
  - contact currents

- Long-term effects and risks resulting from contact with live conductors are not addressed

Exposure limitation

- **Exposure limit values**
  - based directly on established health effects and biological considerations
    - current density
    - SAR
    - power density

- **Action values**
  - the magnitude of directly measurable parameters
    - electric field strength (E)
    - magnetic field strength (H)
    - magnetic flux density (B)
    - power density (S)

Exposure limit values 1

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

Exposure limit values 2

- Up to 1 Hz
  - prevents effects on cardiovascular and central nervous system

- 1 Hz to 10 MHz
  - prevents effects on central nervous system functions

- Current density limits intended to protect against acute effects
  - no modified values for short exposure durations
  - may permit higher current densities in other tissues than CNS under the same exposure conditions

Exposure limit values 3

- Because of the electrical inhomogeneity of the body, current densities should be averaged over cross section of 1 cm^2 perpendicular to the current direction

- For frequencies up to 100 kHz, peak current density values can be obtained by multiplying the rms value by $2^{½}$.

Exposure limit values 4

- For frequencies up to 100 kHz and pulsed magnetic fields, the maximum current density associated with the pulses can be calculated from 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 pulse duration t, the equivalent frequency to apply for the exposure limit values should be calculated as $f=1/(2t)$

Exposure limit values 5

- For current density, safety factor of 10 is applied for occupationally exposed

- Compliance with these limits will ensure that persons who are exposed to EMFs are protected against all known adverse health effects

Action values

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/m^2)	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	—	—

Action values

- Provided for comparison with measured values
- Compliance with action values will ensure compliance with exposure limit values
- If measured values are higher, exposure limit values are not necessarily exceeded
  - more detailed analysis needed

Action values

- For frequencies up to 100 kHz, peak action values can be obtained by multiplying the rms value by $2^{½}$.
- For pulse duration t, the equivalent frequency to apply for the action values should be calculated as f=1/(2t)
- For frequencies 100 kHz – 10 GHz E, H and B are to be averaged over any six-minute period

Simultaneous exposure to multiple frequency fields

- Appropriate methods of assessment, measurement and/or calculation have to be applied
  - capable of analysing the characteristics of the waveforms
  - nature of biological interactions
- Taking account of harmonised European standards developed by Cenelec

Simultaneous exposure to multiple frequency fields

- Broadband measurement
  - No spectral information
  - Usually gives total field strength of all spectral components within measurement range
  - Has to be related to lowest action value within measurement range

- Usually overestimates exposure

Simultaneous exposure to multiple frequency fields

- Frequency selective measurement system
  - Compliance to the action value can be demonstrated using summation formulas
  - ICNIRP: $$\sum_{j=1Hz}^{65kHz} \frac{H_j}{H_{L,j}} + \sum_{j>65kHz}^{10MHz} \frac{H_j}{30.7\mu T} \leq 1$$
    - H_j = the magnetic field strength at frequency j
    - $H_{L,j}$ = the magnetic field action value at frequency j
  - Components 30 dB below action values are disregarded as insignificant
  - No phase information, conservative exposure estimation

Simultaneous exposure to multiple frequency fields

- Weighted field measurements
  - more closely recognises the characteristics of the waveforms and nature of biological interactions
  - relates spectral components to respective action values
  - can be realised by hardware or software
  - result is given as percentage of the limit value

Also to be considered in risk assessment …

- Interference with medical devices
  - metallic prostheses
  - cardiac pacemakers
  - defibrillators
  - implants

- Interference may occur at levels below the action values
  - appropriate precautions and protective measures

- Thank you for your attention!

BIOLOGICAL EFFECTS OF ELECTROMAGNETIC FIELDS RELATED TO WELDING

Luc Verschaeve
VITO – Belgium

Welders are exposed to more than average extreme low frequency electromagnetic fields. As a matter of fact, exposure to especially ELF magnetic fields can be very high and therefore concern exists about possible effects on health.

Research into the potential health effects of exposure to EMF has been underway for several decades. The catalyst for public awareness came from a 1979 study of Wertheimer and Leeper who published an association between residences near certain types of power lines and increased incidence of childhood leukemia and brain cancer. This was followed by other reports showing that ''electrical occupations'' were associated with a higher than the expected incidence of leukemia. Many other studies followed, often with contradictory results. These studies were not only epidemiological investigations but also cancer-related laboratory studies *in vivo* and *in vitro*, studies on the immune, endocrine and cardiovascular system, on effects in reproduction and development, on the nervous system and behavior, on subjective, non specific symptoms etc.

It is quite surprising to see that, to date, almost no conclusions can be reached, despite so many investigations. Usually limited or inadequate evidence is obtained in favor of a biological effect of the electric or magnetic field component. The International Agency for Research on Cancer recently classified ELF-magnetic fields as possible carcinogenic, based on the association between power lines and childhood leukemia, but yet, no causal relationship was discovered so far.
This means that also the situation for ELF-exposed welders is still not very clear, especially as welders are not only exposed to ELF electromagnetic fields, but also to welding fumes and visible and UV radiation. It is therefore not clear whether symptoms or diseases found among certain populations of welders are linked to the exposure to high magnetic field levels or to other exposures or causes.

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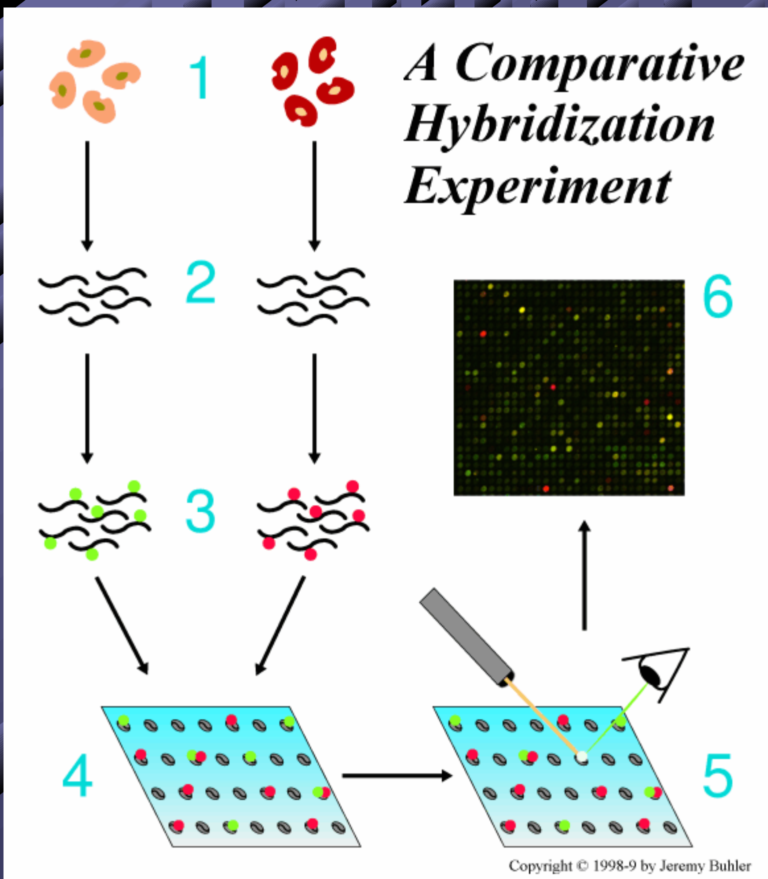
Biological effects of electromagnetic fields related to welding

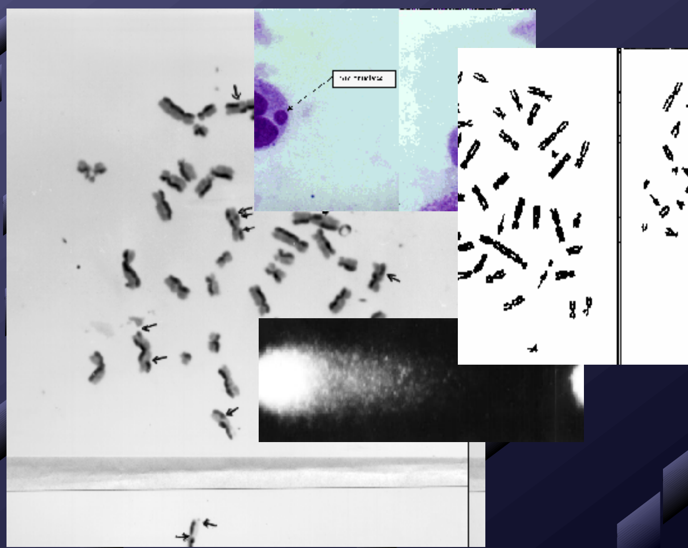
Luc Verschaeve, VITO (Belgium)

Do ELF induce biological effects?

- Yes. It is quite obvious that extreme exposure situations may induce biological effects, e.g., direct stimulation of nerve- and muscle tissue. This occurs when induced currents within the body reach a threshold value. However, also weak electromagnetic exposures, and consequently weak induced electrical signals in the body, can, at least in particular experimental conditions, influence biological tissues.

Genotoxicity and *regulation of gene expression*





Genotoxicity and ***regulation of gene expression***

No consistent picture emerges from the many different investigations. The studies differ substantially in their biological approach and the techniques used; even within the same laboratory, some studies could not subsequently be reproduced.

Most studies were on human lymphocytes – this may be the wrong cell type !!
[REFLEX program – results already controversed; e.g., Mutation Res. (2006) 603, 104-106].

Calcium, signal transduction and proliferation

- Power-frequency EMFs are likely to have some effect on a number of signal transduction related pathways in mammalian cells. But most of the studies, were reported from single laboratories, and the results cannot be considered conclusive.
- No effect on cell proliferation in recent studies

Induction of cytological markers

- The results of the studies do not show a clear pattern of effects of EMF on cytological markers
- Recent studies found marginal effects but no consistent pattern

What effects of ELF-fields have been reported in laboratory studies in animals?

- Investigations were performed on different endpoints and included as well short term as long term bio-effects.
  - Initiation, promotion, cancer

?Overall, animal studies do not indicate that ELF-electromagnetic fields are carcinogenic, neither as a tumour initiator, or as a tumour promoter.

Other effects of ELF-fields in laboratory studies in animals?

Reproductive and developmental effects, immunological-, haematological-, neuroendocrine-, and genetic and related effects.

The overall conclusion so far is that animal studies do not support ELF-field effects on non-cancer endpoints.

EFFECTS IN HUMANS

- blood-levels of the hormone melatonin
- EMF-induced heart rate disturbances
- Investigations on sleep electrophysiology
- Effects on the immune system, hormones and blood chemistry

?Studies so far provided little evidence for any consistent effect.

EPIDEMIOLOGY

- PROFESSIONAL EXPOSURES
- RESIDENTIAL EXPOSURES (children/adults)
- USE OF ELECTRICAL APPLIANCES

Investigations on: leukemia, lymphoma, brain cancer, breast cancer and others

\+ Alzheimer disease, spontaneous abortions, congenital malformations, suicide, multiple sclerosis, etc.

EPIDEMIOLOGY

- IARC MONOGRAPH ON THE EVALUATION OF CARCINOGENIC RISK IN HUMANS -Vol. 80, june 2002

POOLED ANALYSES OF DATA FROM A NUMBER OF WELL CONDUCTED STUDIES SHOW A FAIRLY <u>CONSISTENT</u> <u>STATISTICAL ASSOCIATION</u> BETWEEN <u>CHILDHOOD LEUKEMIA</u> AND POWER FREQUENCY <u>RESIDENTIAL MAGNETIC FIELD STRENGTHS ABOVE 0.4 µT</u> WITH AN APPROXIMATELY <u>TWO-FOLD INCREASE IN RISK</u>

ELF AND CHILDHOOD CANCER

> 0.4 µT

No other convincing data on adverse health effects; e.g., unconvincing data on adult cancer induction

CLASSIFICATION: 2B

IARC

CONCLUSION

- Lack of clear and unequivocal results
- Usually insufficient data to conclude that ELF-EMF are deleterious. But positive findings do exist and recent results on genetic effects may show genotoxicity at least in some cell systems and for some frequencies and exposure conditions.

  Further *in vitro* repeat experiments, confirmation studies in animals and humans are necessary.
- New technologies (proteomics and micro-array technology) are promising but at the present time they do not allow definite conclusions with respect to human health.

- Epidemiological findings so far do not find sufficient support from laboratory investigations with cells and animals.

??? WELDERS ???

CANCER:

increased incidence of tumours of the kidney, pituitary gland, biliary passage, liver and brain, but decreased incidence of colon cancer, and connective tissue…….e.g., Håkansson et al., 2002 (Occup. Environ. Med. 59, 481-486).

Increased incidence of tumours of the endocrine glands (adrenal gland parathyroid gland) …….e.g., Håkansson et al. 2005 (Occup. Environ. Med. 62, 304-308.).

increased incidence of leukemia……...e.g., Bethwaite et al., 2001 (Cancer Causes and Control 12, 683-689).

NEURODEGENERATIVE DISEASES:

Increased risk of Alzheimer’s disease and amyotrophic lateral sclerosis……. e.g., Håkansson et al., 2003 (Epidemiol. 14, 427-428).

CHROMOSOME DAMAGE IN WHITE BLOOD CELLS:

Increased frequencies found …………e.g., Jelmert et al., 1994 (Mutation Res. 320, 223-233).

Welders

Health effects of EMF ??

pro: other data on EMF; e.g., increased risk of pituitary tumours in train personnel

contra: contradictory results, combined exposures (UV, visible light, welding fumes), lack of clear working mechanisms

STANDARDIZATION OF ELECTROMAGNETIC FIELD MEASUREMENTS OF WELDING EQUIPMENT

Geoff Melton
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Welding is a recognized source of electromagnetic fields because of the relatively high currents used in the processes. The highest levels of current and hence magnetic fields are experienced with the resistance welding process, in which resistance heating between sheets of metal is used to form a localized weld. In this process is often called spot welding, welding currents in excess of 100,000A are not unusual. Arc welding is probably the most widely used welding process and although the welding current is lower, the processes is usually used manually and the cables run in close proximity to the welders body.

In 2004 the European Council published Directive 2004/40/EC on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields)[1] . This Directive requires employers to make assessments of the electromagnetic fields in the workplace. Furthermore, manufacturers of electrical equipment are required to demonstrate compliance with the Low Voltage Directive (73/23/EEC)[2], which requires that “measures of a technical nature should be prescribed…, in order to ensure…that radiation which would cause a danger, are not produced.

Consequently, standards are required to support these requirements for

- Workplace assessments by employers
- Product compliance by equipment manufacturers

CENELEC is responsible for electrotechnical standards within Europe and is mandated by the European Commission to produce standards to support European Directives. These standards, when harmonized, provide a presumption of conformity to the Directives. The European Commission has issued two relevant Mandates to CENELEC for standard in support of Electomagnetic Fields

- M/315 Harmonised standards to assess, measure and calculate workers' exposure to electromagnetic fields in the range from 0 Hz to 300 GHz.
- M/305 Harmonised standards covering protection from electromagnetic fields (0 Hz to 300 GHz) generated by apparatus included in the scope of either the Low Voltage Directive 73/23/EEC1, (LVD) or the Radio Equipment and Telecommunications Terminal Equipment (R&TTE) Directive 1999/5/EC.
- European standards for "Assessment of human exposure to electromagnetic fields in the frequency range 0-300 GHz” are the responsibility of CENELEC TC106X, but specific standards for welding equipment are entrusted to CENELEC TC26 (A for arc welding and B for resistance welding equipment).

CENELEC TC26A and B are drafting the following standards

- prEN 50445, Draft 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)

- prEN 50444, Draft Basic standard for the evaluation of human exposure to electromagnetic fields from equipment for arc welding and allied processes

- prEN 50XXX, Draft Basic standard for the evaluation of human exposure to electromagnetic fields from equipment for resistance welding

The basic standards specify assessment methods (measurement and calculation procedures) and describe test set ups and equipment to be used. The product family standard applies the tests from the basic standards, specifies specific calculating methods and limits. The limits that apply are given in European Council Recommendation 1999/519/EC[3] for public exposure and ICNIRPGuidelines[4,5] for occupational exposure.

CENELEC TC106X is drafting a Generic Standard for "Determination of workers exposure to electromagnetic fields and assessment of risk". This standard adopts a zoning system for workplace assessments;

- A Zone 0 workplace is one in which all exposure levels are complying with the relevant general public limits.
- In Zone 1, exposures may be greater than the general public limit but will be compliant with the occupational exposure limit.
- In Zone 2, exposures may be greater than the occupational exposure limit.

If access is possible to Zone 2, then remedial measures to reduce exposure or to restrict or limit access should be taken.

The standards produced by CENELEC TC26 will require manufacturers of equipment to provide information on electromagnetic fields from their equipment which can be used in the risk assessments, as required by Directive 2004/40/EC.

TWI has recently carried out an assessment of magnetic fields from welding processes on behalf of the Health and Safety Executive in the UK. Measurements have been made on typical test setups as specified in the draft basic standards for arc and resistance welding equipment. The full report is available on line at http://www.hse.gov.uk/research/rrpdf/rr338.pdf

REFERENCES

1. Directive 2004/40/EC 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 L159 , 30/04/2004 p. 0001 – 0026

2. Directive73/23/EEC 1973 Council Directive 73/23/EEC of 19 February 1973 on the harmonization of the laws of Member States relating to electrical equipment designed for use within certain voltage limits, Official Journal L 077, 26/03/1973 p. 0029 – 0033

3. European 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, L199, 30/07/1999, p. 0059 – 0070

4. ICNIRPGuidelines 1994 International Commission on Non-Ionising Radiation Protection, Guidelines on limits of exposure to static magnetic fields, Health Physics, Volume 66, 1994, p. 100-106

5. ICNIRP Guidelines 1998 International Commission on Non-Ionising Radiation Protection, Guidelines for limiting exposure in time-varying electric, magnetic and electromagnetic fields (up to 300 GHz), Health Physics, Volume 74, Number 4, 1998, p. 494 – 522

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ELECTROMAGNETIC FIELDS IN WELDING- STANDARDIZATION

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The Physical Agents (EMF) Directive 2004/40/EC

..protection of workers from risks to their health and safety arising or likely to arise from exposure to electromagnetic fields.

Adopted by EU in April 2004

Mandatory limits placed on the EMF exposure of workers

April 2008

The Low Voltage Directive (LVD) 73/23/EEC

..2(b) Temperatures, arcs or radiation which would cause a danger must not be produced.

EU STANDARDIZATION

- CENELEC is the electro-technical standards body for EU
- TC106X is responsible for Assessment of human exposure to electromagnetic fields in the frequency range 0-300 GHz
- TC 26A&B are responsible for electric welding equipment

CENELEC

- CENELEC Standards are Harmonized and provide a “presumption of conformity to EU Directives”

- CENELEC is “mandated” by the Commission to produce standards.

EU Mandates

- M/315 Harmonised standards to assess, measure and calculate workers' exposure to electromagnetic fields in the range from 0 Hz to 300 GHz.

- M/305 Harmonised standards covering protection from electromagnetic fields (0 Hz to 300 GHz) generated by apparatus included in the scope of either the Low Voltage Directive 73/23/EEC1, (LVD) or the Radio Equipment and Telecommunications Terminal Equipment (R&TTE) Directive 1999/5/EC.

World Health Organisation

Sources of magnetic fields

- Resistance welding
- Arc welding
- RF (plastics) welding
- Induction heating
- Magnetic particle inspection

………………………………high current

TC26 Standards

- prEN50445 Product family standard for welding equipment
- prEN 50444 Basic standard for arc welding
- prEN50XXX Basic standard for resistance welding
- Applicable to both PAD and LVD

TC26 Standards

- **Basic standards**
  - Test set ups
  - Measurements
  - Calculations

- **Product standard**
  - apply basic standards
  - Specify limits

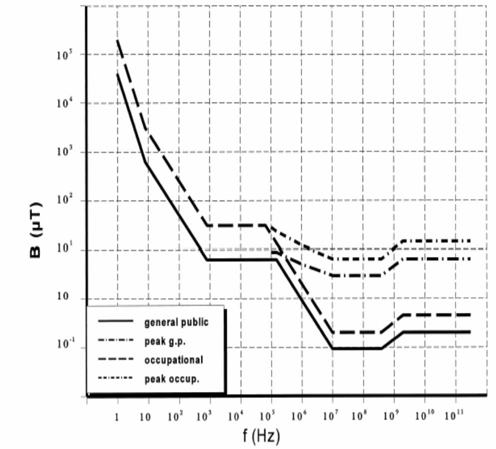


Fig. 2. Reference levels for exposure to time varying magnetic fields (compare Tables 6 and 7).

TWI

Standardisation and the PAD

EMF Directive

Single CENELEC "umbrella" standard
For the assessment of workplace/worker exposure

CENELEC/ETSI Joint WG

New standards,
Eg welding equipment

Procedures from existing product/measurement standards
(IEC, ETSI, CEN, CENELEC)

MEASUREMENTS

Carried out by TWI in 2004/2005 on resistance and arc welding

Measurements

- Arc welding
- Resistance welding

EMF

- Resistance welding
- Current at kA level
- High magnetic fields at power frequencies

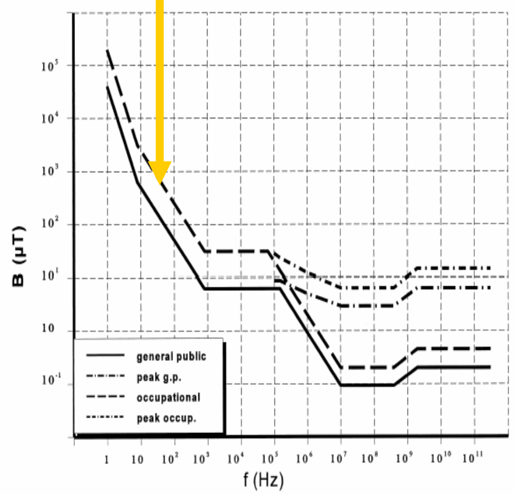
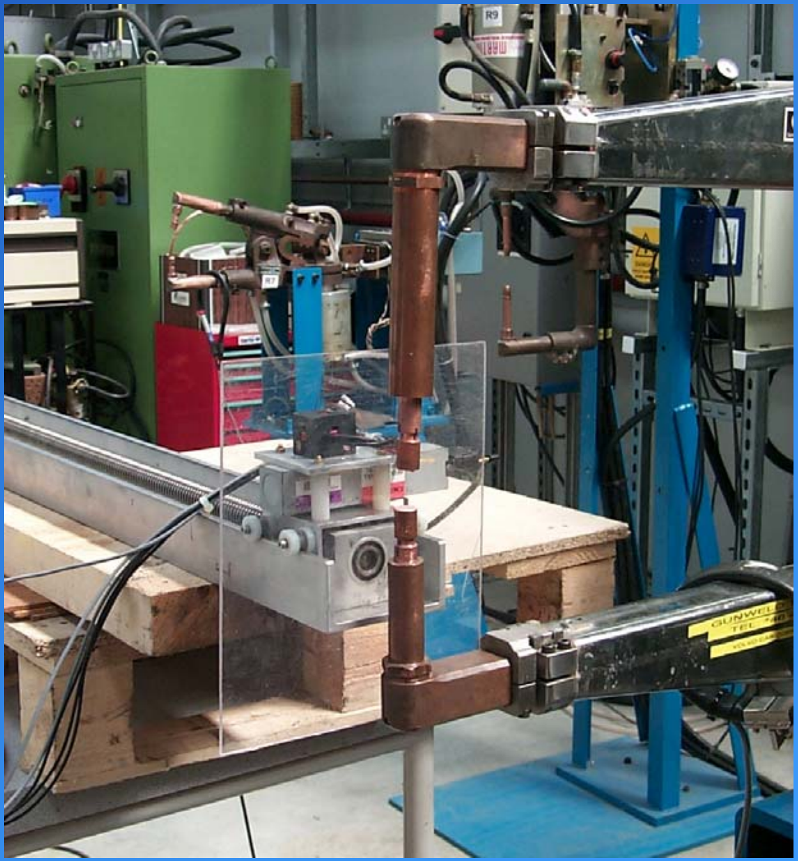
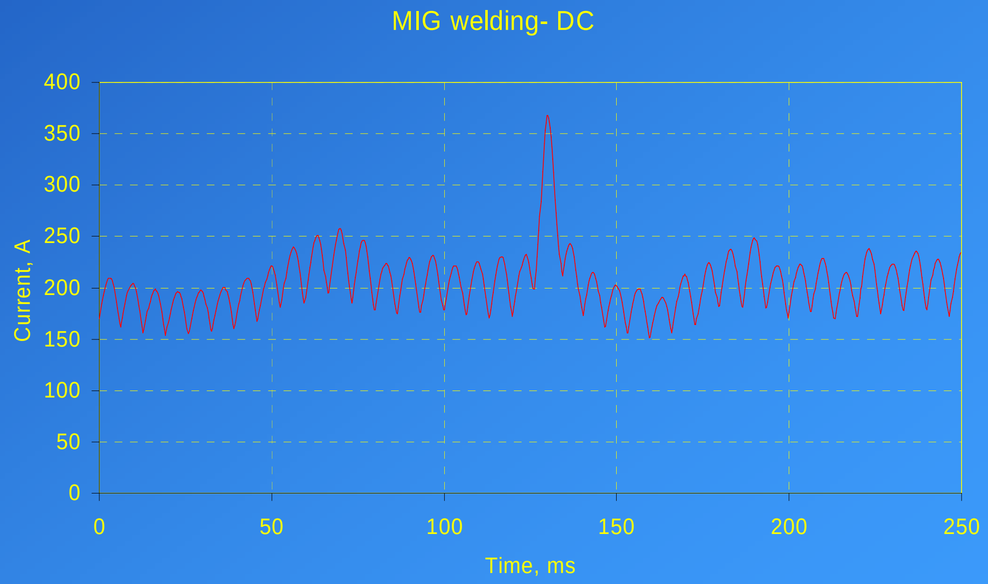


Fig. 2. Reference levels for exposure to time varying magnetic fields (compare Tables 6 and 7).



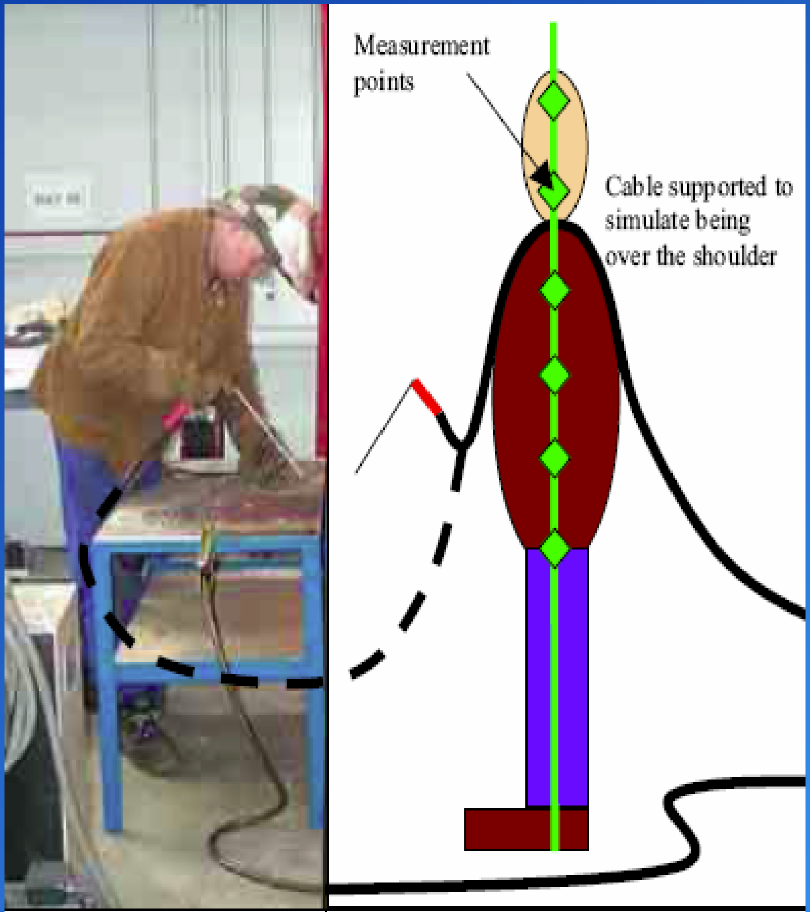
Reference Levels

Arc welding



10cm > reference level > 20cm

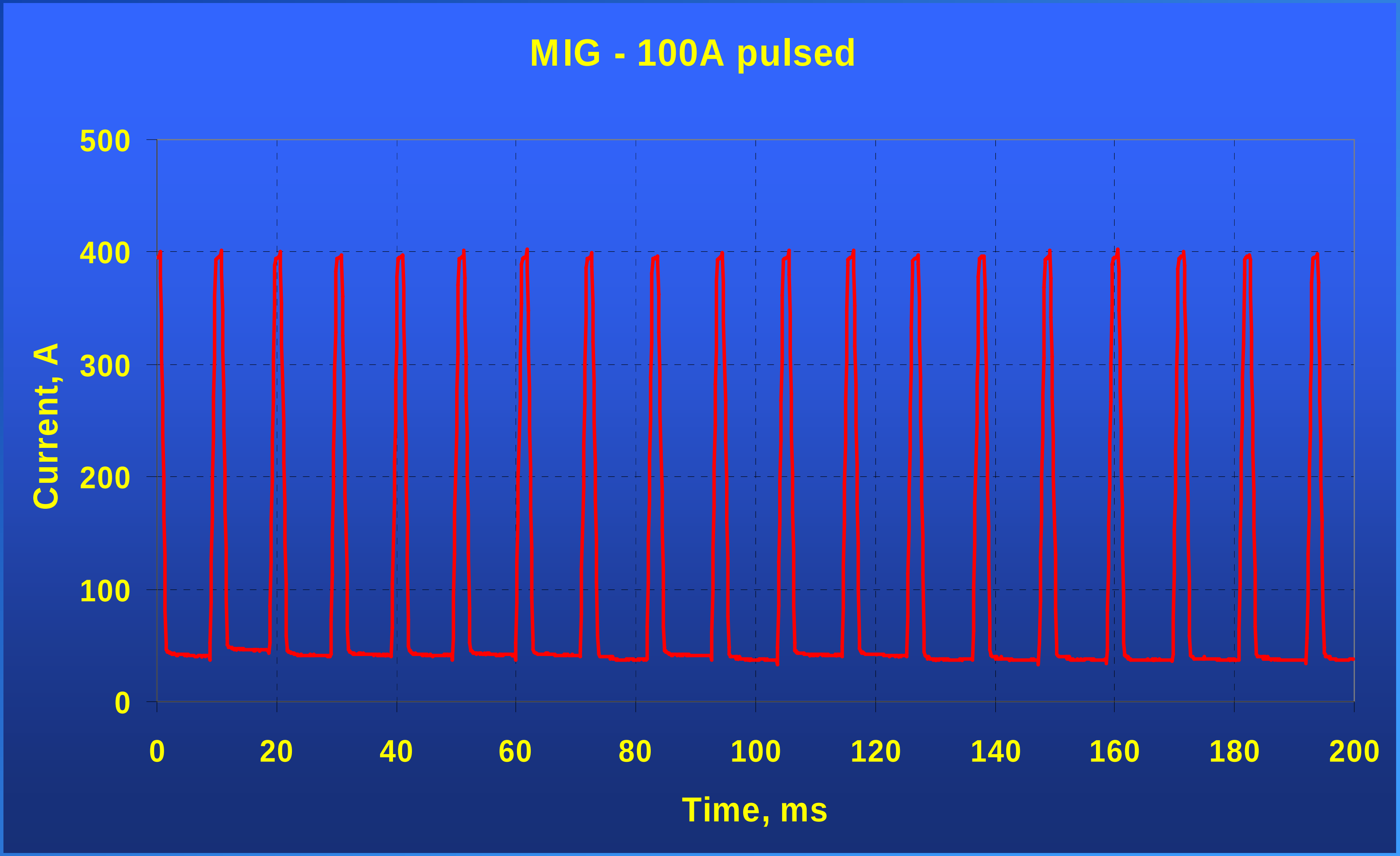
Arc welding measurements



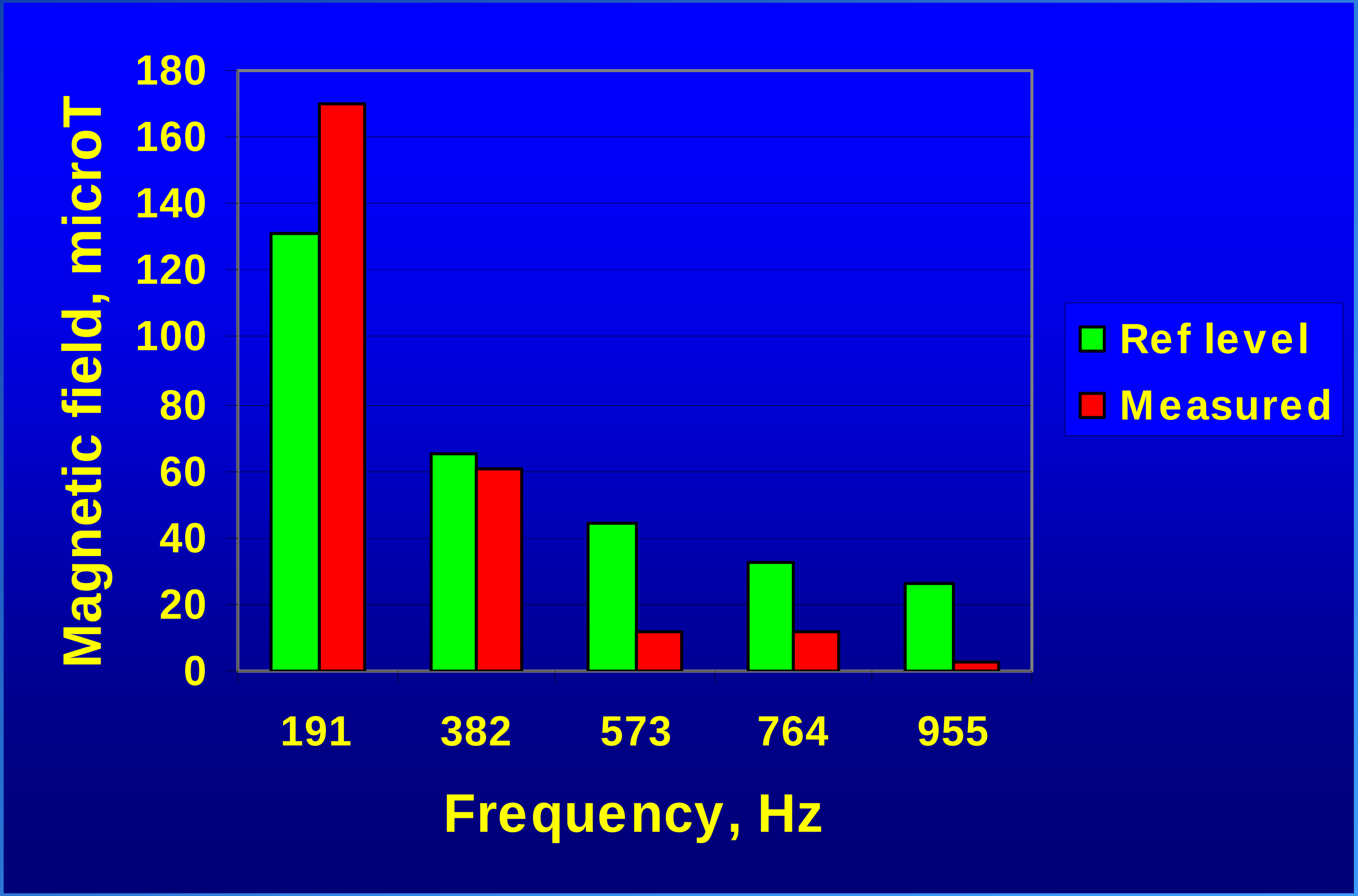
Welder on one side of bench

Measurement set up on other side of bench, with cable supports

Pulsed welding



Pulsed MIG 100A



EMF

- Arc welding
- Lower currents
- Closer
- Higher frequency components

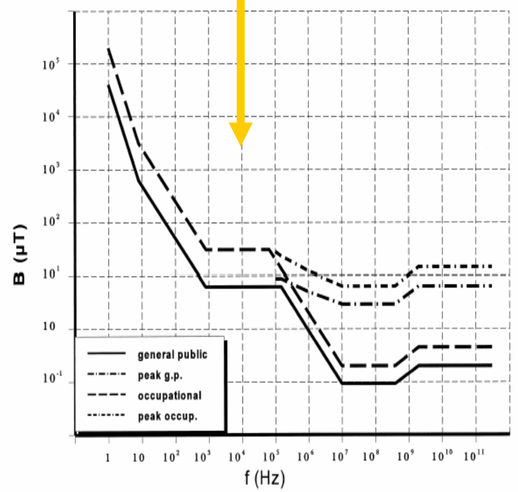
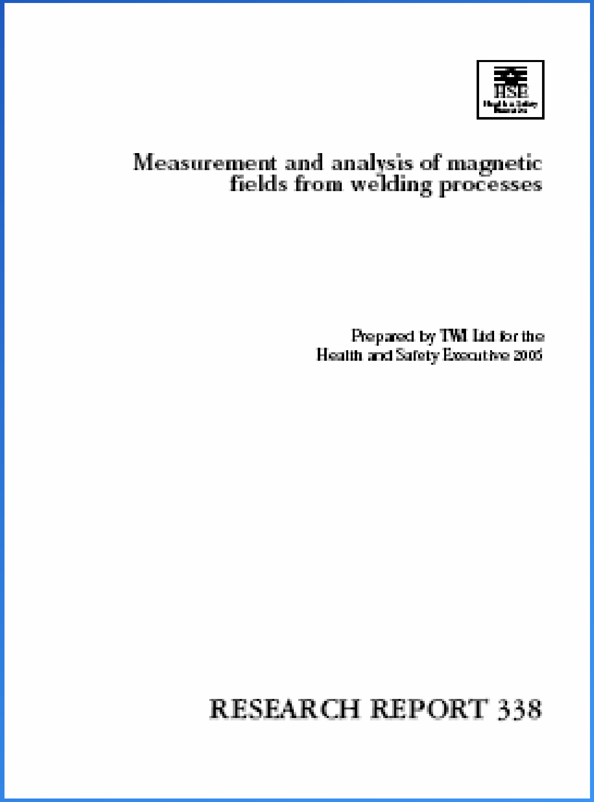


Fig. 2. Reference levels for exposure to time varying magnetic fields (compare Tables 6 and 7).

Reference Levels

For further information

www.hse.gov.uk/research/rrpdf/rr338.pdf


Measurement and analysis of magnetic fields from welding processes

Prepared by TWI Ltd for the Health and Safety Executive 2005

RESEARCH REPORT 338

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Thanks to CENELEC Welding EMF Working Groups

ELECTROMAGNETICAL FIELDS ASSOCIATED WITH ARC WELDING EXAMPLES OF MEASUREMENTS FOR COMPLIANCE

Monica Sandström
NIWL – Sweden

Welding operator is one of the occupations that are highly exposed to electromagnetic fields (EMF) and thereby in conflict with the new EU directive on EMF exposure in working life. Arc welding uses electric currents up to several hundreds of amperes. The current, provided by the welding power source, flows through the torch-cable and the torch to the welding arc, and into the work-piece and than back to the power source via the ground cable. This provides a source for magnetic field to which the worker is exposed during the welding process. The basis for the restrictions in the new EU directive on occupational exposure to EMF in the low frequency range is mainly based on the risk of nerve excitation.

The exposure to magnetic field during the welding process depends primarily on the current flowing through the torch-cable, which in turn depends on the welding process and the power source used. In most cases a rectified three-phase current is used, modified by the welding process with certain ELF components. This means that field components with frequencies well up to the kHz range are present near welding equipment. New equipment uses electronic power supply and therefore frequencies in the kHz range.

In order to find out if the reference values, stated in the EU directive, are exceeded, it is necessary to apply a special measurement procedure. Depending on the welding procedure the harmonic content of the current and therefore also in the magnetic field around the torch-cable is high. Broadband measuring instruments provide no spectral information on the field, and therefore such a result is usually the total field strength of all spectral components within the bandwidth. The results of the broadband measurements must thus be related to the lowest limit value of the reference levels in the frequency range since the limits are frequency dependent. In order to compare exposure in different arc welding procedures with the reference values we have measured EMF generated by a number of commonly used welding applications using a broadband measuring instrument and a spectrum analyser in order to visualize and calculate the harmonic content. In the presentation, examples of measured waveforms from different welding processes will be presented, to serve as a basis for the theoretical calculations of the induced current that is the base for the limits in the EU directive.

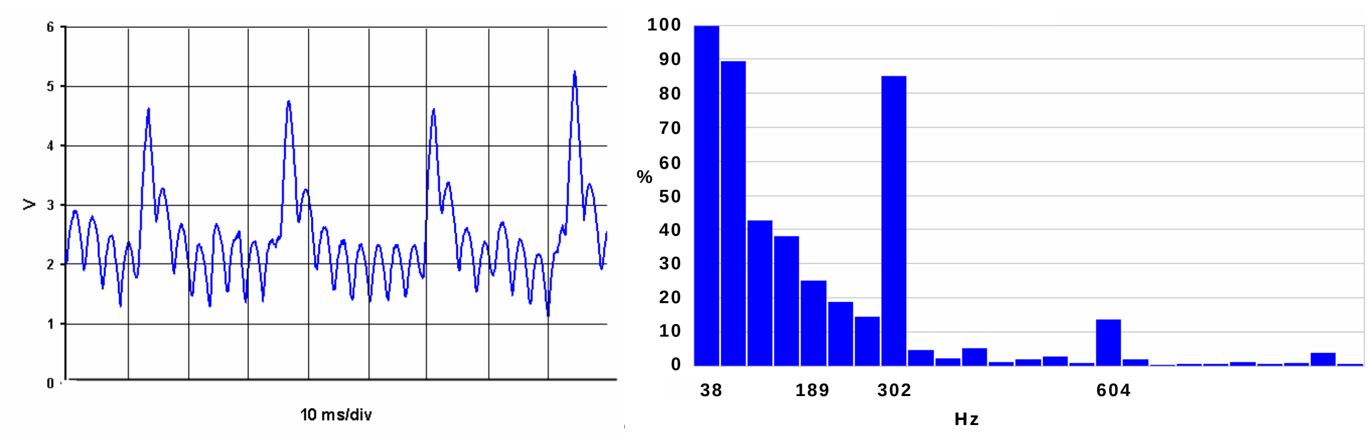
One of the most important issues concerning high exposure during welding is the working position. In the presentation we will show a method (the PIMEX method) that might be used to inform the welding operators of the importance of a correct working position.

References

European Parliament and the Council Directive 2004/40/EC 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/EEG. PE-CONS 3655/04, SOC 190, CODEC 586. 2004:04

Mair P. (2005). Assessment of EMF (electromagnetic fields) and biological effects in arc welding applications. Internat´l Inst of Welding, Commission XII, intermediate meeting, Fronius International, February 2005.

The PIMEX method. http://www.arbetslivsinstitutet.se/pimex/default.asp



form and a histogram of the frequency content in an ordinary MIG process. In the pictures the short circuit ELF peaks nibbling of droplets of the wire is seen with a frequency of about 38 Hz, and also the 300 Hz and harmonics ripple from the three phase rectification is seen between the ELF short circuit peaks. The broadband measurement value was 135 μT and the sum calculations show that the reference value is exceeded.

This project was partially funded by the Coordination Action EMF-NET "Effects of the Exposure to Electromagnetic Fields: from Science to Public Health and Safer Workplace" (European Commission FP6 Coordination Action, Thematic Priority 8, Policy support and anticipating scientific and technological needs, Contract N° SSPE-CT-2004-502173, 2004-2008)

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Electromagnetic fields associated with Arc welding - examples of measurements for compliance

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2006 04 06 VITO NV Mol, Belgium

Welding

Complex situation from occupational exposure point of view

- Electricity
- Fumes
- Fire
- Noise
- **Electromagnetic fields**
- **DC, ELF, VLF,** **IR, UV**
- Ergonomics

Information
Education

In electric welding high currents – hundreds of Ampere are used and the corresponding magnetic field will be high and possibly exceeding the reference levels in the EU directive.

The field-properties around welding equipment are defined by the properties of the welding current, which in turn depends on the welding process and capabilities of the equipment.

The current path – cable position – in relation to the welder is of outermost importance for the exposure.

Two issues

- Emission properties of products
- Welding operators exposure

CENELEC TC26A draft

EU directive 2004/40/EC

Arbetslivsinstitutet

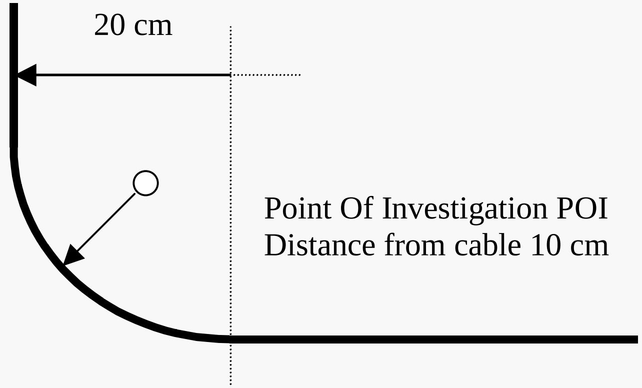
Monica Sandström

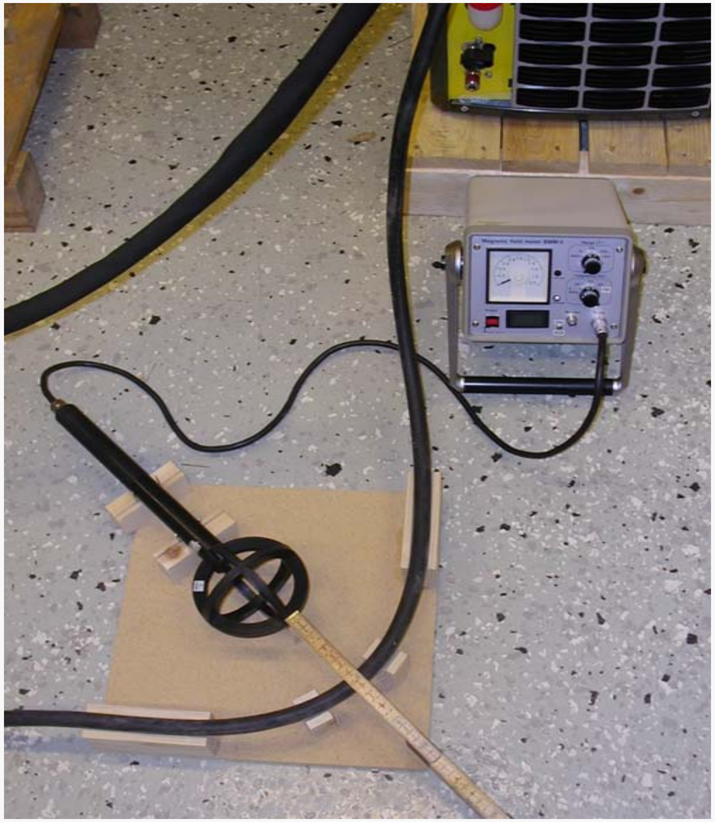
We have measured the magnetic field from several different welding equipments. We have used the method introduced by the CENELEC working group TC 26A draft.

The magnetic field was measured with a broadband instrument with the isotropic field probe at a distance of 0.1 m from the half circular loop of radius 0.2 m.

The frequency spectrum was recorded by the use of a oscilloscope in FFT mode connected to the shunt.

Set-up for measuring the broadband magnetic field





Instrument: BMM3

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Monica Sandström

Set-up for registration of the waveform

Clip-on ammeter connected to an oscilloscope in FFT mode

An oscilloscope in FFT mode connected to the shunt

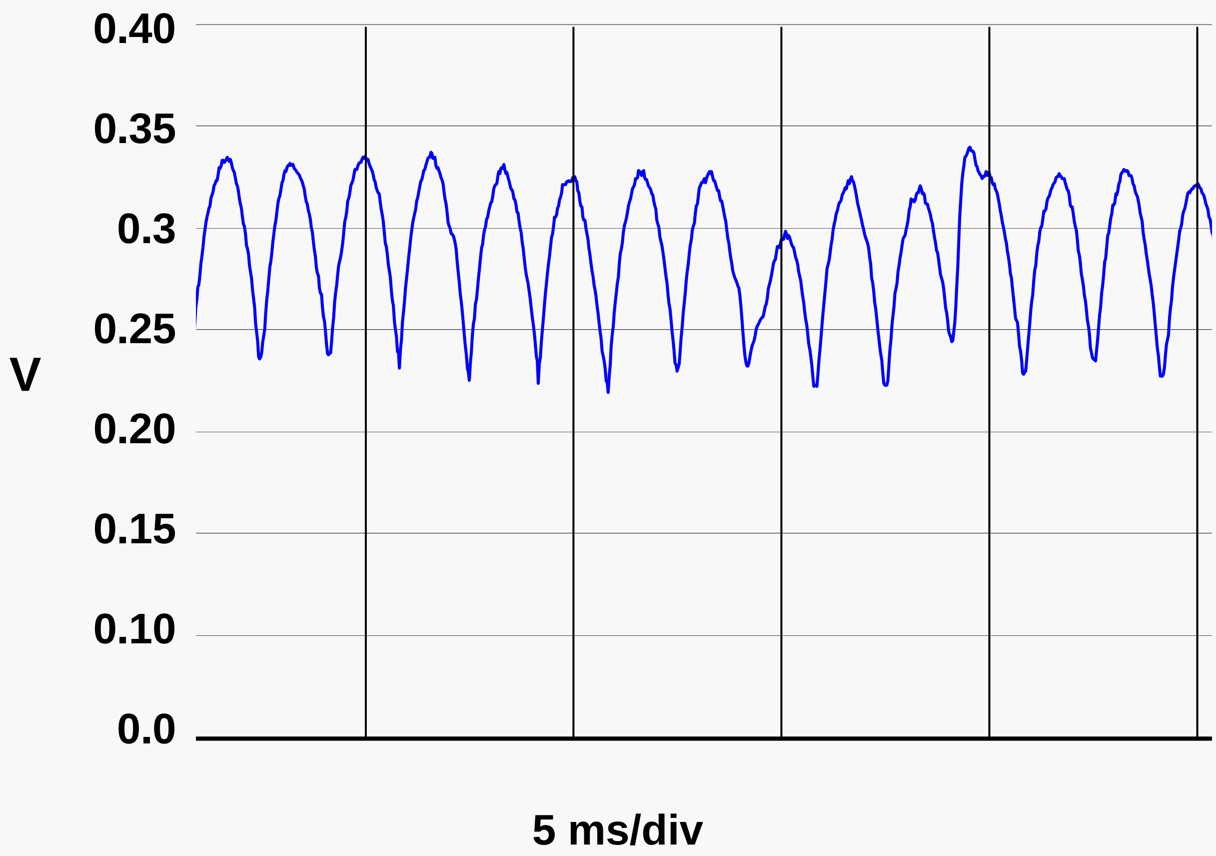
Arbetslivsinstitutet
Monica Sandström

The magnetic field for each frequency component where calculated and compared to ICNIRPs reference levels:

$$\sum_{j=1Hz}^{65kHz} \frac{B_j}{B_{L,j}} + \sum_{j>65kHz}^{10MHz} \frac{B_j}{b} \leq 1$$

B is the magnetic field strength at frequency j
$B_{L,j}$ is the magnetic field reference level for frequency j
b is 30.7 µT for occupational exposure

Spray arc welding



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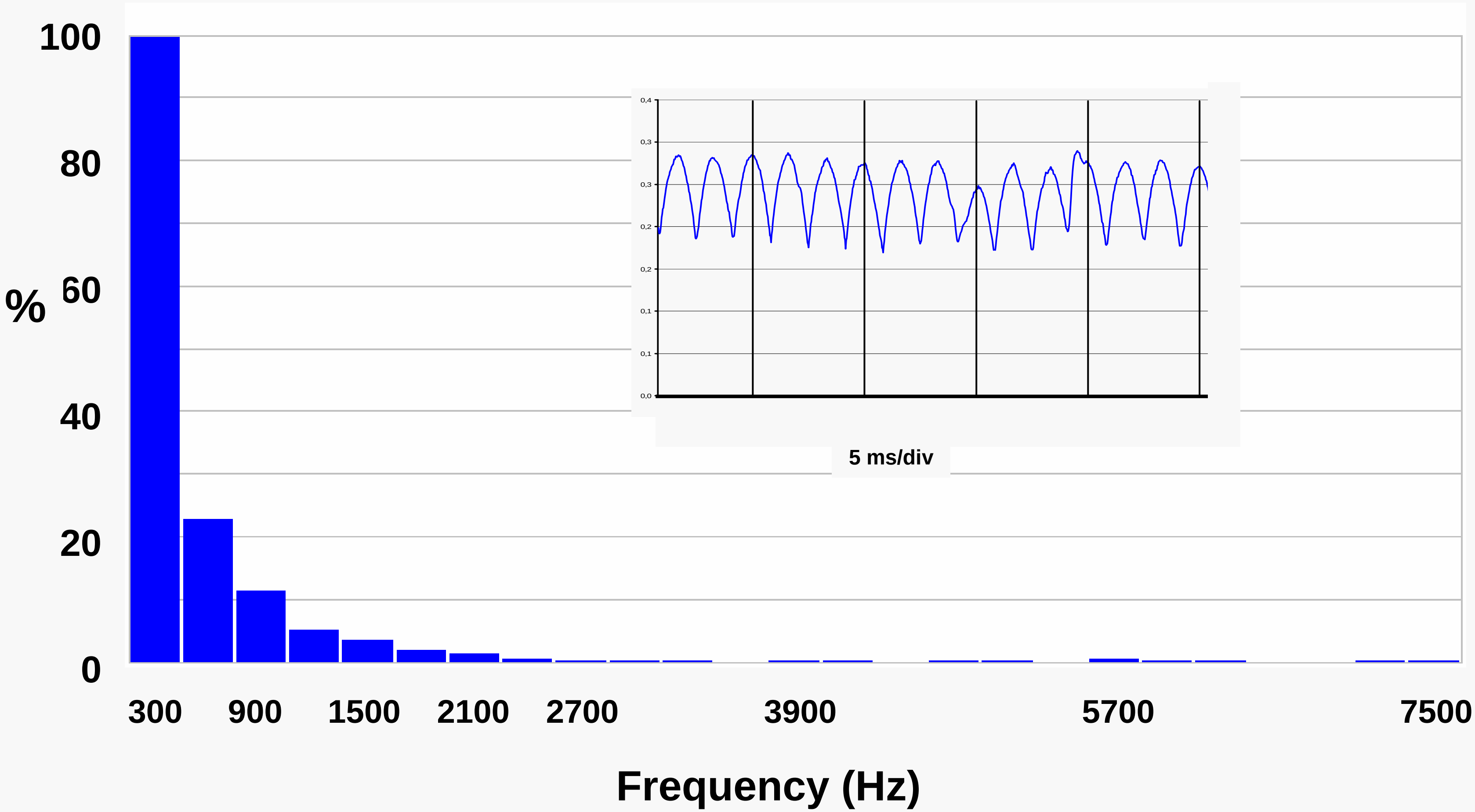
Spray arc welding



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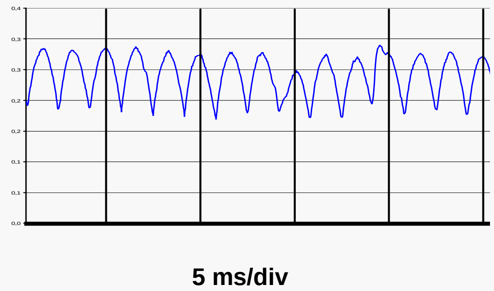
Spray arc welding



Broadband value 90 µT

Freq. Hz	Measured µT	Ref. µT	Measured /Ref.
300	87,0	83,3	1,04
600	20,0	41,7	0,48
900	9,6	30,7	0,31
1200	4,4	30,7	0,14
1500	2,6	30,7	0,09
1800	1,7	30,7	0,06
		Sum	**2,1**

$$\sum_{j=1Hz}^{65kHz} \frac{B_j}{B_{L,j}} \le 1$$

Reference value is exceeded

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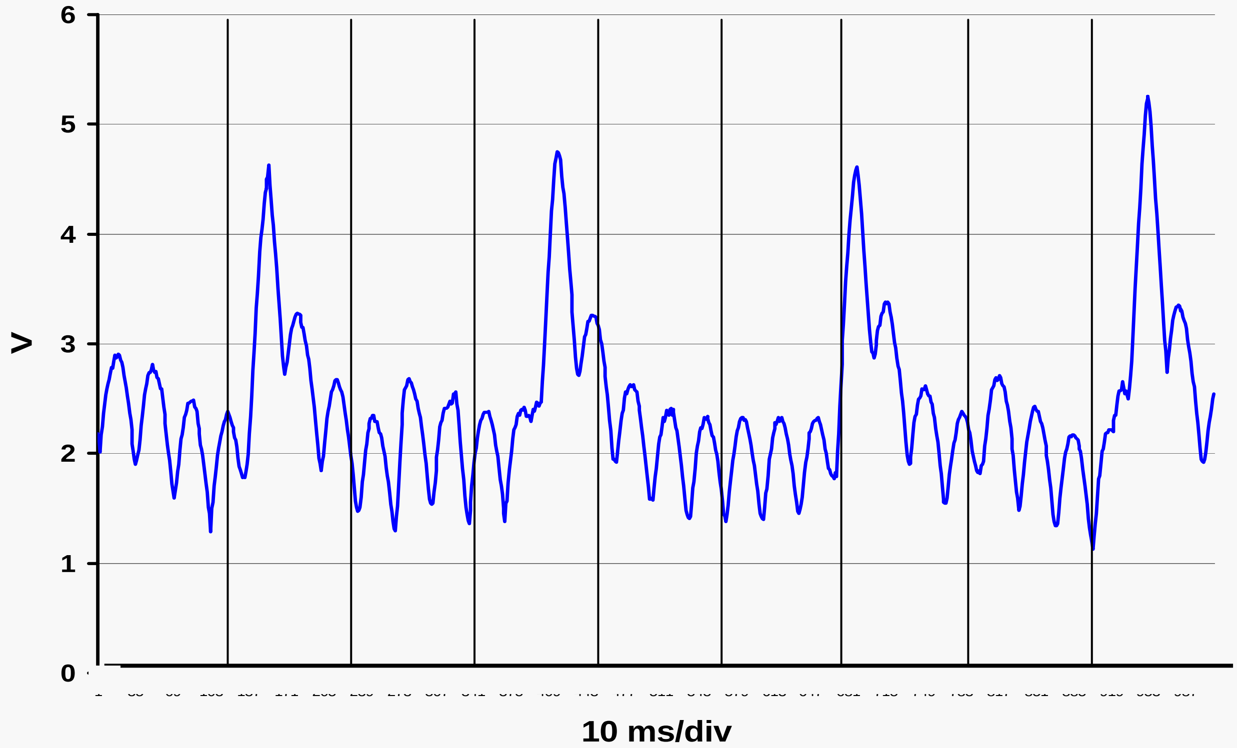
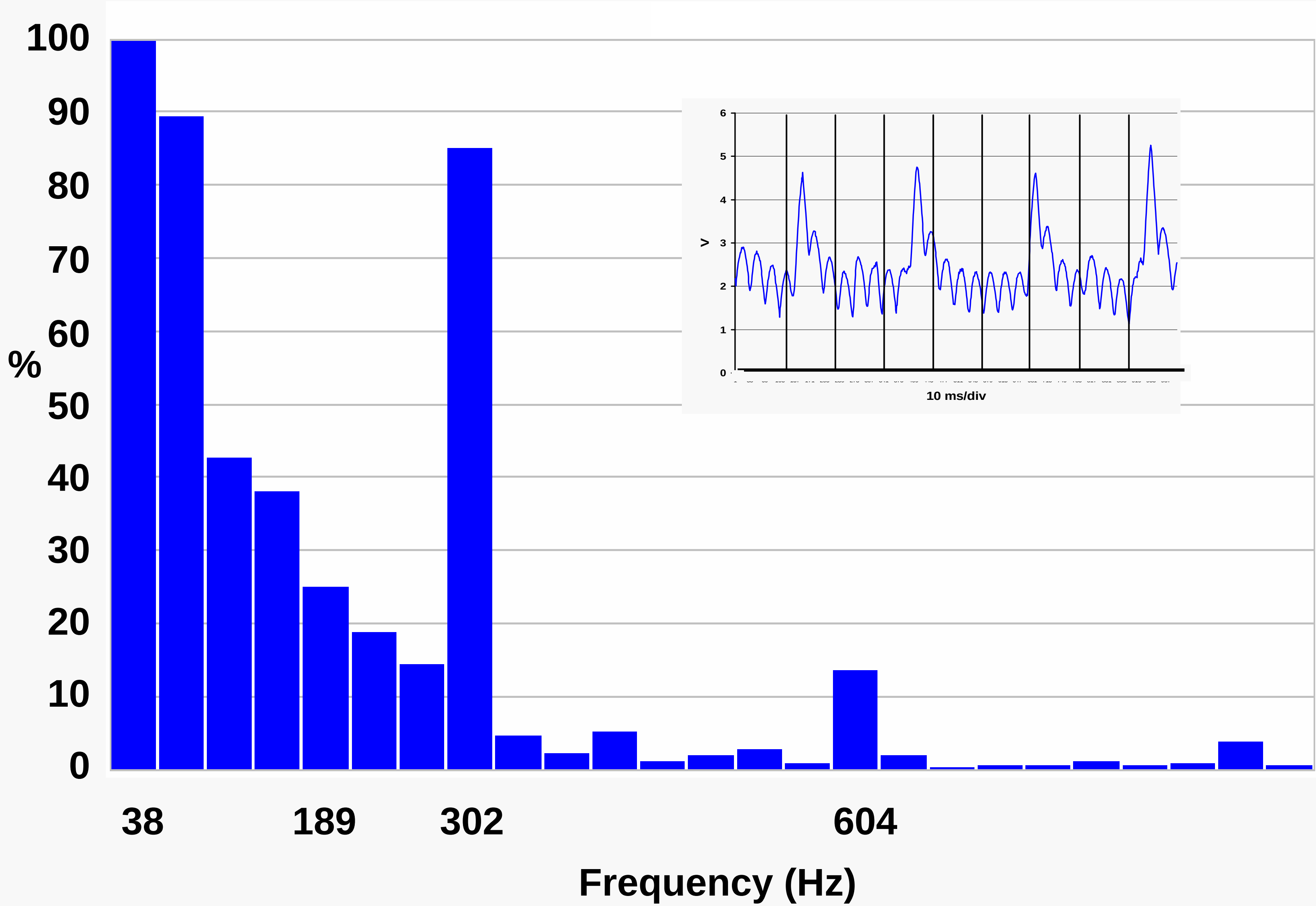
Short arc welding



Short arc welding



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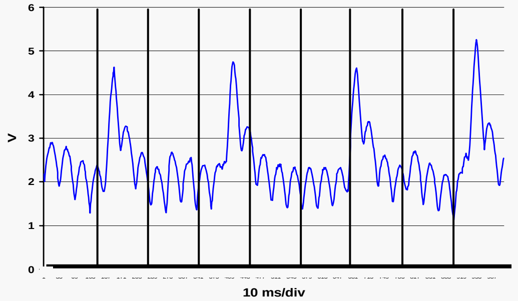
Monica Sandström

Short arc welding

Broadband value 135 µT

Frequency Hz	Measured µT	Ref. µT	Measured /Ref.
38	77,0	657,9	0,12
76	69,3	328,9	**0,21**
110	33,1	227,3	0,15
150	29,3	166,7	0,18
190	19,3	131,6	0,15
230	14,6	108,7	0,13
260	10,8	96,2	0,11
300	65,5	83,3	0,79
340	3,9	73,5	0,05
380	1,5	65,8	0,02
420	3,9	59,5	0,06
450	0,8	55,6	0,01
490	1,5	51,0	0,03
530	2,3	47,2	0,05
570	0,8	43,9	0,02
600	10,8	41,7	0,26
640	1,5	39,1	0,04
680	0,0	36,8	0,00
720	0,8	34,7	0,02
760	0,0	32,9	0,00
790	0,8	31,6	0,02
830	0,8	30,7	0,03
870	0,8	30,7	0,03
900	3,1	30,7	0,10
		Sum	2,57



$$\sum_{j=1Hz}^{65kHz} \frac{B_j}{B_{L,j}} \leq 1$$

Reference value is exceeded

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Next step ?

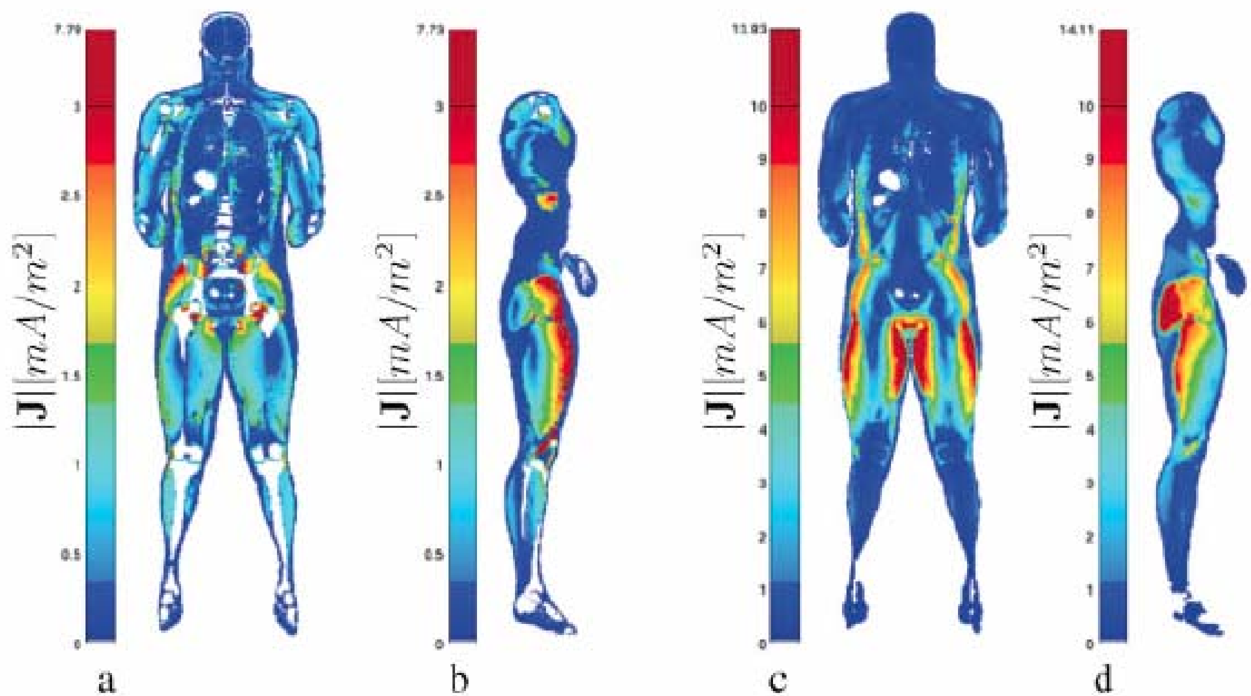

Fig. 5. The induced current density on the cross sections $y = 0.13$ m and $x = 0.13$ m (for definition of x and y see Fig. 1); (**a**) and (**b**) are calculated for case 1, and (**c**) and (**d**) for case 2, respectively.

Magnetic Field From Spot Welding Equipment Is the Basic Restriction Exceeded?
M Nadeem, Y Hamnerius, K Hansson Mild, and M Persson
Bioelectromagnetics 25:278-284 (2004)

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Changing the electrode bare-handed causes a risk of high contact current!

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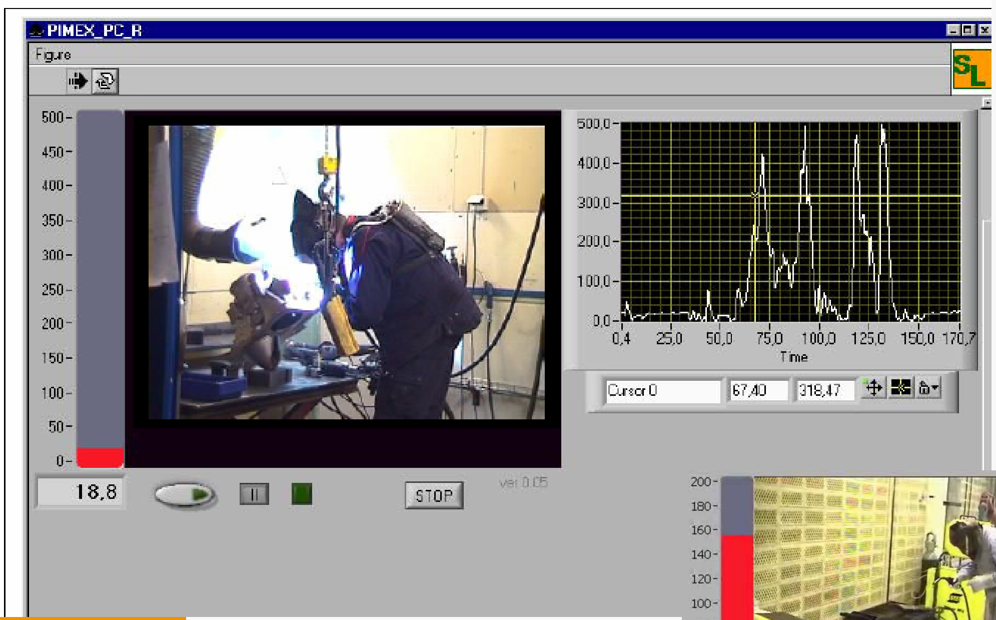
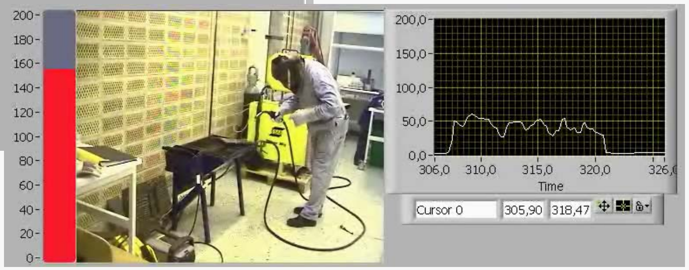
Health risks made visible using video
Video Exposure Monitoring –
The PIMEX method

http://www.arbetslivsinstitutet.se/pimex/default.asp





- Direct intervention at workplaces
- Production of training films
- Research

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Position of the cable and the magnetic field measuring device

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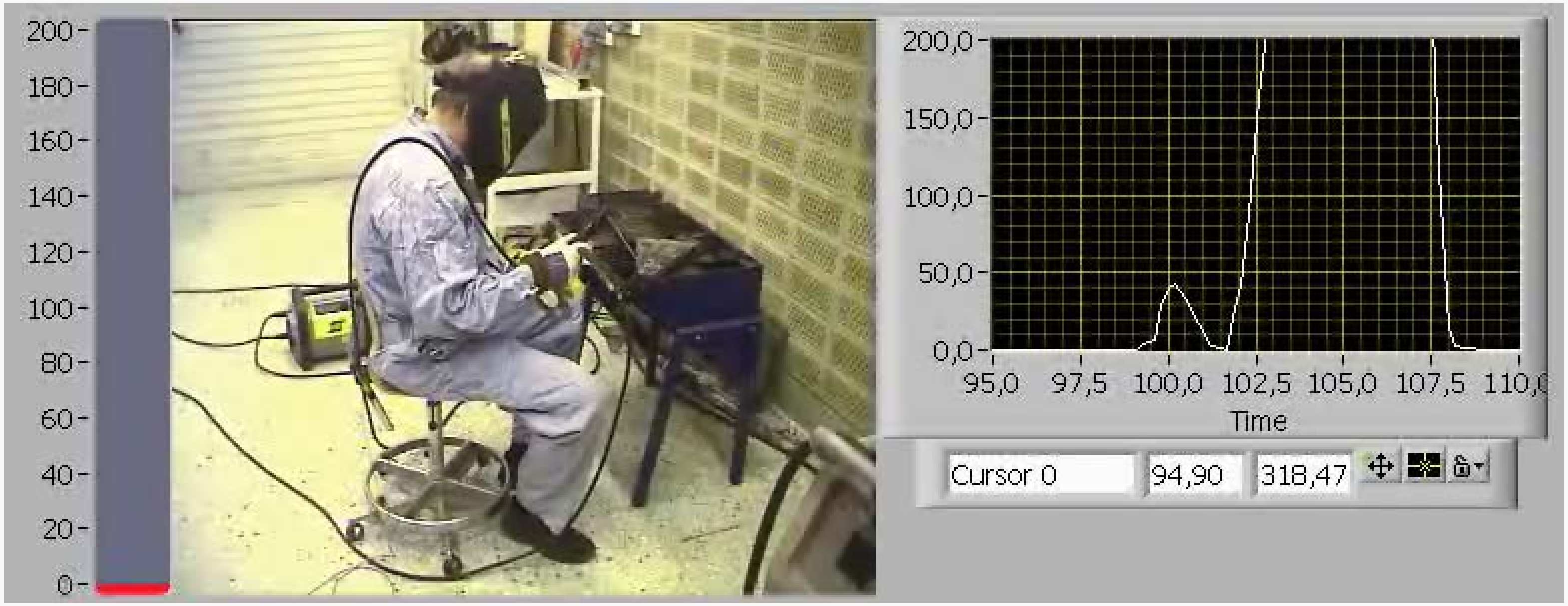

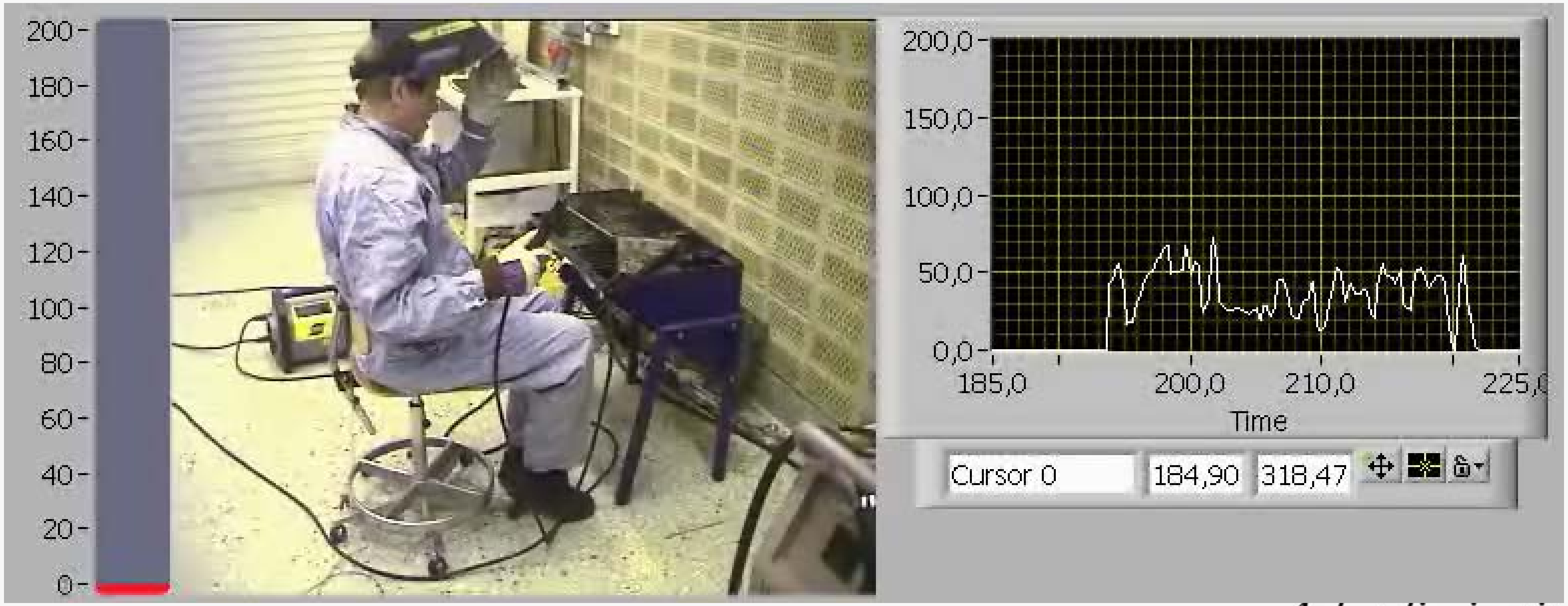

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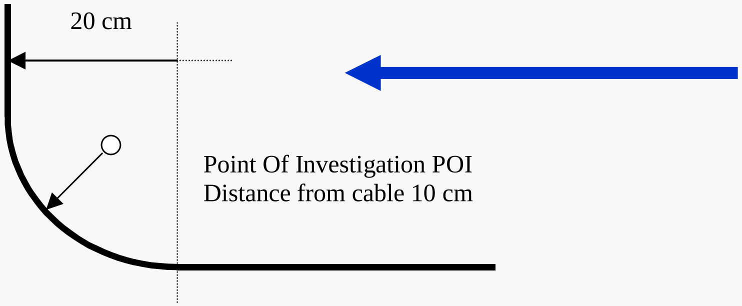
Summary

- Measurements according to TC 26A draft have shown that the reference values might be exceeded
- In most cases numerical dosimetric calculations are needed to show compliance with the EU directive
- Increase the awareness of how to reduce the exposure
- Need for education

To be discussed

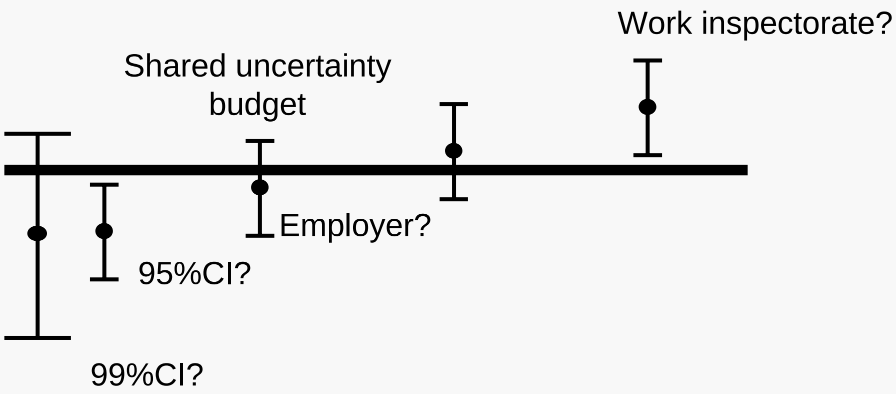


Changed distance ?
Probe tip ?

Worst case scenario ?

Complexity of standard - practical use ?

Comparison of products ?



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GENERAL TECHNIQUES FOR NUMERICAL CALCULATIONS FOR COMPLIANCE

P. Rossi & R. Falsaperla
ISPESL – Italy

Directive 2004/40 CE on the protection of workers from exposure to electromagnetic fields claims the employer to a specific risk assessment, and to verify the respect of limits of exposure that are expressed in terms of dosimetric quantities, that is induced current density (frequencies up to 10 MHz) and SAR - Specific Absorption Rate (frequency from 100 kHz to 10 GHz). At common frequencies involved in welding technology, induced current is the most significant parameter. Current density is defined as current per unit (1 cm^2) cross-sectional area flowing inside tissues as a result of direct exposure to electromagnetic fields.

Reduction of welders' exposure can be mostly achieved by proper workers' training, but in the case action values established by EU directive are exceeded, the evaluation of induced currents can be necessary, and numerical dosimetry is very useful to such aim.
In order to calculate the current density distribution in an exposed subject, numerical techniques adopt the following general approach:

- development of a set of differential or integral equations in order to model the electromagnetic problem (Maxwell equations);
- segmentation, that is the realization of a discrete model of the exposed subject and surrounding environment, subdivided into small homogeneous elements (pixels in 2D problems, voxels in 3D problems);
- assignment of dielectric properties (frequency dependent) to each element;
- transformation of differential or integral equations into a set of algebraic ones;
- resolution by means of standard computational algorithms.

There are several different calculation methods, many of which are listed in the CENELEC standard EN 50392 [1]:

- BEM (boundary element method);
- FDFD (finite difference frequency domain);
- FDTD (finite difference time domain);
- FEM (finite element method);
- FIT (finite integration technique);
- MoM (method of moments).

Many of these methods are implemented on commercial SW packages, provided with CAD tools able to represent sources and environment; nevertheless, results are affected by some intrinsic limitations, in particular the lack of detailed knowledge of dielectric properties of human tissues especially at the lowest frequencies, the need of very high resolution models of human body (i.e. able to represent typical occupational complex postures). The packages can be also of very complicated usage, so that little changes in parameters setting up can lead to significantly different results.

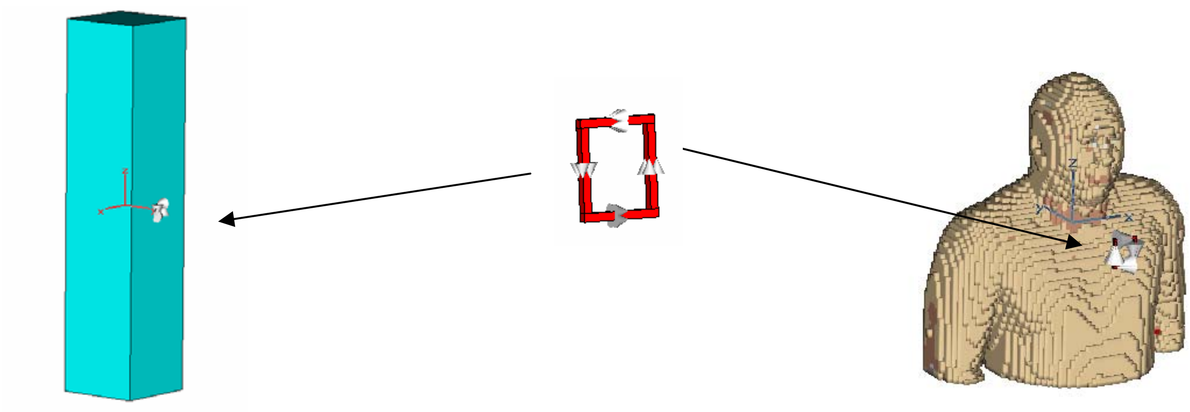
The choice of proper resolution of human tissues database (voxel dimension) is crucial, since the accuracy of the results depends on the resolution of the body model, and the induced current is calculated at the resolution of the model. Many body models are based on MRI medical data or anatomical cross sectional diagram/pictures, processed in order to recognize different tissue types and assign proper conductivity values, including CNS (Central Nervous System) such as the brain and the spinal cord. The models can be scaled to fit with the standard man as defined by the International Commission for Radiological Protection (ICRP), that is a man 1.76 m tall with a mass of 73 kg [2]. The most common example of body model are the MEET Man and HUGO, based on data from the Visible Human Project from the National Library of Medicine. Norman (NORmalized MAN) is another useful dataset based on medical imaging data, scaled to match with the ICRP Standard Man.

Low-frequency applications of numerical dosimetry take advantage of quasi-static approximation (QSA), where the time derivatives of the fields in Maxwell equations are set to zero. In this condition the electric and magnetic field problems are decoupled and can be solved separately. QSA is applicable when, in the exposure theatre, the linear dimensions of the involved objects and the distances among them are small if compared to the wavelength. QSA could be applied up to few hundreds of kHz, but applications up to a few tens of MHz have been reported.

According to CENELEC standard EN 50392, also RF (radio frequency) software codes can be employed, applying frequency scaling method.

In order to show the influence of body model on results, an example of calculation with different human body representations is presented. Figure 1 refers to exposure to a 50 Hz magnetic field source. The field source is a square loop, 50 mm of side length, with a current I = 1 A. In the first scenario (Figure 1a), the body is represented by means of an homogeneous cuboid (0.4 x 0.4 x 1.8 m) with electric conductivity σ of 0.1 S/m. In the second one, (Figure 1b), the body is represented by the anatomical database HUGO. The distance between the magnetic field source and the human model is 10 mm in both cases. The characteristics of the cuboid are the same defined in CENELEC Standard EN 50392, for the validation procedure outlined to test the accuracy of induced current calculation of commercial software.

The simulations have been carried out by the ElectroMagnetic Studio (EMS) package by CST- Germany, based on FIT (*Finite Integration Technique*) enhanced by PBA technique (*Perfect Boundary Approximation*) [3].



a) b)

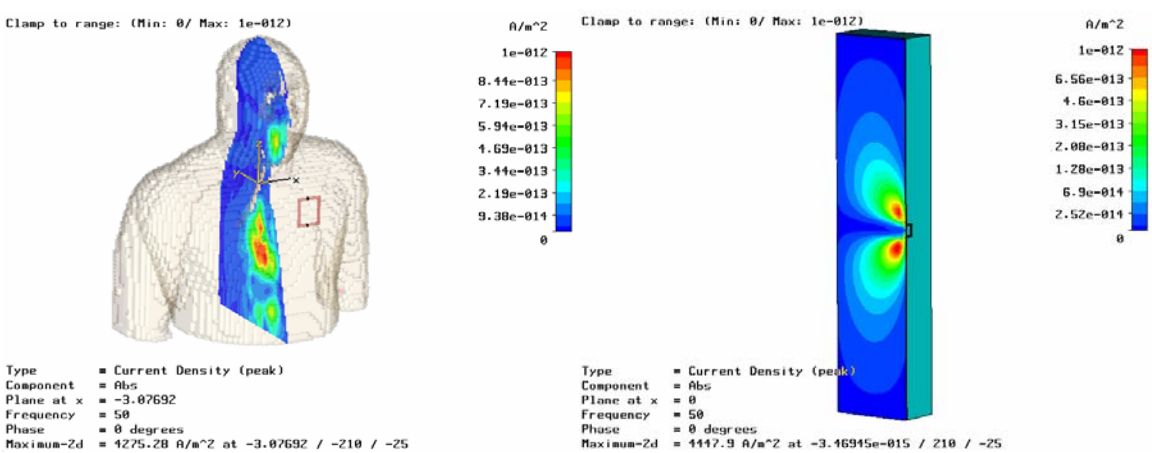
Figure 1

Table 1 shows the spatial resolution of calculation domain for the two different simulations. The total number of cells is derived from the segmentation step.

Table 1

	HUGO	Cuboid
Min mesh step [mm]	4.62	5
Max mesh step [mm]	36.04	35.25
Meshcells (number)	700434	56940

Figure 3 shows a 2D scalar representation of the induced current density (peak values at 0° phase) on a sagittal plane.



a) b)

Figure 3

Table 2 summarizes the results (mean and maximum J values) from the two simulations.

Table 2 – Induced current J [A/m^2]

	HUGO	Cuboid
J_{mean}	1.03×10^{-7}	6.77×10^{-8}
J_{max}	4.17×10^{-7}	5.24×10^{-6}

As shown in Table 2, results differ of one order of magnitude, due to the different accuracies of anatomical models.

For assessment of occupational exposures, the accuracy of results is affected by other factors, like complex postures, sources, and indoors electromagnetic environment.

Directive 2004/40/CE poses a demand on dosimetry in occupational exposures, and Work-Package 12 of Main Task 2 of EMF-NET 6FP Co-ordination Action has the aim of addressing which methods or SWs can be used in different situations, and how refined or approximated should be the representation of the exposure problem.

References

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[2] EN 50357: 2001-10: Evaluation of human exposure to electromagnetic fields from devices used in Electronic Article Surveillance (EAS), Radio Frequency Identification (RFID) and similar applications, CENELEC Standard.

[3] CST Computer Simulation Technology: 2006, EM Studio, User's Manuals, October 2005, Darmstadt, Germany.

FUTURE EU DIRECTIVE ON OPTICAL RADIATION (RELATED TO WELDING PROCESSES).

Georges Herbillon
European Commission

The directive of the European Parliament and of the Council on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (optical radiation) has been adopted very recently, more precisely on 14 February by the European Parliament and on 23 February 2006 by the Council. The final formal step, the signature of the adopted text by the Presidents of the 2 institutions is foreseen on 5 April 2006. The publication in the Official Journal should follow later in April or early May.

The history of the file follows the same route as the one of directive 2004/40/EC and is already addressed in the presentation "Electromagnetic fields: public and workers protection in the European Union".

As already said there, on the invitation of the European Parliament, the Commission tabled a proposal for a directive for protection of the workers against the effects of different physical agents: vibrations, noise, electromagnetic fields and optical radiation. A slightly amended proposal was published in 1994 after the first reading in the European Parliament.

The issues were of very technical nature and the discussions of the proposal only started in the Council in 1999, after the decision had been taken to split the proposal into four parts and to discuss each component separately. The first directive was adopted by the Council and the Parliament in 2002 on “vibrations” (2002/44/EC), a second one in 2003 on “noise” at work (2003/10/EC) and the third one on electromagnetic fields in 2004 (2004/40/EC). The discussions on the fourth and last component “optical radiation” started in June 2004 under Irish Presidency. Very intensive technical discussions took place under subsequent Dutch and Luxembourg's presidencies in the Council. The Council adopted a Common Position which contained provisions covering optical radiation of both artificial and natural origin. However after intense discussions in the European Parliament, the scope has been limited to optical radiation of artificial origin. The related directive - which is binding legislation - was adopted as indicated above.

What is the philosophy of the optical radiation directive?

As it is the case for most EU directives covering occupational health and safety aspects, the *optical radiation directive* is “prevention” oriented and is built upon the same principles as the so-called *framework directive* 89/391/EC[5] *on the introduction of measures to encourage improvements in the safety and health of workers at work*.

[5] O.J. L183 of 29.6.1989, p.1

The principles laid down there can be summarized as follows: in his enterprise the employer is responsible for the health and safety of the workers working for him directly or under a subcontracting agreement. He is responsible for the determination and assessment of risks; he must put in place provisions aiming at avoiding or reducing the risks, giving priority to collective protective measures before personal ones. He must also ensure appropriate and timely information and training of workers, foresee consultation and participation of them, and guarantee appropriate health surveillance in line with the national rules and practices.

The *optical radiation directive* explains, in some details for the specific case of occupational exposure to optical radiation of artificial origin (introducing exposure limits etc.), the obligations of the employers which were already made compulsory in the *framework directive*. As welding processes produce or use optical radiation of "artificial origin", the provisions of the directive will fully apply to the welders community once the directive will have been transposed into national legislation by the Member States (April 2010).

What does the *optical radiation directive* actually cover?

This directive covers the wavelengths range from 100 nanometres (far Ultraviolet) up to 1 mm (far Infrared) and introduces binding *Exposure Limit Values* (ELVs): in annex 1 for non coherent radiation and in annex 2 for laser radiation. Contrary to the recent EMF directive, the *optical radiation directive* does not introduce *Action Values*.

It must be emphasized that during the intense discussions in the Council, many technical experts and scientists from the Member States were involved and real attention was paid to align exposures limits on existing international recommendations or standards. In many Member States these limits are already compulsory, so no major changes should be observed there. In other States, some limits are not compulsory yet but those proposed by various standardization bodies are applied or recommended. There, the binding character of the imposed limits under the directive may affect some operational practices.

As said before, the scope of the directive is limited to optical radiation of *artificial origin.* Radiation of natural origin (mainly sunlight) is thus not covered but remains to be covered under the more general provisions of the *framework directive.* But as long as artificial radiation is concerned, *the provisions of the directives apply to all sectors* without exception!

Subsequently to repetitive requests from Member States and Members of the European Parliament, the European Commission has accepted to be imposed a specific obligation under the directive despite the usual legal practice agreed between the Institutions that the provisions of a directive are normally addressed to the Member States. Article 13 says: *"In order to facilitate implementation of this Directive, the Commission shall draw up a practical guide…*".

This will be given due attention by the Commission and work will be started in 2007 in order to be ready before the end of the time span foreseen for transposition in the Member States (April 2010).

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LASER WELDING – BIOLOGICAL EFFECTS AND SAFETY ASPECTS

Agnieszka Wolska
CIOP – PIB – Finland

Introduction

Industrial applications of lasers include marking, welding, cutting and other material processing. Laser welding constitutes about 21% of all industrial laser applications in Europe [11].
From among all laser material processing welding process is one of the most intense artificial sourcesof optical radiation both coherent and incoherent.
The purpose of this paper is to present some aspects of biological effects and safety related tooptical radiation emitted during the laser welding.
Lasers used for welding are characterized by significant power output and use a focused beamof infrared radiation to achieve very precise welds. Depending on the kind of material which is weldedand kind of welding method, different kind of lasers and power output are used. The major hazard ofthose lasers' powerful beam is to the eyes, which can be partially or even permanent blinded when hit with the beam and to the skin which can be seriously burn [10]. Important fact is that laser radiationused in laser welding equipment is invisible (infrared radiation), so the hazard may not be visible andin result it is more difficult to convince others to take precautions against hazards they cannot see and may not understand [9]
Important thing is that during welding process both visible and invisible radiations are produced. During the interaction with the workpiece, high levels of hazardous blue lightand ultraviolet incoherent radiations are produced. This kind of radiation is often called plasma-related plume radiation or secondary radiation. It is often reflected from workpiece into the work area. So in fact hazard exists from two kind of optical radiation**:** invisible infrared laser radiation (direct and diffusely scattered beam) and incoherent ultraviolet and visible radiation (secondary radiation).

Laser biological hazards

Optical radiation can cause biological damage both through thermal and photochemicalreactions. The damage related to laser radiation is mostly caused by temperature effects due to absorbed high energy. But incoherent ultraviolet and blue light radiations which appear during the welding process can cause photochemical reactions and injuries both to eye and skin.

Eye injury

Hazardous effects can occur to various parts of eye depending on the wavelength of the laser radiation. Ultraviolet with wavelengths from 200 – 215 nm (UV-C) and infrared with wavelengths of 1400 nm or greater (IR-B and IR-C) are absorbed in the cornea. Near ultraviolet (UV-A) is absorbed in the lens. Wavelengths from 780 to 3000 nm (IR-A and IR-B) are also partially absorbed in the lens. Visible radiation (400 – 780 nm) and near infrared (IR-A) are transmitted to the retina. So the components of the eye most affected to optical

radiation damage are the cornea, retina and lens. The adverse effects of the eye exposure to different wave bands of optical radiation are presented in table 1. All of those injuries may be permanent and serious. The special attention is paid on retinal injury (from the optical spectrum between 400 and 1400 nm), which can be particularly hazardous. That wave band is also known as the “retinal hazard region” [1, 6]. It is because of focal magnification of the eye (focusing effect of the lens), which is approximately 100,000 times [6, 8, 10]. A laser beam of several millimeters in diameter may be focused to a spot on the retina of 10 mm diameter what means that the irradiance of 1 mW/cm2 entering the eye is effectively increased to 100 W/cm2, when it reaches the retina [8]. In result that value of irradiance is more than enough to cause the damage [10].
Depending on the place on retina where the laser radiation is focused the hardness of injury is different. Injury of the fovea may result in permanent blindness, but injury in peripheral areas of fovea is less serious and sometimes when the injury is in the peripheral part of retina the effects are not noticeable or distracting. The other aspect which is important for eye injury is ocular focusing effect. If the eye is not focused at a distance or if the beam is reflected from diffuse surface, much higher levels of laser radiation would be necessary to cause injury [10]. Duration of exposure and pulse duration (for pulsed lasers) also play the important role to the eye injury.

Table 1 Relationship between eye injuries and the range of optical radiation

Range of radiation	**Eye Injury**
UV-A	Cataract (delayed – occurs after many years of chronic exposition
UV-B and UV-C	Keratoconjuctivitis (welder’s flash), photokeractoconcjunktivitis)
VIS and IR-A	Photoretinitis, retinal burns, scotoma (blind spot in the fovea)
IR-B and IR-C	Corneal burns and lesions

Skin injury

Skin is the largest organ of the body, and is at the greatest risk of contact with laser beam. The most likely skin surfaces to be exposed to the beam are hands, head and arms [7]. Skin consists of four main components: stratum corneum (dead layer), epidermis, dermis corium and subcutaneous tissue.
The first (the most outer) skin component – dead layer -protects the living tissue from water loss, injury from physical objects and radiant energy and in fact makes the protection layer of the skin. The epidermis is outermost living tissue layer, in which tanning process take place. Dermis consists of tissues which give the skin elasticity and supportive strength. The subcutaneous tissue is made mostly of fatty tissues serving insulation and shock absorption medium. Laser effects on skin tissue depend on the power density of the incident beam, absorption of tissues at the incident wavelength, duration of exposition and the effects of blood circulation and heat conduction in the affected area [7]. The short term effects of exposure to laser radiation above MPEs are skin burns or erythema. Usually it is thermal injury following temperature elevation in skin tissues or photochemical injury from excessive levels of UV. Long term effects means delayed adverse effects from repeated or chronic exposition to laser radiation. Only ultraviolet is considered to cause long-term effects like skin aging and skin cancer. The adverse effects of the skin exposure to different ranges of optical radiation are presented in table 2.

Table 2 Relationship between skin injuries and the range of optical radiation

Range of radiation	**Skin injury**
UV	Erythema, sunburn, skin aging (long term), skin cancer (long term)
VIS	Thermal damage
IR	Thermal damage

Laser safety aspects

Since the unprotected eye or skin are extremely sensitive to laser radiation and can be permanently damaged from direct and reflected beams, it is extremely important to undertake all possible measures against ocular and skin injuries of users. Usually injuries are in result of unintended exposition to direct beam or scattered laser radiation. Additional hazard exists from incoherent ultraviolet and visible radiation which is generated during the welding process.
The most effective prevention of injury from a laser beam is to ensure that laser beam is encapsulated so that no human exposure can occur [6]. The level of exposure which is the boarder between safe and potentially harmful is called "Maximum Permissible Exposure" (MPE) [12, 13, 14].
As the optical and thermal properties of eye and skin are different, the MPE for the eye and skin differ.
Consequently there is a set of MPE values for ocular exposure and another for the skin exposure. Taking into account complicated method of hazard evaluation based on MPEs, international standardization committees developed laser safety classification. According to that classification, lasers are grouped into seven classes with similar hazard potentials. The classification scheme, requirements and test procedures are laid down in international standard EN 60825-1 [15], and manufacturers are obligated to classify theirs products and place adequate warning labels on them. In most cases lasers used to welding are ordered to class 4, because of high power optical beam. It means that both direct beam and diffuse reflected laser radiation are hazardous to eye and skin and protective measures such as appropriate guards around the processing zone and filters for viewing windows need to be taken to ensure safety.

Hazard of coherent radiation during laser welding

Laser welding process consists of two or three phases: 1) surface treatment – the radiant energy induces the increase of welding material temperature simultaneously with increasing the absorption factor until welding puddle appears, 2) welding puddle – junction of welding materials, 3) plasma – appears only when irradiance of laser radiation exceeds the distraction level of welded material. Sometimes could happen that plasma appears immediately without previous two phases.
There are some published results of the intensity of scattered laser radiation during welding. For example, the results of measurements carried out by Rockwell [5] showed that irradiance was about 7.2 W/m2 at a distance of 1 m at the normal output power of 1 kW CO_2 laser. That relatively small value of irradiance could point that the measurements were made during the second phase of welding i.e. welding puddle. The other results of measurements carried out by Hietanen at all [2]

indicated that irradiance of scattered reflection during surface treatment phase was about 1,2 MW/m2 at a distance of about 1 m at the normal output power of 2.5 kW of CO_2 laser. This amount of irradiance can easily injure both eye and skin. This is why additional shielding against reflected laser
radiation should be applied, especially for that first phase of welding. The application of additional protective shield against that kind of radiation seems to be relevant from safe usage point of view. In order to solve that problem some calculations of shield parameters need to be done. First of all, the solid figure of reflected radiation should be developed. It depends both on laser parameters like wavelength, output power, kind of work (continuous, pulsed), properties of shielding gas used in welding processing (gas refraction factor) and properties of workpiece surface. Having these data, MPEs values and eye parameters (aperture and eye distance from point of reflection on the workpiece)
it is possible to calculate the minimum angle of the shield. To make that work easier and quicker the special computer program “Laser shield solver” was prepared by CIOP-PIB. An example of results of computer calculations of shield angle for HPLD laser welding is shown in table 3.

Table 3 Results of shield angle calculations for laser welding (surface treatment phase)

Welded material	*Silver*
Type of laser	*HPLD*
Wavelength of radiation	*940 nm*
Output power	*2005 W*
Spot area	*7 mm²*
Irradiance on the welded surface	3.6×10^7 *W/m²*
Calculated max. irradiance of an eye surface	1.7×10^7 *W/m² (aperture of eye: 7mm)*
Calculated shield angle - β	*85°*

Having shield angle it is easy to calculate the semidiameter (*R0*) of shield using the formula:
$R0 = d \cdot \cos b$, where d is the distance between shield and reflecting surface.

Hazard of incoherent optical radiation during laser welding

During the plasma phase of welding process appears the hazard related to secondary radiation.It concerns ultraviolet and visible incoherent radiation. Results of plasma related radiation measurements carried out by international working group [4] and other researchers [2, 5] show that exposure limit values fro UV and blue light hazard were exceeded [2, 4] so that kind of radiation is capable of causing photokeratitis in the eye (welder’s flash) [4]. The example of incoherent radiation measurements results during CO_2 welding are presented in table 4.

Table 4 Irradiance of UV and visible radiation at a distance of 1 m from CO2 laser welding [2] and adequate Threshold Limit Values (TLVs) [13]

Laser Power	*Material*	*Euveffµ W/cm²*	*TLV for UV hazard*	*Eblue µW/cm²*	*TLV – for blue light hazard*
1.8	*Carbon Steel*	*24*	*0.1 µ W/cm²*	*4*	*1 µ W/cm²*
1.8	*Stainless steel*	*31*		*15*	

Conclusions

In general commercial laser machines are inherently safe and safety issues usually only need to be dealt with by the manufacturer and by the service personnel. Only under certain conditions laser safety issues need to be considered in detail, like [6]: service and maintenance, installation of laser system, constructing and building laser systems, science and research applications, using a laser system for other than intended purpose or modifying the system. However some accidents related to unintended exposition to laser radiation also happen mostly because of mirror reflection from shiny surfaces during welding [2]. The most frequent eye injuries were found for laser adjustment and alignment resulting from lack of laser safety eyewear, reflected laser beam and insufficient users' knowledge about danger of lasers [3].

The risk could be reduced considerably by decreasing the working time near the laser beam, by avoiding reflecting surfaces at work station, by careful eye protection, and appropriate application of shields. During welding operations the laser beam is almost totally enclosed, but machine errors can lead to situations involving the risk of specular reflections [2].

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OCCUPATIONAL HEALTH COSIDERATIONS ON ELECTROMAGNETIC FIELDS OF WELDING

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Health hazards of welding

Welders work with a variety of materials under varied conditions and are exposed to many health hazards, including air contaminants (metal fumes, particulates, gases), physical agents such as infrared and ultraviolet radiation, noise, electricity, electromagnetic fields and ergonomic stress.
Common air contaminants of different welding processes and their potential hazards are:

Iron oxide	benign pneumoconiosis, siderosis
Manganese	neurotoxicity, parkinsonsm, pneumonia
Chromium	lung cancer, allergy
Nickel	lung cancer, allergy
Cadmium	oxide acute lung injury, nefropathy
Zinc oxide	metal fume fever
Fluoride	skin or respiratory irritation
Silicium	dioxide silicosis
Beryllium	sensitization, granulomatous inflammatory lung disorder
Copper	granulomatous liver disease
Vanadium	chronic obstructive lung disease, neurobehavioral disturbances
Molybdenum	lungfbrosis
Ozon	respiratory irritation, asthma
Nitrogen oxides	acute lung injury
Carbon monoxide	systemic poisoning

Coatings or contaminants may present additional hazards, particularly when their presence and potential hazard are unknown or unsuspected. The formation of toxic gases, fume or vapours is usually due to the heating of a coated or treated metal, although phosgene exposure is related to the action of ultraviolet radiation or heat onchlorinated hydrocarbon vapours.

Physical hazards welders are exposed to and their potential health effects:
Ultraviolet radiation photokeratitis, skinerythema, T cell immunomodulation
Infrared radiation burns, cataract
Electromagnetic fields induction of currents, stimulation of excitable cells
Electricity shocks, electrocution
Noise hearing loss, stress reaction, hypertension
Ergonomic stress muscle strain

Epidemiology of the health of welders

Harm to several body systems has been attributed to the emissions from welding processes.

Respiratory system

While the fact of a cause-effect relationship is seldom a matter of contention for acute effects of inhalation of welding fumes on the respiratory system, the possibility and nature of chronic effects of exposure have long been the subject of research studies and, as the results have not been at all consistent, these remain a matter of debate.

Probable reasons for the variations in conclusion include a requirement for more subjects than there have been welders available to give sufficient power to test the hypothesis of individual studies satisfactorily; the variety in the nature of welding work and thus of fume exposure between welders; failure to appreciate this variety when seeking to consolidate small, possibly disparate, groups of welders into a large and supposedly homogeneously exposed study group; the absence of contemporaneous records of work or exposure from which some estimate of dose might be made; and failure to take account of confounding exposure in a group with a generally higher exposure to asbestos than most. Moreover, many of the effects of metal fumes and gases remain poorly understood. It should also be emphasized that the results of the published studies relate mainly to exposures some time in the past and are not necessarily relevant for the present day conditions in modernised industries.

Metal fume fever is an unpleasant but, in its uncomplicated form, self-limiting acute flu-like illness caused by a single exposure to freshly formed metal oxide fumes. The concentration need not to be high.

Chronic bronchitis

Over the years the studies reporting no excess prevalence of chronic bronchitis in welders have almost been matched by those which have found an excess of the symptom complex or of individual symptoms, especially if the welders were tobacco smokers.

Occupational asthma may be caused by inhalation of irritants or sensitising agents. Welding fume can be rich in both. Overall, reports of occupational asthma in relation to welding are few in comparison with the other health effects. This suggest an infrequent occurrence of the disease in association with welding.

The risk of welders who have been exposed to fumes in the past developing lungcancer is about 30 % greater than for that of the general population. Compound of chromium and nickel, proven carcinogens in other industrial circumstances, were initially thought to be the cause. The excess however is not confined to stainless steel welders who are the most likely to be exposed to the fume containing these compounds, but it is also found in those who weld only mild steel and thus have no such occupational exposure. The excess may be explained in part by tobacco smoking and/or with previously inhaled asbestos.

Central and peripheral nervous system The brain is a recognized target for aluminium toxicity. Long-term exposure to aluminium-containing welding fumes may be related to an excess in neuropsychiatric symptoms and, on testing, deficiencies in short-term memory, attention and motor function, with some evidence of a dose-effect relationship suggesting cumulative toxicity due to aluminium exposure. Welders may be sufficiently exposed to manganese fume during welding operations to suffer toxic consequences exhibited as encephalopathy and disturbed motor function (parkinsonism). Some studies suggest an association between amyotrofic lateral sclerosis and welding.

Reproductive system

Welders of mild or stainless steel may run a small risk of occupationally induced reduced fertility but the evidence is by no means constant. Observed effects on semen quality appear to be irreversible in the short term but increasingly reversible as the years pass after exposure to welding has ceased. Suggested causes include exposure to radiant heat or to metals such as chromium, nickel, manganese and cadmium in welding fume.

Skin

Ultaviolet and infrared from electric arc processes commonly cause ray burn (erythema) and, ultimately, persistent pigmentation in unprotected areas of skin.
Eyes
Welders have a high incidence of eye injuries, especially due to foreign bodies and from the arc's ultraviolet radiation, the latter causing arc-eye.
Other systems
There is no evidence to link welding with disease of the urinary, gastrointestinal or blood forming systems. There is a possibility of a relationship between welding and ischemic heart disease. A general hypothesis linking inhalation of particles to the occurrence of ischemic heart disease via an inflammatory process is discussed.

The health effects of exposure to magnetic fields of welding.

There are only few studies that have investigated the relationship between the magnetic field exposure in welding industries and the occurrence of disease. Håkansson 2002 made a study on cancer incidence and magnetic field exposure in industries using resistance welding in Sweden. Men in the very high exposure group showed an increased incidence of tumours of the kidney, pituitary gland, and biliary passages and liver. For these cancer sites an exposure-response relation was indicated. Women in the very high exposure group showed an increased incidence of astrocytoma I-IV, with a clear exposure-response pattern. An association was suggested in the high exposure group only, for cancer of the corpus uteri and multiple myeloma. Decreased risks in the very high exposure group among men were found for cancer of the colon and the connective tissue/muscle.
Håkansson 2003 studied the risk of neurodegenerative disease in welders exposed to high levels of magnetic fields. The risk of Alzheimer's disease as primary or contributing cause of death increased with increasing exposure to ELF-EMF among both men and women, with a relative risk of 4.0 and a 95 % confidence interval of 1.4 – 11.7 in the highest exposure group for both sexes combined. There was a relative risk of 2.2 with a 95 % confidence interval 1.0 – 4.7 for amyotrophic lateral sclerosis in the highest exposure group with the suggestion of an exposure-response relationship. No evidence of increased risk was seen for Parkinson' disease or multiple sclerosis. Håkansson 2005 made a case control study on the relationship between resistance welding and tumours of the endocrine glands. There was an overall increased risk for all tumours of the endocrine glands for individuals who had been welding sometime during follow up. The increased risk was attributable to arc welding; for resistance welding there was no clear evidence of an association. The authors found an increased risk for the adrenal gland in relation to arc welding, and for the parathyroid glands in relation to both arc welding and resistance welding. An imprecise increase in risk was also noted for tumours of the pituary gland for arc welding. The increased risks of endocrine gland tumours related to welding might be explained by exposure to high levels of ELF magnetic fields.

Conclusion

Welders are exposed to a lot of different health hazards.
Welding fumes can cause effects on the lung, the nervous system and probably other systems.
There is no clear evidence that the magnetic fields to which welders are exposed cause adverse health effects.
Studying the health effects of magnetic fields of welding is difficult because of confounding.

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