A photograph of an industrial facility, likely a power plant or refinery, at dusk. Several tall, dark smokestacks rise from a large, multi-story building. The sky is a deep blue, and the facility's lights are visible, creating a silhouette effect. The overall scene is industrial and somewhat somber due to the low light.

# Good measurement practice (GMP) in the exposure assessment of occupational ELF electromagnetic fields

Gilbert Decat  
VITO, Mol, Belgium  
[gilbert.decat@vito.be]

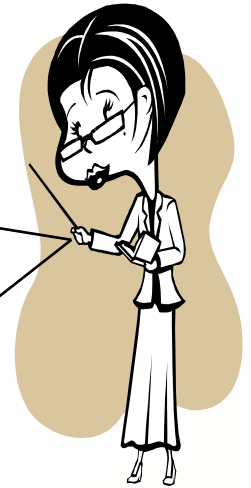


# CONTENT

- Field & source characterization
- Experimental design
- GMP and Case Studies



# FIRST GMP REQUIREMENT



MASTERING THE PHYSICAL  
BACKGROUND FOR:

- FIELD CHARACTERIZATION
- SOURCE CHARACTERIZATION



# Field characterization

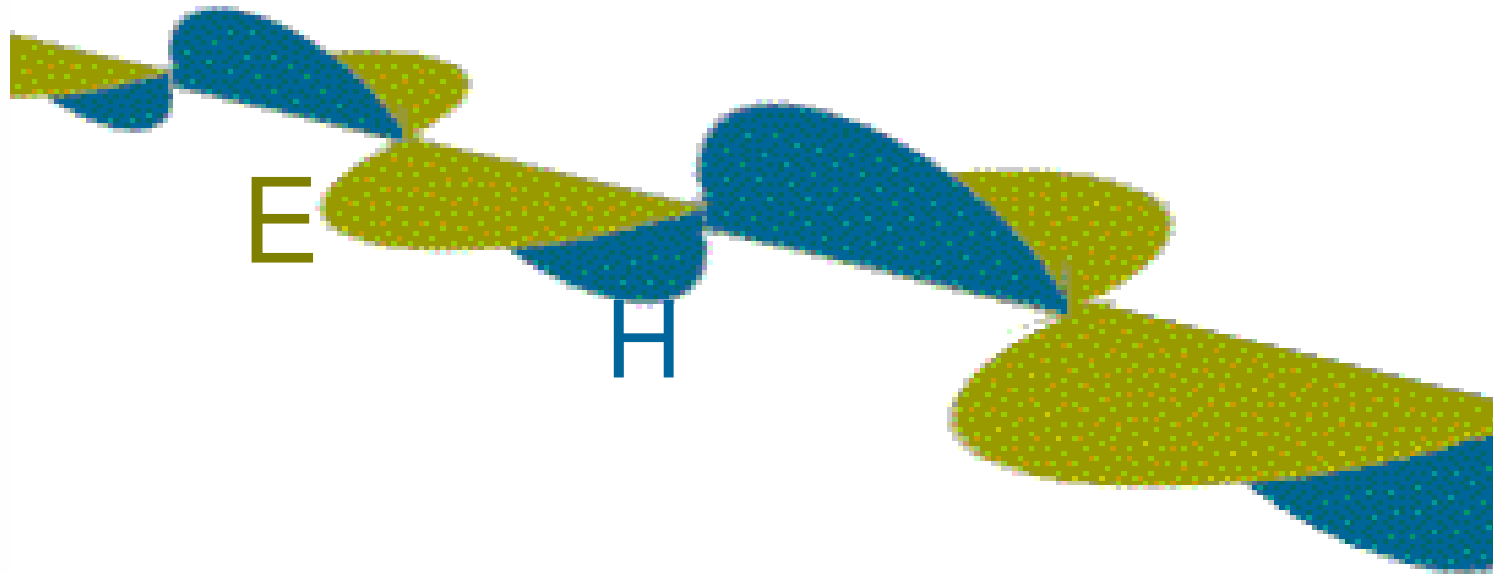
Magnitude  
&  
Frequency

Waveform

Polarization



# WHY MEASURING THE ELF ELECTRIC & MAGNETIC FIELD APART?



- **Far field** :  $E/H = 377\Omega$
- **Near field:  $E/H \neq 377\Omega$ : E- & H uncoupled**
  - ELF  $\lambda = 10\ 000\ \text{km} > \text{object} = \text{influence zone}$
  - E & H- don't radiate away from the source



# GMP = knowledge about frequency, harmonics, magnitude metrics

- **ELF Frequency: 30 - 300 Hz**
- **Harmonics: n x fundamental frequency**
- **E- & H are separate forces:**
  - **E related to  $U_{(eff.)}$  : constant over time**
  - **H related to  $I_{(eff.)}$  : varies highly over time**
  - **E relation to B : depends on  $\lambda$**
  - **H related to B :  $B = \mu.H$  (T)**
- **E & B varies during cycle:  $[B = B_{peak} \sin wt]$**
- **I, E & B expressed as rms  $[B_{(rms)} = B_{peak} / \sqrt{2}]$**
- **RMS-value is used for compliance testing**

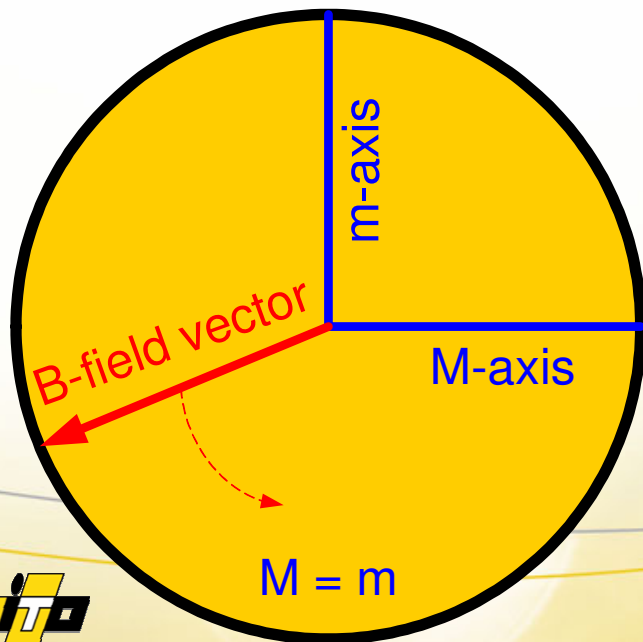
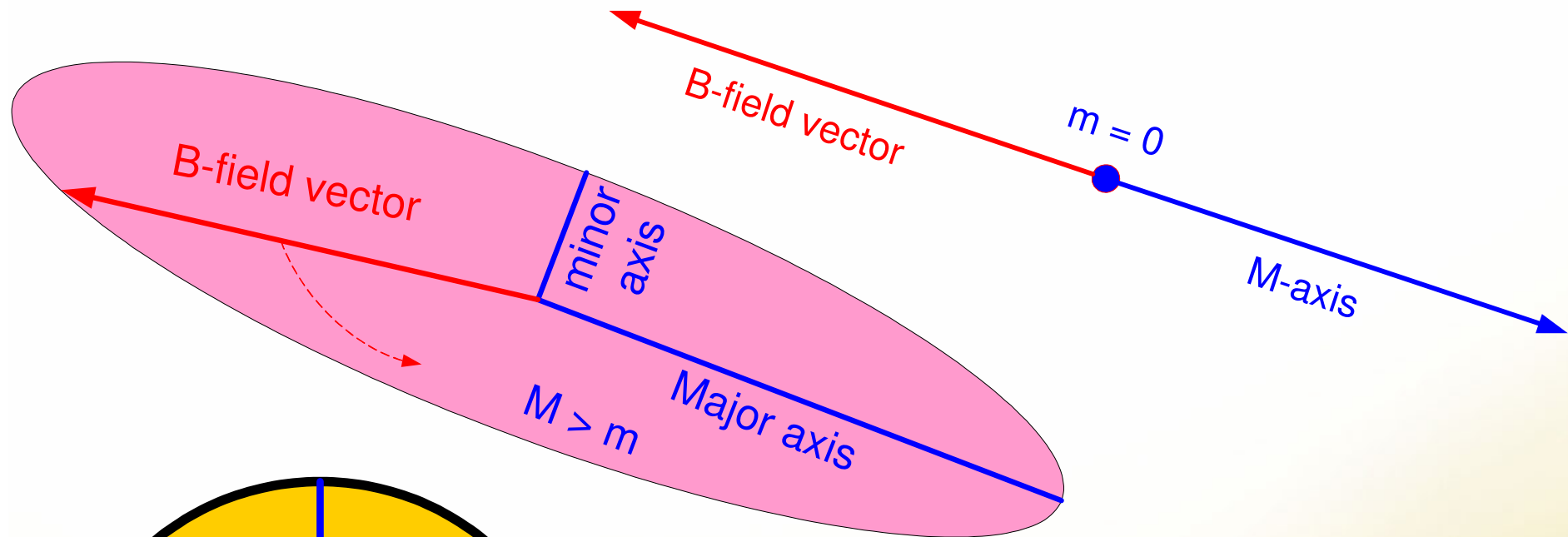


# GMP = waveform characterization

- **Sinusoidal fields**: characterized by their frequency
- **Non-sinusoidal waveforms**: frequency range > nominal frequency of the source. Additional parameters to be specified: rise time, decay time, pulse duration, and pulse repetition rate
- **Transients** may contain significant amounts of energy and therefore may be expected to be more likely to affect biological systems.
- **Time rate of change of B (dB/dt)**: relates B & f  
[sinusoidal B-field:  $\text{dB/dt} = 2\pi f B_{(\text{peak})}$ ]  
↑ dB/dt = ↑ body coupling = ↑ induced current
- **High dB/dt occupational source**: scarce



# GMP deals with field polarization



$$R = (B_x^2 + B_y^2 + B_z^2)^{1/2}$$

# GMP = Source & exposure characterization

- **EMF's are produced by sources which generate, transmit, and use electric energy**
- **Large variation in size of the sources**
- **Differences in positioning with respect to workers and adjacent locals**
- **Occupational sources classified in: low, middle and high exposure sources**



# Source Operation Characteristic and exposure duration

Matrix with Source Operation Characteristics						
Power (%)	Effective				Exposure	Remarks
	Power	Voltage	Current	Frequency	Duration	
25	TTTTT	TTTTT	TTTTT	TTTTT	TTTTT	TTTTT
50	TTTTT	TTTTT	TTTTT	TTTTT	TTTTT	TTTTT
75	TTTTT	TTTTT	TTTTT	TTTTT	TTTTT	TTTTT
100	TTTTT	TTTTT	TTTTT	TTTTT	TTTTT	TTTTT



# GMP = Calculation of whole workplace Exposure Load (EL)

$$EL = \sum_{p1}^{pn} (\sum (BE_{c1}^{cn} \cdot ED_{c1}^{cn}))$$

- $\sum_{p1}^{pn}$  : sum exposure from place 1 to place n
- BE: best estimator of the real exposure from exposure condition 1 to condition n
- ED: exposure duration per exposure condition 1 to condition n

**= BEST APPROACH FOR EMF JOB CLASSIFICATION**



# EXPERIMENTAL DESIGN

Stationary vs  
Personal  
exposimetry

Controlled  
and in situ  
GMP

BASIC DOCUMENTS



# GMP = Balanced experimental design

- Based on CENELEC standards and other doc. like NIOHS etc.
- Consult with safety staff about the exposure problem & conditions
- Defining the complexity of the measurement situation by careful inspection of the working environment.
- List of the relevant sources
- List of field characteristics
- Notation about the position and orientation with respect to the workers or adjacent offices



# GMP = restricting variability & uncertainty

- Variability & uncertainty are a part of each measurement scenario.
- Variability is a property of nature related to value heterogeneity over time, space and subjects
- Uncertainty is a lack of knowledge about the true value of exposure due to measurement errors or other factors



# GMP = good statistical practice

**Recommendations and decisions are based on adequate and powerful statistics:**

- **Sampling theory**
- **Reproducibility testing**
- **Distribution fitting**
- **Best estimator of real exposure: parametric or non-parametric location parameter**
- **Outliers theory**
- **Curve fitting**



# GMP = questioning about the most realistic exposure assessment approach

## MEASUREMENTS

Controlled conditions

Personal exposure

Stationary exposure

Workplaces conditons.

Personal exposure

Stationary exposure

→ # of replicates



# GMP = selection of instruments

PERSONAL  
EXPOSURE



Broad band  
exposimeters

STATIONARY  
EXPOSURE



- Broad band meters
- Small band meters
- Oscilloscopes
- dB/dt meters

# GMP = selection of basic documents

Exposure standards

Compliance testing

- ICNIRP (1998)
- ICNIRP (2003)
- Eu 2004/40/EC dir.
- 

CENELEC standards

regarding:

- Cable distance
- Averaging
- Uncertainty

NIOHS documents



# GMP and case studies

Handheld antitheft  
activator

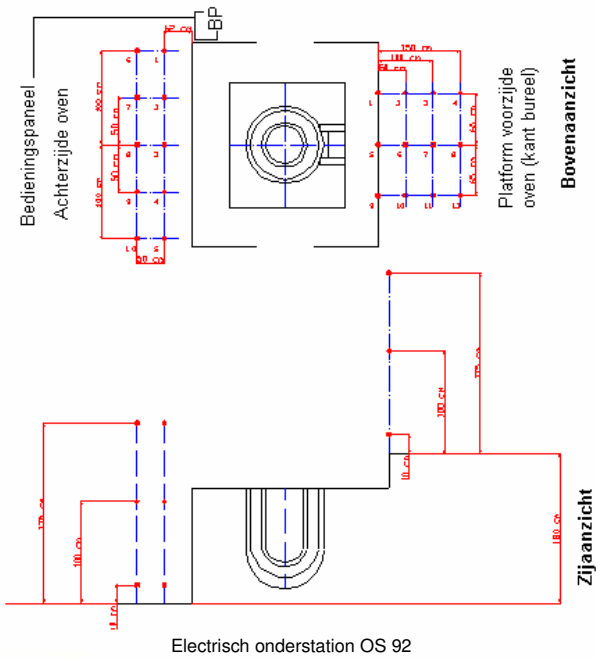
Welding

Induction ovens

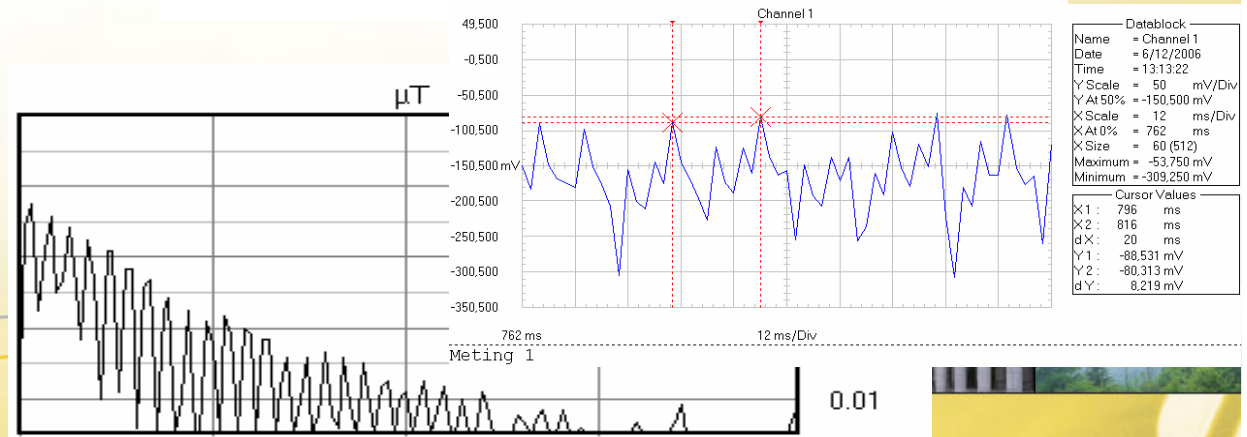
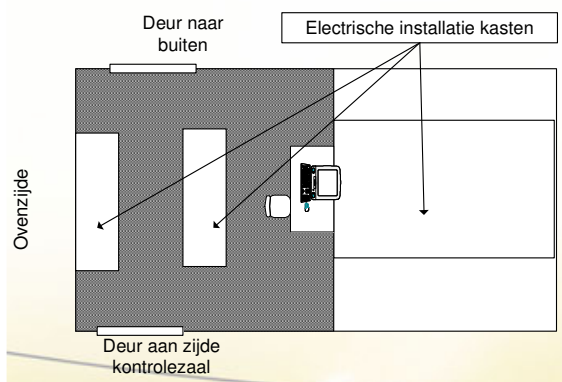
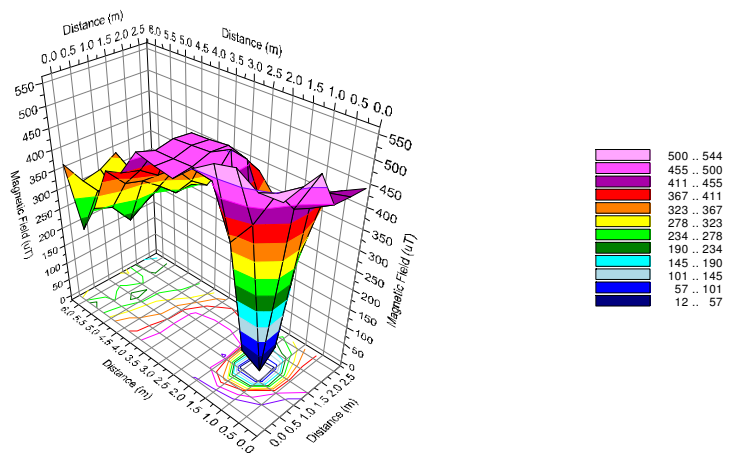
ESD



# GENERAL GMP APPROACH



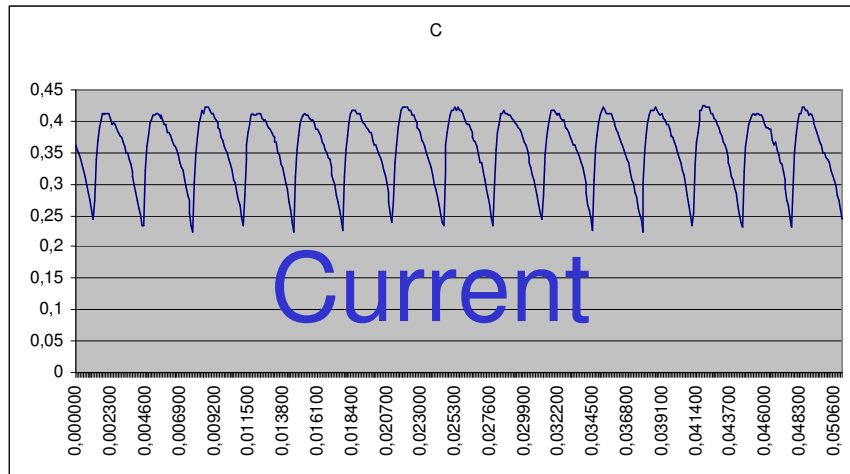
Source Operation Characteristics				
Power (%)	Effective			
	Power	Voltage	Current	Frequency
50000	50000	50000	50000	50000
50000	50000	50000	50000	50000
50000	50000	50000	50000	50000



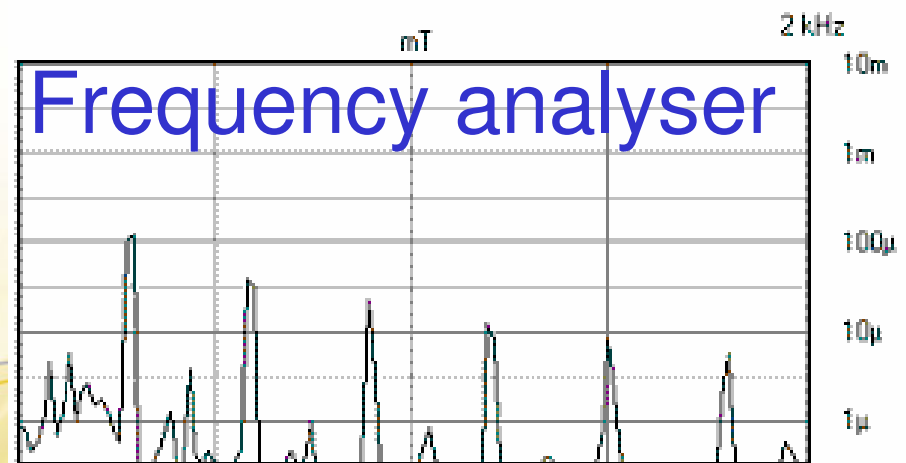
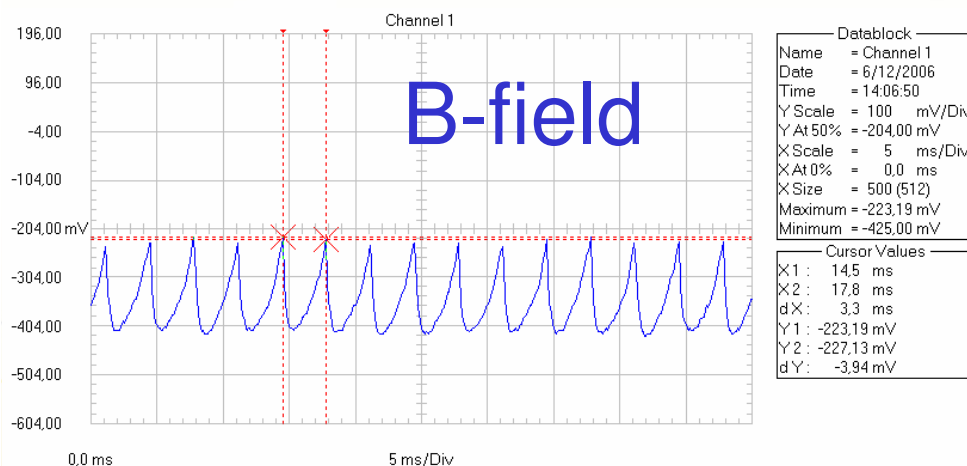
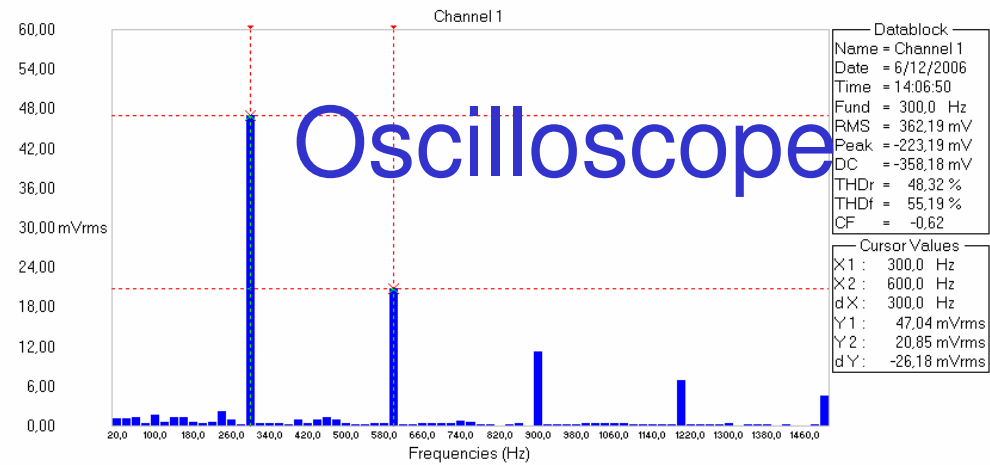
Gebied waarin het magnetisch veld groter kan zijn dan 500 µT tijdens oven in werking bij vol vermogen

# GMP and spray welding (Cenelec TC26A)

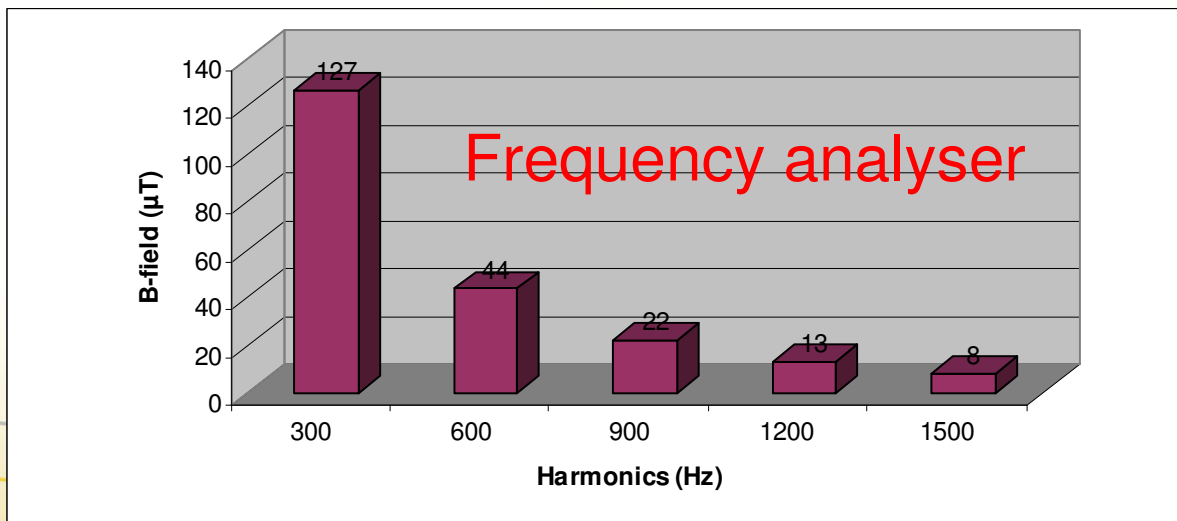
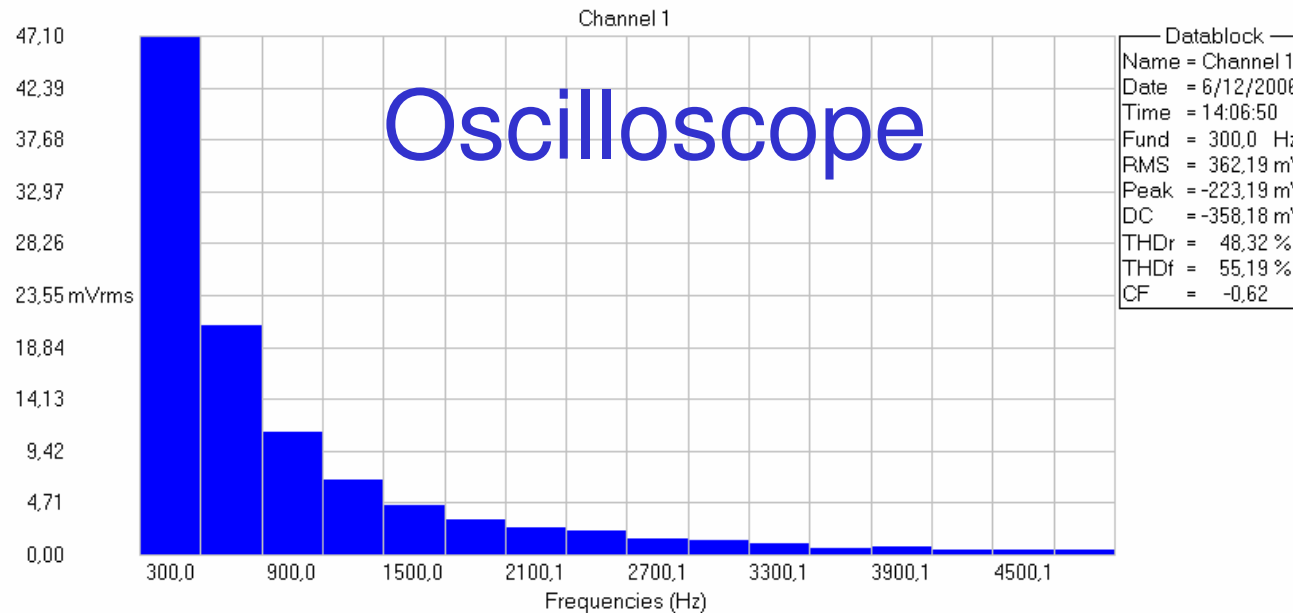
## Waveform



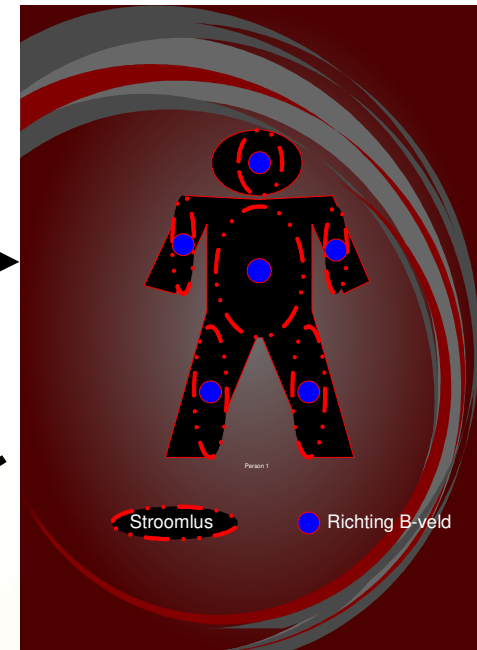
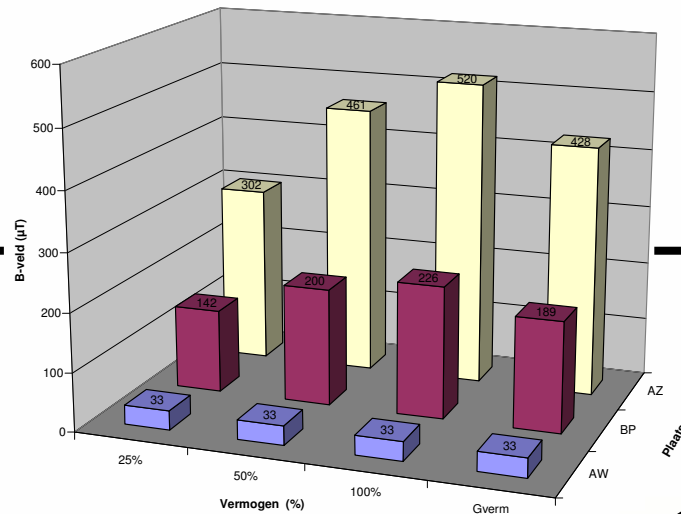
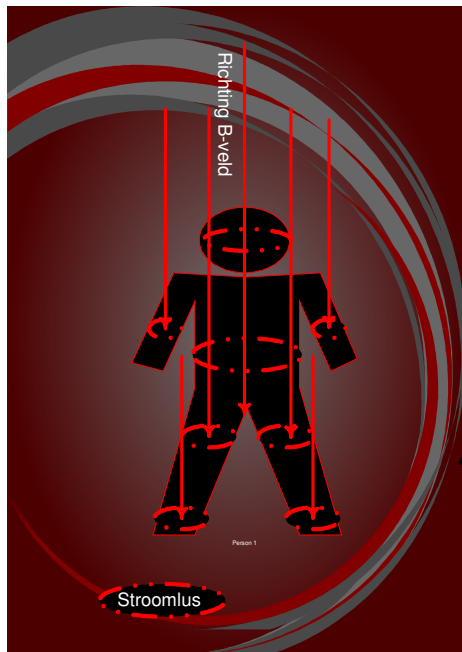
## Harmonics



# Harmonics' histograms: scope vs FA



# GMP and Arc & induction ovens

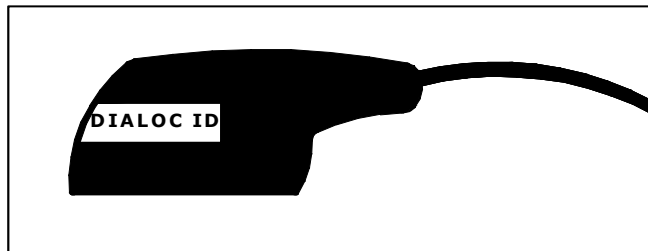


$$J = Rf\sigma B > 10 \text{ mA.m}^{-2}$$

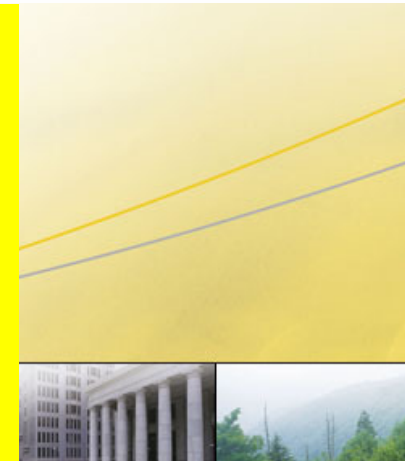
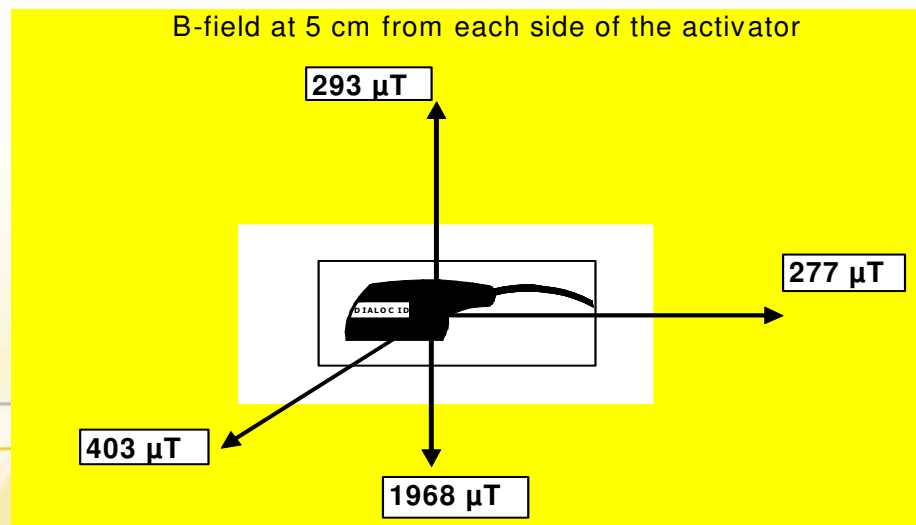
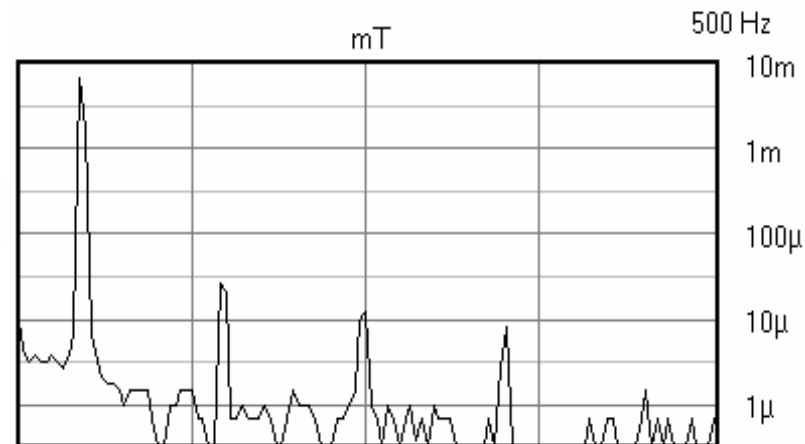
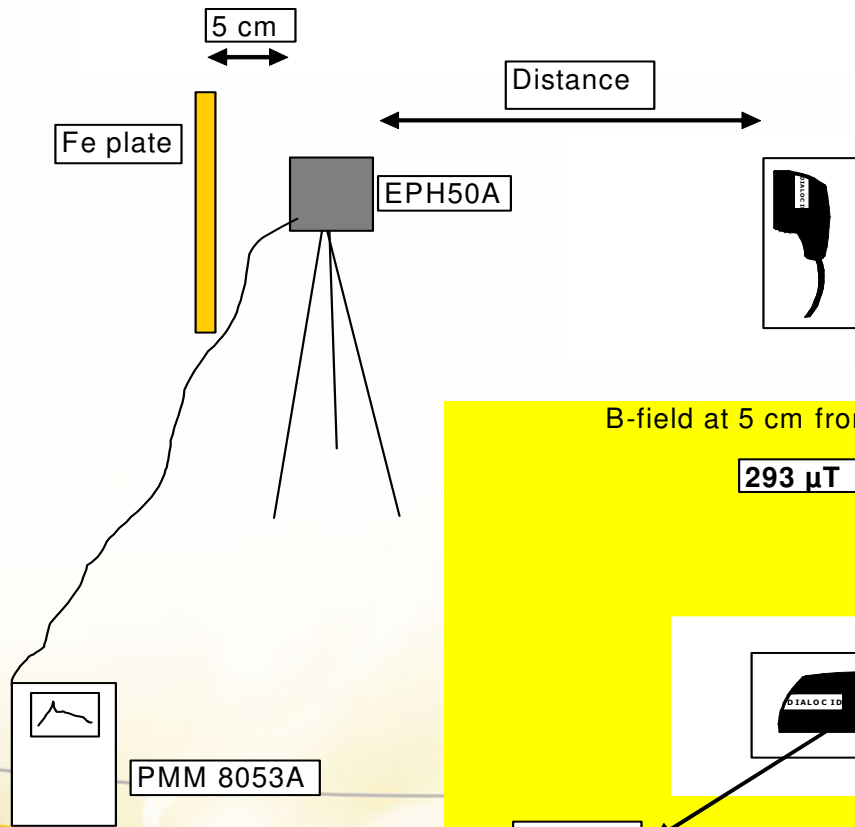
**MITIGATION**



# GMP and 50 Hz handheld activator for magnetization of safety strips in libraries



EHP 50 22.05.06 14.13.18  
Level: 6,59 mT (Wide Band)



# ELECTROSTATIC DISCHARGE (ESD)



# Human body ESD by tribo-electricity, and E- and H-field

The human body can be highly charged by tribo-electricity.

A 15 kV charged human body can generate :

⇒ E-field of 12 kV/m

⇒ H-field of 30 A/m

⇒ Frequency range: 0 Hz – several GHz



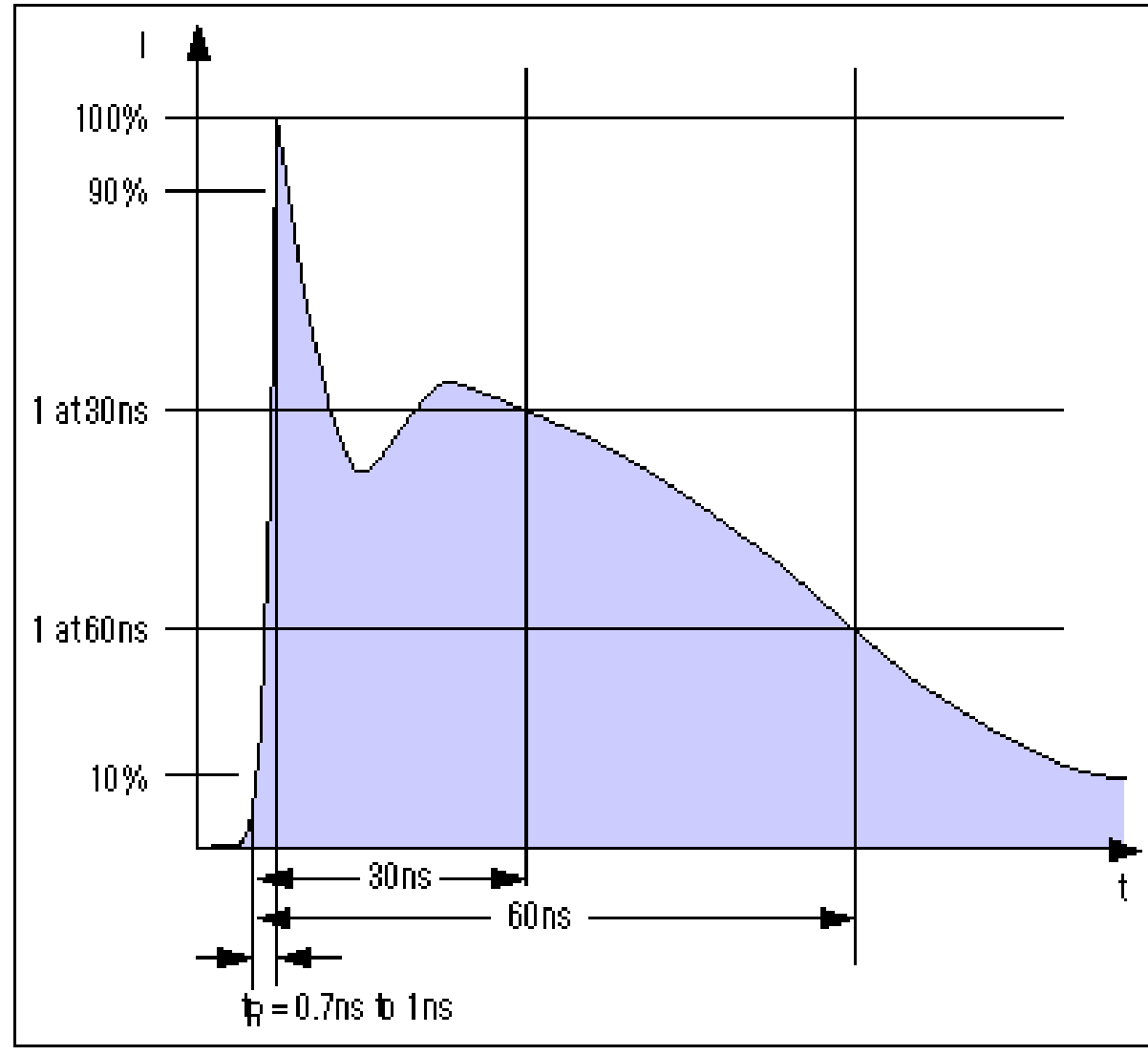
# Lipoatrophia Semicircularis



Source: Curvers B., 2002



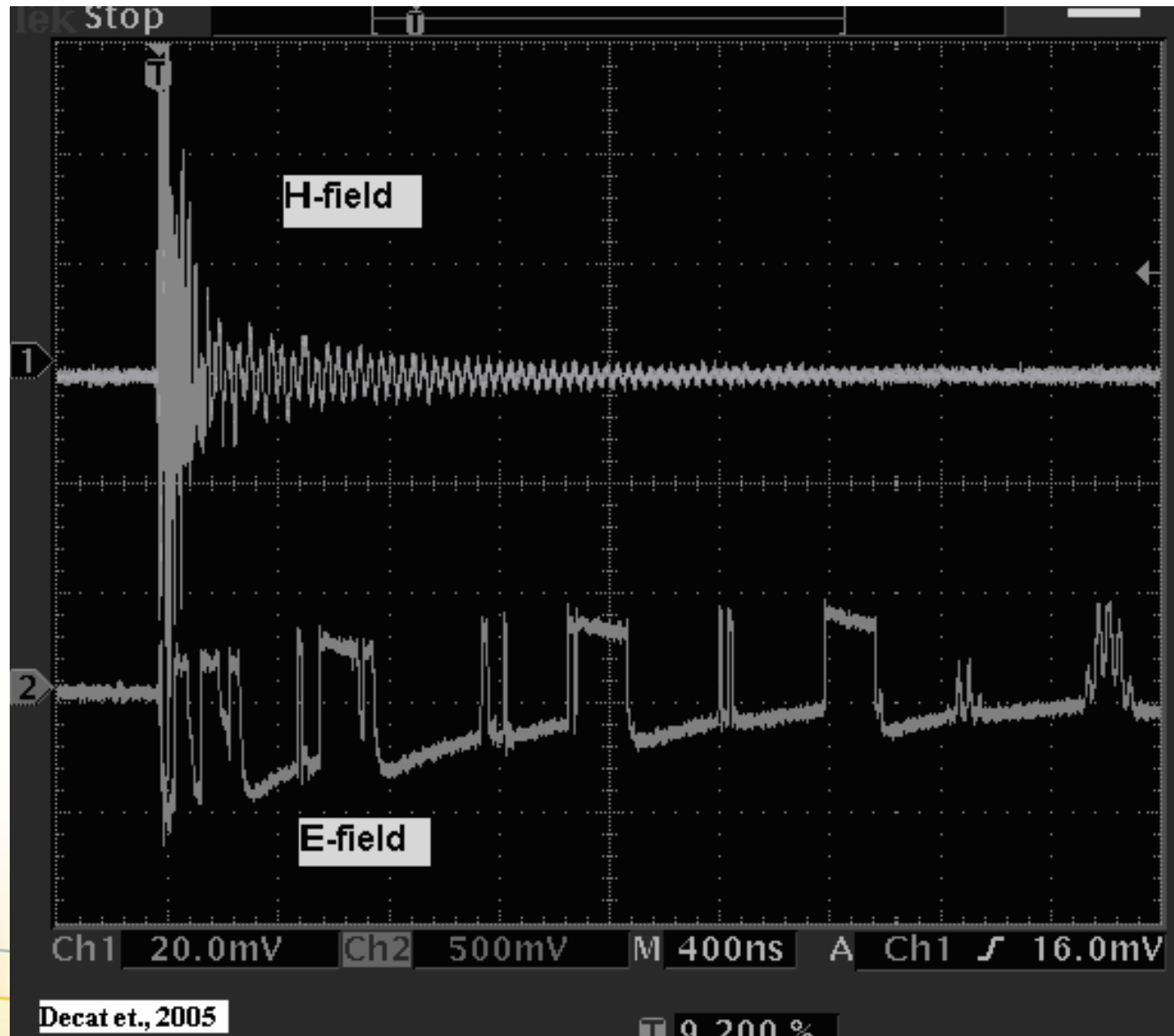
# ESD waveform's parameters (peak current, rise time, amplitude at 30 & 60 ns)



IEC 1000-4-2 specifies ESD testing both by contact discharge and by air discharge.



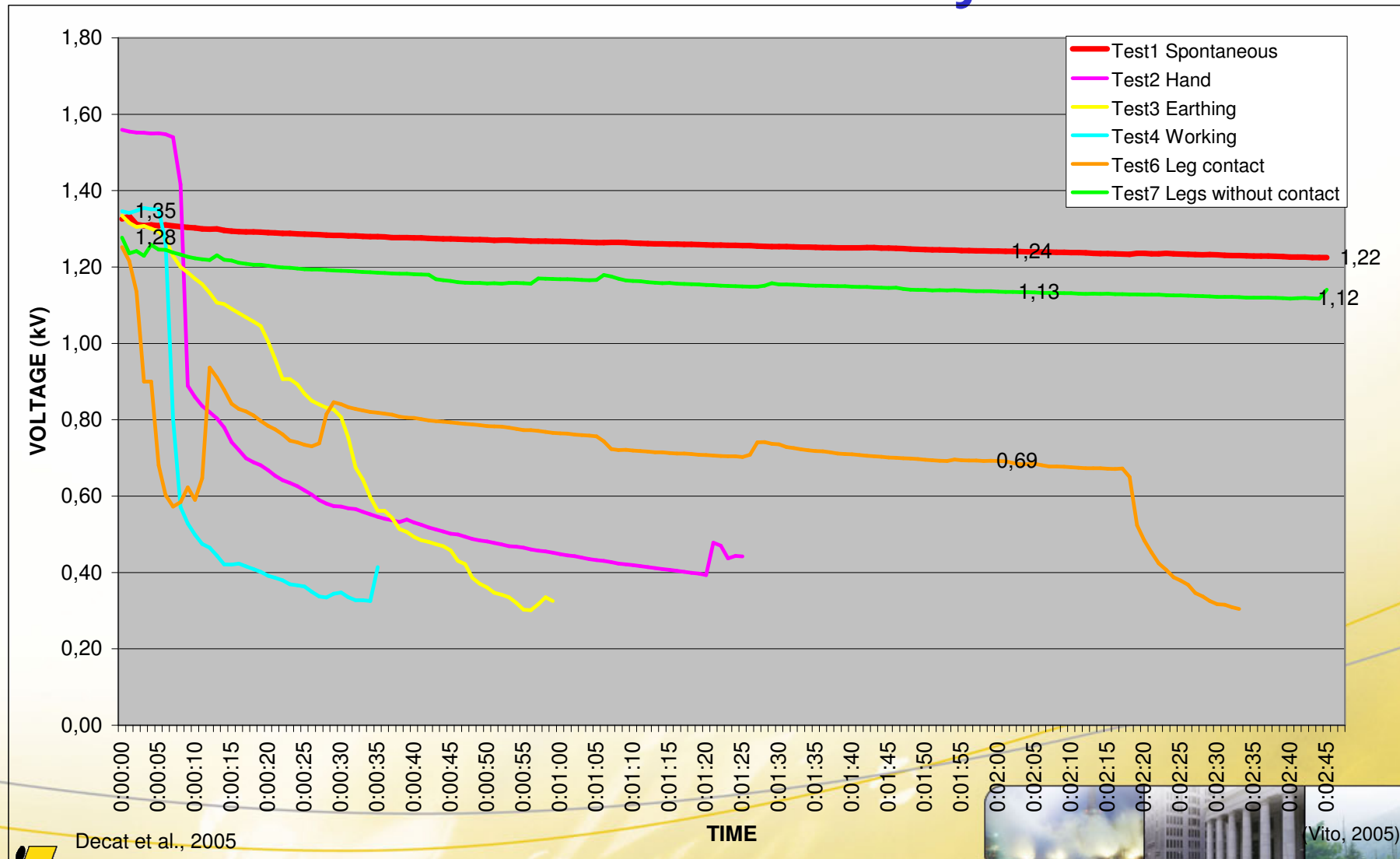
# E- & H-field of ESD-event (HBM)



Decat et., 2005



# Charged table surface voltage transfer to human body



# CONCLUSION

**GMP**



**RELIABLE EXPOSURE DATA**

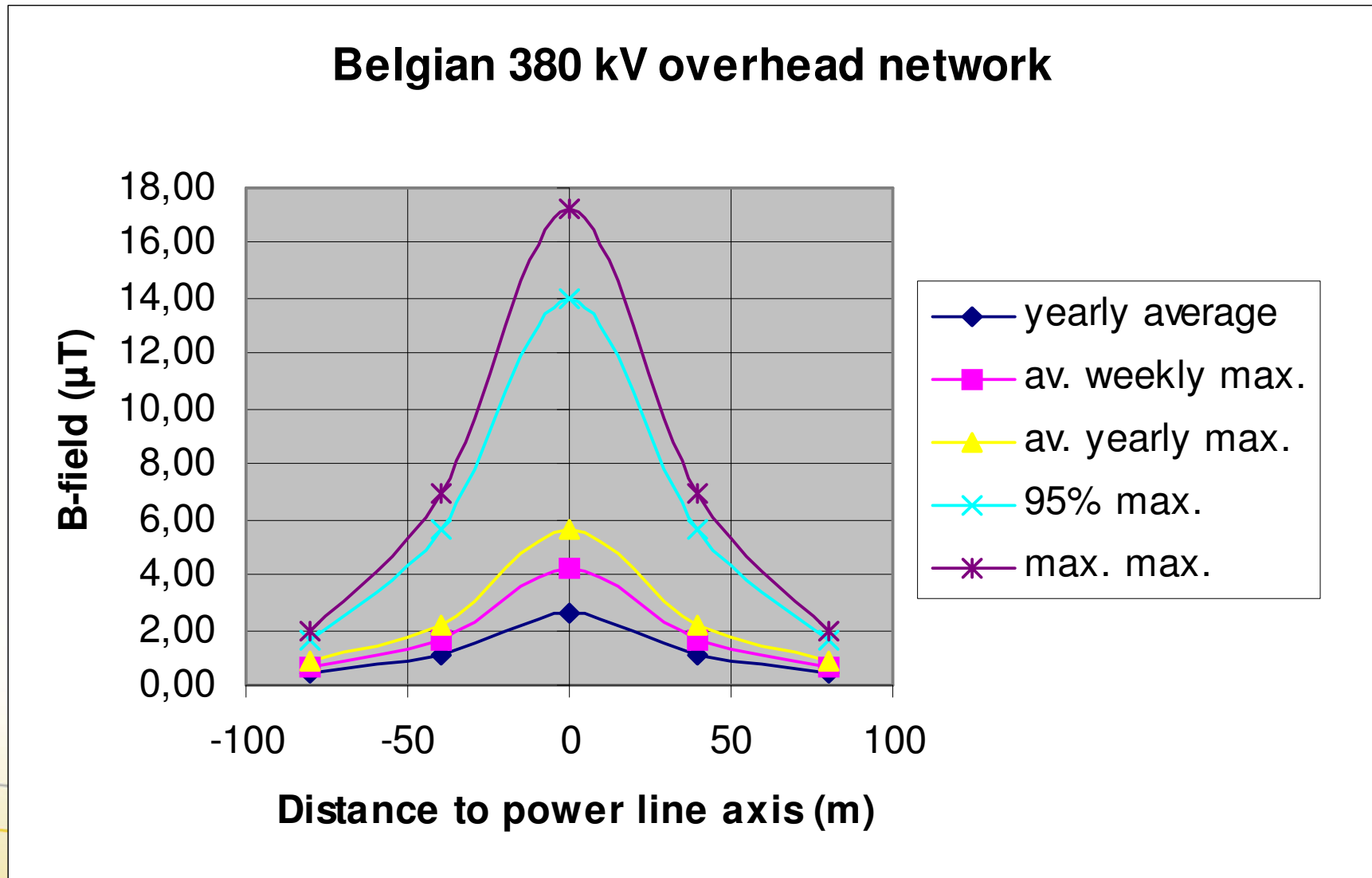
**GOOD RECOMMENDATIONS**



**RIGHT DECISIONS**



# Suggestion: Occupational GMP should be based on Power line EA approach



**THANK YOU**

