BS EN 50519:2010

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Assessment of workers' exposure to electric and magnetic fields of industrial induction heating equipment

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National foreword

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The UK participation in its preparation was entrusted to Technical Committee GEL/106, Human exposure to low frequency and high frequency electromagnetic radiation.

A list of organizations represented on this committee can be obtained on request to its secretary.

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ISBN 978 0 580 62929 7

ICS 13.280; 25.180.10

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 April 2010.

Amendments issued since publication

Amd. No.	Date	Text affected

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 50519

March 2010

ICS 13.280; 25.180.10

English version

Assessment of workers' exposure to electric and magnetic fields of industrial induction heating equipment

Evaluation de l'exposition des travailleurs aux champs électriques et magnétiques produits par les équipements industriels de chauffage par induction

Beurteilung der Exposition von Arbeitnehmern gegenüber elektrischen und magnetischen Feldern von industriellen induktiven Elektrowärmeanlagen

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: Avenue Marnix 17, B - 1000 Brussels

Ref. No. EN 50519:2010 E

Foreword

This European Standard was prepared by WG 9 WP 1 “Induction Heaters” of the Technical Committee CENELEC TC 106X, Electromagnetic fields in the human environment.

The text of the draft was submitted to the formal vote in February 2009. On the basis of the established voting results, CLC/TC 106X decided to prepare an amendment for inclusion in the standard to make it fully protective for doing workers exposure assessments in all eventualities.

The text of the draft amendment (FprAA) was submitted to the Unique Acceptance Procedure and the combined text was approved by CENELEC as EN 50519 on 2010-02-01.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN and CENELEC shall not be held responsible for identifying any or all such patent rights.

The following dates were fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2011-02-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2013-02-01

This European Standard has been prepared under Mandate M/351 given to CENELEC by the European Commission and the European Free Trade Association and covers essential requirements of EC Directive 2004/40/EC.

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1 Scope

This European Standard specifies procedures for assessment of electric, magnetic and electromagnetic fields produced by industrial and professional induction heating equipment.

NOTE This European Standard does not apply to household appliances.

Typical induction heating applications are for example:

- melting;
- zone-melting;
- heating before hot forming;
- heating by tunnel-inductor;
- hardening / coaxial transformer handheld devices;
- tube welding;
- tube annealing;
- hardening;
- soldering;
- hard-soldering /brazing;
- bonding;
- annealing;
- metal-strip and wire heating;
- tempering;
- sintering;
- shrinking.

This product standard covers the frequency range up to 30 MHz taking into account the specific characteristics of industrial and professional induction heating equipment and its usage.

This European Standard may also be used for assessment regarding the requirements of Directive 2004/40/EC [1] *on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields),* provided that no other relevant field sources are present in close proximity. If other field sources are present, additional assessment according to EN 50499:2008 is necessary.

This European Standard does not cover protective measures for people with active implants.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 50413:2008, *Basic standard on measurement and calculation procedures for human exposure to electric, magnetic and electromagnetic fields (0 Hz – 300 GHz)*

EN 50499:2008, *Procedure for the assessment of the exposure of workers to electromagnetic fields*

EN 12198-1, *Safety of machinery - Assessment and reduction of risks arising from radiation emitted by machinery - Part 1: General principles*

IEC 60050-841:2004, *International Electrotechnical Vocabulary - Part 841: Industrial electroheat*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

SI-units are used throughout the standard.

3.1
action values
the magnitude of directly measurable parameters, provided in terms of electric field strength (*E*), magnetic field strength (*H*), magnetic flux density (*B*) and power density (*S*), at which one or more of the specified measures in Directive 2004/40/EC must be undertaken. Compliance with these values will ensure compliance with the relevant exposure limit values (from 2004/40/EC)
[EN 50413:2008, 3.1]

3.2
contact current (I_C)
current flowing into the body resulting from contact with a conductive object in an electromagnetic field. This is the localised current flow into the body (usually the hand, for a light brushing contact), expressed in Ampere (A)
[EN 50413:2008, 3.4]

3.3
electric field strength (*E*)
vector quantity obtained at a given point that represents the force (*F*) on an infinitely small charge (*q*) divided by the charge:

$$E = \frac{F}{q}$$

electric field strength is expressed in volt per metre (V/m)
[EN 50413:2008, 3.7]

3.4
employer
any natural or legal person who has an employment relationship with the worker and has responsibility for the undertaking and/or establishment (from 89/391/EEC)
[EN 50499:2008, 3.2]

3.5
exposure
for the purpose of this standard exposure occurs whenever and wherever a worker is subjected to magnetic fields from industrial induction heating equipment

3.6
exposure limit values
limits of exposure to electromagnetic fields, which are based directly on established health effects and biological considerations. Compliance with these limits will ensure that workers exposed to electromagnetic fields are protected against all known adverse health effects (from 2004/40/EC)
[EN 50413:2008, 3.9]

3.7
induced current (*I*)
current induced inside the body as a result of direct exposure to electromagnetic fields, expressed in Ampere (A)
[EN 50413:2008, 3.13]

3.8
inductor
a heating inductor for creating the magnetic field, which induces currents in a metal charge or in a crucible of conductive materials
[IEV 841-27-48:2004, mod.]

3.9
iso-field-line
line with constant values of a recorded field (e.g. magnetic field strength *H* or magnetic flux density *B*)

3.10
magnetic field strength (*H*)
vector quantity obtained at a given point by subtracting the magnetization *M* from the magnetic flux density *B* divided by the permeability of free space μ_0:

$$H = \frac{B}{\mu_0} - M$$

Magnetic field strength is expressed in Ampere per meter (A/m)

NOTE In vacuum, the magnetic field strength is at all points equal to the magnetic flux density divided by the permeability of free space: $H = \frac{B}{\mu_0}$.

[EN 50413:2008, 3.16]

3.11
magnetic flux density (*B*)
the field vector in a point that results in a force (*F*) on a charge (*q*) moving with the velocity (*v*):

$$F = q\,(v \times B)$$

The magnitude of the magnetic flux density is expressed in Tesla (T)

[EN 50413:2008, 3.15]

3.12
measuring distance
distance between a reference surface of the appliance and the geometrical centre of the field probe

3.13
modulation
process of modifying the amplitude, phase and/or frequency of a periodic waveform in order to convey information
[EN 50413:2008, 3.17]

3.14
peak value
the peak value of the electric or magnetic field strength or magnetic flux density represents the maximum magnitude of the field vector. It is composed of three individual components of the electric or magnetic field strength or magnetic flux density, which are instantaneous values in three mutually orthogonal directions

$$V_\mathrm{P} = \max\left[\sqrt{V_x^2(t) + V_y^2(t) + V_z^2(t)}\right]$$

[EN 50413:2008, 3.19]

3.15
probe
input device of a measuring instrument, generally made as a separate unit, which transforms the measured input value to a suitable output value
[EN 50413:2008, 3.24]

3.16
worker
any person employed by an employer, including trainees and apprentices but excluding domestic servants (from 89/391/EEC)

NOTE This definition may be subject to national adaptation which then takes precedence.

[EN 50499:2008, 3.9]

3.17
work place
location where workers have access as part of their duties
[EN 50499:2008, 3.8]

3.18
worst case operating conditions
operating conditions of the equipment, where the maximum exposure occurs

(See also Annex A, list of relevant items for particular equipment with reference to the list of typical application in Clause 1).

4 General considerations

The principle layout of an induction heating installation consisting of power source and load is shown in Figure 1 as a parallel compensated circuit. Serial compensated circuits are used as well. The load is a resonance circuit comprising a compensating capacitor bank, high current conductors and an inductor or an inductor coil including matching transformer, if applicable.

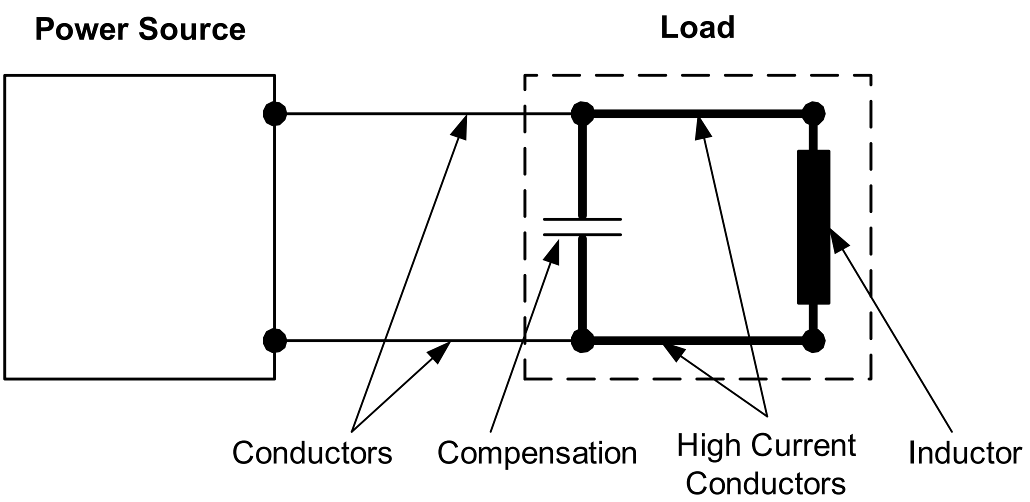


Figure 1 – Principle layout of an induction heating installation

Inductor and high current carrying conductors are the main sources of magnetic fields.

Contact currents generated by electromagnetic fields and electric fields from induction heating installations with frequencies below 1 MHz are usually below the action values. Therefore they are not taken into account in the context of this standard.

Contact currents from shielded, and some unshielded, induction heating installations at frequencies of 1 MHz or above can approach the action values and they may need to be measured. If so, this should be done in accordance with EN 50413.

Electric fields from some unshielded induction heating installations at frequencies of 1 MHz or above can approach the action values and they may need to be measured. If so, this should be done in accordance with EN 50413.

5 Classification of induction heating equipment

Induction heating equipment can be divided in three groups:

(1) equipment using inductors with cylindrical coil/s operating in horizontal position;

(2) equipment using inductors with cylindrical coil/s operating in vertical position;

(3) equipment not belonging to groups (1) and (2).

In general groups (1) and (2) contain high power equipment, e.g. for melting, sintering, heating of billets before hot forming. Their field distribution is approximately rotationally symmetrical. However, the field distribution may be influenced by metallic construction elements (e.g. yokes, frames and cages).

Group (3) contains equipment with non-cylindrical inductors, which may have complex geometries and are used e.g. for hardening, annealing, soldering etc. Their field distribution could be very complicated.

6 Assessment procedure

The assessment of the equipment can be based on measurements, calculation / simulations or on their combination. Assessment results previously obtained for an equipment may be used for the exposure assessment of an equipment with similar design and working conditions.

In cases where calculation or simulation show that permissible values of exposure are not exceeded, a further measurement procedure is not necessary.

General information on measurement and calculation procedures may be drawn from EN 50413:2008.

During the measurements the equipment shall be operated under conditions at which the maximum exposure is expected, including start up, adjusting, maintenance and repair. The assessment shall take account of the spectral content of the emitted electromagnetic fields in accordance with EN 50413.

If the conditions prevailing during the measurement procedure do not correspond exactly to the possible maximum exposure (worst case) calculation of the maximum exposure situation, e.g. by extrapolation based on measured values, may be applied. For a constant load the maximum magnetic flux-density at rated conditions B_r for a given measurement point may be calculated from the measured values B_m using the following formula:

$$B_r = B_m * \frac{U_{ind\,r}}{U_{ind\,m}}$$

where

B_r	maximum magnetic flux-density at rated conditions;
B_m	measured magnetic flux-density values;
$U_{ind\,r}$	rated inductor-voltage;
$U_{ind\,m}$	measured inductor-voltage for the measured magnetic flux-density.

NOTE The magnetic flux density of induction heating equipment is in principle linearly proportional to the inductor current. Under condition that the load (see Figure 1) remains constant during the measurement procedure the inductor-voltage U_{ind} is linearly proportional to the inductor current. The maximal exposure is not always at the maximal power. It may depend of the type of the furnace and its working condition.

In cases where the rated values of power or voltage cannot be attained during the measurement procedure, the field level $B_{ifl\ red}$ for the identification of the iso-field-line for the maximum exposure situation has to be reduced according to the following formula:

$$B_{ifl\ red} = B_{ref} * \frac{U_{ind\ m}}{U_{ind\ r}}$$

where

$B_{ifl\ red}$ reduced magnetic flux-density values;

B_{ref} reference magnetic flux-density values.

The extrapolation procedures presented above can be applied as long as the spectral distribution of the emissions remains constant over the variation of the power or voltage.

If this is not the case as with some induction heating equipment with uncompensated load/inductor operating with semiconductor power-control which may affect the spectrum of the emissions, then the worst-case exposure power settings at the working place of the installation shall be determined in accordance with EN 50413, and exposure under those power conditions assessed taking account of the emission spectrum in accordance with EN 50413.

The magnetic flux density *B* shall be measured all around the magnetic field sources at locations where workers must have access as part of their duties (work places). The measurement points shall represent the location of head and trunk of the worker. In the interest of comparability it is recommended to use measurement heights in the range of 0,9 m to 1,9 m for upright working positions.

Reference levels relevant for the evaluation of worker's exposure shall be taken from National regulations, if they exist. In their absence the action values given in the EU Directive 2004/40/EC [1] or the reference levels for occupational exposure given in the ICNIRP-Guidelines [2] can be used.

The persons executing the measurements shall ensure that they are not over-exposed, that they are not positioned between the field source and field probe or measuring antenna during the measurement, and that all persons, who are not involved in the measurement leave the area of the measuring site.

7 Measurement

7.1 Preparation of the measuring action

For the preparation of the measuring action, the following steps are recommended:

- procure or prepare layout drawings of the equipment with the areas to which workers have access as part of their duties;
- define a system of co-ordinates (x, y, h) in the relevant layout drawing and mark it on the floor and provide a vertical scale (h) for the identification of the measurement points;
- prepare a table to fill in the coordinates of the measurement points, the recorded field values as well as the values characteristic for the operating load condition (e.g. power, voltage, current frequency);
- procure technical data on the field sources (frequencies, generator power, field characteristics, modulation, if applicable, conductor currents and voltages);
- consider type of the field: geometrical distribution among others with a view to maximum field strength (e.g. horizontal or vertical inductor axis) (see Annex B);

- consider the time behaviour of the source (e.g. duty cycle) for the type of measurement, the choice of the instrumentation and the evaluation.

  In the case of multiple field sources of induction heating equipment consider their position and characteristics (e.g. power, frequency, etc.) as well as the eventual impact of interference phenomena;
- procure information about the operating conditions of the equipment(s) to determine the worst case operating condition (see 3.17) with respect to exposure (e.g. empty furnace);
- consider the exposure conditions (place and duration of workers stay);
- consider special situations e.g. starting up of the equipment, adjusting, maintenance or repair;
- consider the protection of the measuring device, because exceeding the maximum measuring range may lead to its destruction, as well as the impact of temperature possible deteriorating it or influencing the measurement.

7.2 Initial field topology scan

At the workplace an initial field topology scan shall be performed in order to find the location of the maximum value of the magnetic flux density *B* within the height range defined in Clause 6.

NOTE The maximum value and its location may change during the operation cycle.

To avoid overloading or destruction of the measuring system a preliminary scan should be started at a sufficient distance to the field source.

For group (1) equipment the measurement maximum values of magnetic flux density (*B*) are to be expected in the height of the inductor axis.

For group (2) equipment the maximum field values are to be expected at the nearest accessible point to the inductor. Due to the influence of yokes and high current feeding conductors they may vary with the radial direction. Therefore the radial direction with the maximum field values has to be identified.

For group (3) equipment the maximum field values are to be expected at the nearest accessible point to the inductor, however generally there are no symmetrical field structures present.

If the magnetic flux density values measured during the initial field scan are below the considered reference values (action values) there is no need for further measurements. The maximum magnetic flux density values obtained however are to be noted in the documentation including their position.

7.3 Final measurement

The objective of the final measurement is to find and record the iso-field-line of the relevant reference level of the magnetic flux density *B* in the accessible areas.

The coordinates of the established iso-field-lines are to be recorded as well as the values characteristic of the operating load condition (e.g. power, voltage, current frequency).

For the final measurement it is recommended that the probe is positioned on a tripod (of non-conductive material), to insure a precise reference to the location.

Perturbations caused by the motion of the probe (e.g. vibrations) should be avoided.

For group (1) equipment the measurement may be started from the location of the maximum value of the magnetic flux density found in 7.2 increasing the distance between field source and probe, until the measured value reaches the considered reference level of the magnetic flux density. Then the probe should be moved systematically around the equipment to follow up an iso-field line (the reading of the measurement instrument remaining constant). The measuring probe should be fixed on a tripod in the pre-determined height h_m.

For group (2) equipment with constant operating load conditions over the measurement cycle the measurement may be made in the radial direction with the maximum magnetic flux density found in 7.2 starting from the nearest accessible point to the inductor. The height of measurement points should represent the location of head and trunk of the worker (see Clause 6). The result will be an iso-field-line in a plane rectangular to the ground. The rotational symmetry of the field may be checked starting from the point of the iso-field-line with the maximum distance from the inductor encircling the equipment.

In the case of equipment with load conditions which due to the operating process may vary during the measurement cycle the raster scan procedure as recommended for group (3) equipment has to be applied.

For group (3) equipment the measurement may be started with the definition of a grid system (raster) followed by a raster scan of the field.

If the power (P) of the equipment varies over the measurement cycle, the measured field values can be corrected according to the following formula:

$$B_r = B_m \times \sqrt{\frac{P_r}{P_m}}$$

where

B_r	magnetic flux-density at rated conditions;
B_m	measured magnetic flux-density values;
P_r	rated power;
P_m	measured power.

NOTE On condition that the load voltage remains constant and that the spectral content of the emitted electromagnetic fields do not change with power (see 6.2).

8 Documentation

The test report shall include at least the following items, if applicable:

- site / user;
- time and place of measurement;
- identification of the installation/ appliance:
    - type, fabrication number;
    - manufacturer;
    - year of fabrication;
    - category of EN 12198-1.
- field source:
    - purpose of use;
    - installed inductor;
    - work piece;
    - mode of operation;
    - operating frequency;
    - output power;
    - operating voltage and/or current;
    - load matching setting (capacitors, transformer taps).

- plan or sketch of site;
- location of measuring sites and measuring points;
- field limit values used for the assessment;
- applied field limit set;
- measured maximum values;
- even if action values are not exceeded the results are to be documented by the values measured and the position of the measurement points;
- method of extrapolation from measured values (see Clause 6) in case of deviation of operating conditions from rated condition;
- effective exposition time per day, cycle times;
- specification of the measuring equipment used;
- declaration of the validity of the calibration of the measurement system used;
- name of measuring persons;
- the standard according to which the assessment has been established (e.g. EN 50519);
- in case of an assessment based on field calculation/simulation, the method has to be reported.

Annex A
(informative)

Particular induction heating applications and worst case operating conditions

Table A.1 - List of particular induction heating applications (as listed in Clause 1) indicating specific features with the view to particular characteristics to be considered for the measuring procedure

Typical induction heating applications	Worst case operating condition	Particular characteristics relevant for the measuring procedure
Melting	Presumably: minimum charge in induction crucible furnaces? *Check maximum field values as function of level of metal in induction crucible furnace* *(by calculation or tests)*	Rotationally symmetrical field Max. field value may vary with the metal level in Induction Crucible Furnaces Conditions may vary over the measuring process !
Zone-melting		
Heating before hot-forming	Start and end of billet/bar… heating for forging	Rotationally symmetrical field
Heating by tunnel-inductor		Non-rotationally symmetrical field
Automatic hardening		Short time heating “Duty cycle”
Hardening using coaxial transformer handheld devices		Short time heating “Duty cycle”
Tube welding	Largest difference between inductor-and tube- diameters	
Tube annealing		
Hard-soldering /Brazing		“Duty cycle”
Bonding		
Annealing		
Metal-Strip heating		
Tempering		
Sintering		
Shrinking		
NOTE The list may be completed by introducing particular features.		

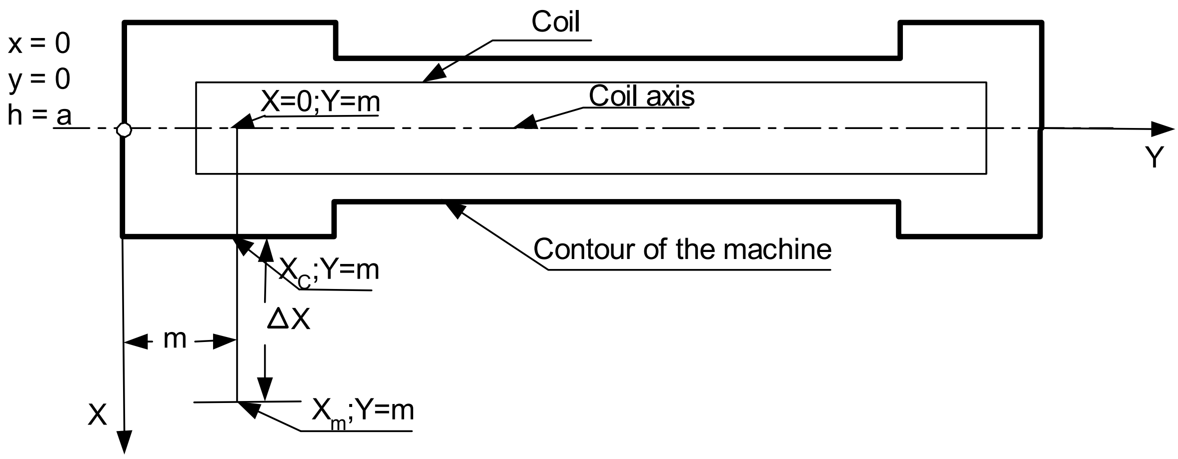
Annex B
(informative)

Examples of magnetic field-measurements

B.1 Example for the assessment of the magnetic-field of a horizontal source

For the magnetic-field of a horizontal source (e.g. induction billet heater) the position of the point with maximum magnetic flux density above ground h_m may be determined first. (This is to be expected at the level of the coil axis, see Figure B.1). Measurements taken at this level eventually allow establishing iso-field-lines.

It is helpful to define a system of co-ordinates (x, y, h) in the relevant layout drawing comprising the accessible area. y is preferably the coordinate along the outer edge of the equipment parallel to the coil-axis, the origin of which may be freely chosen e.g. at one edge of the equipment. x is rectangular to the coil axis.



h_m; y_m; x = 0 = position of coil axis
h_m; y_m; x_C = position of contour
h_m; y_m; x_m = position of measuring point
Δx = x_m- x_C = distance of measuring point from contour
index m = refers to the measurement point
a = height of coil axis above ground

Figure B.1 - Example of system of co-ordinates x, y, h in a layout drawing of an induction heating equipment for the assessment of the magnetic-field of a horizontal source

Table B.1 - Example of a working table to introduce the co-ordinates of the measuring points relating to example Figure B.1

Y	ΔX_m	X_m

Table B.2 - Example of a form for the report of the measuring procedure

Type, fabrication number of the equipment and/or Inventory number at user's site	
Purpose of use	
Installed inductor	
Work piece	
Operating frequency	
Output power	
Operating voltage and/or current	
Load matching setting (capacitors, transformer taps)	
Measuring equipment used	
Validity of the calibration of the measurement system used	
Name of measuring persons	
Date of the assessment	

B.2 Example for a documentation of the measurement results

Kunde: NNNNNN

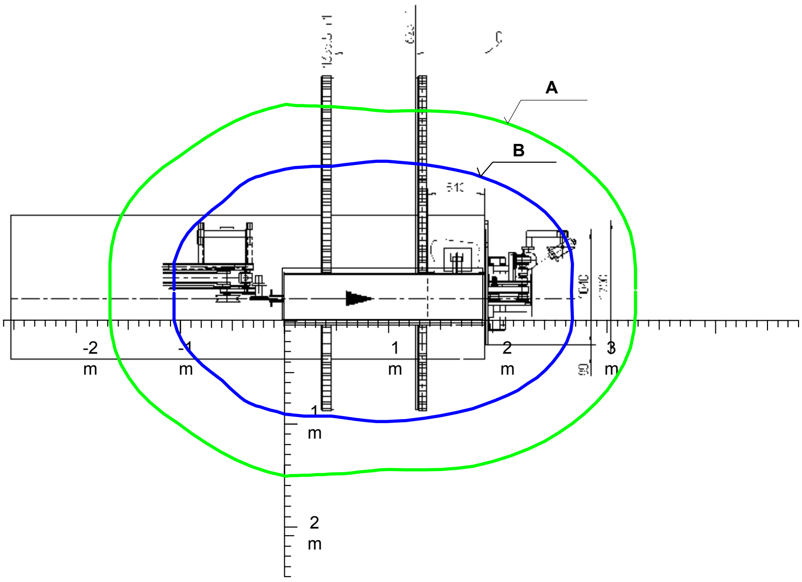
Kom.Nr. xyzxyz
Type of machine
Generator: inbuild
Place: Remscheid
Date . 04.07.2002
Category 2 (EN 12198-1)

Testperson: H.Köhler

Test method:
Weighted Measurement

Used reference levels :

A = Action values according to Directive 2004/40 EC
B =reference level according to Council Recommendation 1999/519/EC



Measurement System
Manufactorer/ Type
Ser.No. XYZXYZ
Probe: NNNN

Operating data:
(Empty furnace)
U~ 750V RMS
f = 2600Hz
Power 74 kW

This document must be stored additional 10 years after beeing out of operation

Index-Bemerkung					Company
Schutzvermerk nach **ISO 01616** beachten		Tag	Name	Maßstab:	Zeichnungs-Nummer
	Gezeichnet	04.07.2002	Henning Köhler		
	Geprüft			Maße ohne Toleranzangaben nach:	
	Normgeprüft				
Benennung:	**EMF check of a forging furnace**				
CAD-Ablage:	Ursprung		Blatt: 1 von 1		

Figure B.2 - Example for the documentation of the measurement results

Bibliography

[1] 2004/40/EC — *Directive 2004/40/EC of the European Parliament and of the Council of 29 April 2004 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) (18th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC),* OJ L 159, 30.4.2004, p. 1–26

[2] ICNIRP-Guidelines — International Commission on Non-Ionizing Radiation Protection*, Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz)* Health Physics, April 1998, Volume 74, 494-522

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