Application of ICNIRP Exposure Guidelines for 50 Hz Power Frequency Fields

Purpose

The information in this note provides further clarification on advice on exposure guidelines for 50 Hz electric and magnetic fields (EMFs) and practical approaches to demonstrating compliance.

Background

Up to 31 March 2005 the National Radiological Protection Board (NRPB) had a statutory responsibility for advising UK Government Departments on protection standards for exposures to ionising and non-ionising radiations. This responsibility now lies with the Radiation Protection Division (RPD) of the Health Protection Agency (HPA). As part of its responsibility, NRPB provided advice on exposure guidelines for EMFs from 0 Hz to 300 GHz, including the extremely low frequency (ELF) fields associated with the power frequency of 50 Hz. Following a comprehensive review of the science and advice from experts, NRPB placed a consultation document on its website in May 2003 and provided an opportunity for interested individuals and groups to submit comments. In addition to considering the views expressed in response to the consultation document, in December 2002 NRPB hosted a public open meeting in Birmingham to discuss EMF concerns about power lines.

In March 2004, NRPB published its formal advice on limiting exposure to EMFs (NRPB, 2004a). This was supported by a review of the scientific evidence (NRPB, 2004b). This advice recommended adoption of guidelines from the International Commission on Non-Ionizing Radiation Protection (ICNIRP) for limiting exposures to EMFs (ICNIRP, 1998). For occupational exposure to 50 Hz fields the guidance by ICNIRP is for a limit on induced current density in the brain and central nervous system (CNS) of 10 $mA\,m^{-2}$. This is the same as previous NRPB advice given in 1993. For public exposure, the adoption of the ICNIRP guidelines represents a reduction over previous NRPB guidance from 10 $mA\,m^{-2}$ to 2 $mA\,m^{-2}$.

These values for limits on induced current density are known as *basic restrictions* and cannot be measured in living tissues directly. Consequently dosimetric techniques are used to compute measurable external field values, termed *reference levels*, that are associated with the basic restriction values.

The adoption of the ICNIRP guidelines results in a reference level for exposures to 50 Hz magnetic fields of 500 µT for workers and 100 µT for members of the public. A further consequence of adopting the ICNIRP guidelines is that the reference value for 50 Hz electric fields is 10 $kV\,m^{-1}$ for workers and 5 $kV\,m^{-1}$ for the public. These reference levels are not limits, but are values that should trigger further investigation into compliance with the exposure guidelines. The use of the electric field reference levels reduces the likelihood of perception of the field and of *indirect* effects such as microshocks.

The consideration of scientific uncertainty and aspects of precaution had been specifically requested by Government as an input to the development of NRPB advice on EMFs. This advice acknowledged that at power frequencies there remain uncertainties with some areas of the science, particularly in relation to an epidemiological association found between an increased risk of childhood leukaemia and exposure to power frequency magnetic fields above about 0.4 µT (NRPB, 2004a,b). This value is at the upper end of the distribution of the range of residential exposures. NRPB therefore recommended that Government consider the need for further precautionary measures. Melanie Johnson MP, the Parliamentary Under Secretary of State for Public Health, welcomed the advice and was pleased to note the inclusion of the NRPB recommendation to Government on precautionary measures.

A Stakeholder Advisory Group on ELF EMFs (SAGE) has been established. This is managed by the Department of Health and is exploring further the practical applications of precautionary measures.

Health Effects

It was concluded from the review of the scientific evidence (NRPB, 2004b) that the most coherent and plausible basis from which guidance could be developed on exposures to ELF EMFs concerned weak electric field interactions in the brain and CNS (NRPB, 2004a). A cautious approach was used to indicate thresholds for possible adverse health effects.

The brain and nervous system operate using highly complex patterns of electrical signals. Therefore, the basic restrictions are designed to limit the electric fields and current densities induced in these tissues so as not to adversely affect their normal functioning. The adverse effects that might occur cannot be easily characterised according to presenting signs or symptoms of disease or injury. They represent potential

changes to mental processes such as attention and memory, as well as to regulatory functions within the body. Thus the basic restrictions should not be regarded as precisely determined values below which no adverse health effects can occur and above which clearly discernible effects will happen. They do, however, indicate an increasing likelihood of effects occurring as exposure increases above the basic restriction values.

Adults are likely to show variations in sensitivity to induced electric fields, and people with certain diseases are considered to be potentially more sensitive to the effects of fields than healthy adults. For example, people with epilepsy, a family history of seizure, or those using tricyclic anti-depressants, neuroleptic agents and other drugs that lower seizure threshold are likely be more sensitive than people without these conditions. For these reasons, the basic restriction of one-fifth of that for workers is considered appropriate for members of the public.

Electric charge is induced on the surface of a person exposed to an electric field. Its presence can be perceived as a result of the movement of body hair. This may become annoying to some people in fields of 15-20 kV m^{-1}.

In addition, the electric charge on the surface of the body can be discharged to ground by contacting earthed items (such as metallic fences or gates) - this can result in a microshock. Depending on the field strength and other exposure factors, these responses range from the barely perceptible, through annoyance, to being painful. There is a paucity of data investigating the effects of microshocks; however on the basis of the available evidence, the direct effects of microshocks on the body are not considered capable of producing lasting harm. The response to some extent will depend on the sensitivity of the individual. Although the possibility of microshocks cannot be ruled out, in field strengths up to about 5 kV m^{-1} they are unlikely to be painful to the majority of people. The extent to which microshocks may be a problem in practice is unclear at present (NRPB, 2004a). Further studies of situations where microshocks arise would assist in defining the extent of any problem and in clarifying any research needs.

It is also possible to receive a microshock when a grounded person touches a large, ungrounded object (such as a vehicle) within an electric field. For these situations, the probability and the magnitude of the effect depend on the field strength and the size of the ungrounded object.

From the results of epidemiological investigations, there remain concerns about a possible increased risk of childhood leukaemia associated with exposure to magnetic fields above about 0.4 μT. In this regard, it is important to consider the possible need for further precautionary measures.

Basic Restrictions

Basic restrictions are intended to avoid adverse health consequences by limiting current density in the CNS that can occur as a direct effect of exposure to 50 Hz fields. NRPB concluded that 10 mA m^{-2} is an appropriate basic restriction on induced current density in the CNS for occupational exposure.

Since the public may include people with increased susceptibility to induced electric currents, possibly due to disease or as a consequence of taking certain medications, NRPB concluded that 2 mA m^{-2} is an appropriate basic restriction on induced current density in the CNS for exposure of members of the general public.

For both workers and members of the public, continuous exposures resulting in current densities below values corresponding to the basic restrictions are not considered to cause clinical effects or to result in physical harm.

Reference Levels

Reference levels are provided for practical hazard assessment. These are expressed as measurable field and electric current quantities in order to assist the assessment of compliance with the basic restrictions for particular exposure situations. For electric fields, adherence to the reference levels will limit the possibility of other effects, which include annoyance due to perception of surface charge and microshocks.

NRPB (now RPD) advice is not prescriptive with regard to setting field values as ‘limits’, in order to allow the health and safety professional to use the most up to date measurement and computational techniques in assessing compliance with the basic restrictions and actions that may be necessary to avoid indirect effects.

For occupational exposure to 50 Hz fields, the reference level for electric fields is an electric field strength of 10 kV m^{-1} and for magnetic fields a magnetic flux density of 500 μT.

The equivalent levels for public exposure are 5 kV m^{-1} and 100 μT.

Clarification on Dosimetric Aspects of Exposure Guidelines

At 50 Hz, basic restrictions are expressed in terms of induced current density. This quantity cannot easily be measured in living people. Therefore, to assist assessment of compliance with basic restrictions, frequency-dependent reference levels of external field strength corresponding to the basic restrictions have been derived.

Over the past few years, there has been extensive dosimetry work published on the quantitative relationships between external and internal fields. The published work is based on computational modelling of such interactions using a variety of numerical methods and anatomically realistic voxel (**vo**lume pi**xel**) models of the body. These models represent the organs and tissues of the human body as many millions of volume elements each characterised by specific electrical properties. These models have been derived using medical imaging techniques. NRPB has taken a leading position in developing voxel models and in publishing results in the scientific literature that are useful for linking external fields and internal basic restriction quantities. Research in this area is continuing.

Reference levels are calculated for exposure conditions expected to give maximal coupling of the person with the field. That is, they lean towards caution. It is emphasised that reference levels are not, and should not be used as, limits or restrictions on exposure but are a tool to be used in assessing compliance with the basic restrictions. The reference levels additionally provide a guide to the need to address the likelihood of indirect effects of exposure, including microshocks.

This system, first developed by NRPB, provides a framework for the health and safety professional to assess compliance with the exposure guidelines. It has proved effective in practice and is used by a number of national advisory bodies, and by ICNIRP.

In its advice, NRPB recommended that the ICNIRP reference levels should be used at the initial stage of assessing compliance with basic restrictions on limiting exposure (NRPB, 2004b). This recommendation recognised that, when ICNIRP derived the reference levels given in its 1998 report (ICNIRP, 1998), anatomically realistic models of the body were not generally used. Recent increases in computer speed and memory, combined with the availability of such models, have enabled fine resolution calculations of fields induced in the body. Such calculations, as carried out by NRPB, have been used to provide more definitive information on the appropriateness of the ICNIRP reference levels for compliance assessment.

These recent calculations indicate that the reference levels corresponding to the 1998 ICNIRP 50 Hz basic restrictions are conservative. This also applies for other frequencies up to 10 MHz. Overall, the ICNIRP reference levels provide an appropriate tool for use at the initial stage of compliance assessment, as described below.

Compliance Assessment for Basic Restrictions

RPD is not a technical standards body and does not wish to be prescriptive in specifying how detailed compliance assessments might be carried out. Different professionals undertaking such assessments will have access to different types and models of measurement equipment and a variety of computational and experimental tools as well as information on the particular circumstances of any exposure.

RPD notes that technical standards bodies, such as the International Electrotechnical Commission (IEC) and the European Committee for Electrotechnical Standardization (CENELEC), are developing methods for compliance assessment.

Where compliance assessment includes the need for measurement and/or calculation of the external fields, RPD suggests the following structured approach based on three stages of increasing complexity.

First stage

The external fields to which people may be exposed should be evaluated and compared with the ICNIRP reference levels. If the results are at or below the reference levels, then compliance should be assumed. Otherwise, assessment should proceed to the second stage.

Second stage

The results of the evaluation should be compared with the values of external fields required to produce the basic restrictions in the body. Such values can be derived from calculations using anatomically realistic models of the body and examples are given in figures 1-4 of the published NRPB Advice (NRPB, 2004b). The associated values are tabulated in the peer-reviewed publications by Dimbylow (1998, 2000). The

latest dosimetry from Dimbylow (2005) concerning the development of a female voxel phantom includes further calculations of induced current density and internal electric fields in the frequency range from 50 Hz to 10 MHz.

These calculations indicate that for occupational exposure an electric field strength of approximately 46 kV m^{-1} and a magnetic flux density of approximately 1800 μT correspond to an induced current density of 10 mA m^{-2}. Corresponding values for the general public equivalent to 2 mA m^{-2} are approximately 9 kV m^{-1} and approximately 360 μT.

These values have been calculated for idealised exposure geometries, in uniform fields, with perfect grounding conditions and alignment with the field to give maximal coupling. If the results of the field assessments are at or below these values, then compliance with the basic restrictions can be assumed. Otherwise, assessment should proceed to the third stage.

Third stage

To demonstrate compliance with basic restrictions, a detailed assessment should be carried out taking into account factors that represent the actual exposure conditions. Such conditions might include partial body exposure, non-uniform fields, grounding, polarisation, body posture and proximity to the source. The assessment should include calculations and/or measurements taking into consideration relevant specific exposure conditions. If, following such assessment, the basic restrictions are exceeded, the exposure is non-compliant.

RPD considers that this structured approach and the values of external fields corresponding to the ICNIRP basic restrictions as stated above are appropriate at this time for demonstrating compliance with the basic restrictions for exposure to 50 Hz electric and magnetic fields. However, in assessing compliance with the basic restrictions it is important to set out the basis for the selection of the method and the data employed.

Surface Charge and Indirect Effects

For power frequency electric fields, the reference level for occupational exposure is 10 kV m^{-1}. This will prevent annoying direct stimulation effects on the body due to surface charge for most people. Where electric field strengths exceed this value the possibility of such effects causing annoyance increases. Such exposure situations should be monitored and work practices considered with the aim of minimising the possibility of such effects.

There is also the possibility of adverse indirect effects (microshocks) which can be controlled in occupational environments. For the general public, the reference level of 5 kV m^{-1} will prevent microshocks in most people.

References

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