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To

AFQ Inspectors (Bands 0-4)

RSG/SSG Specialist Inspectors (Radiation and Elec) (Bands 0-3)

RSG/SSG Medical Inspectors

OSD Inspectors (Bands 0-3)

Railway Inspectors (Bands 0-3)

CHID Inspectors (Bands 0-4)

Mines Inspectors (Bands 0-2)

ELECTROMAGNETIC FIELDS AND RADIATION

This 2-part OC gives advice about occupational sources of electromagnetic fields and radiation, describes the possible risks to health and indicates what inspectors should expect of employers by way of assessment and management of the risks. The attached [Information Document](#) may be copied and given to interested persons outside HSE.

INTRODUCTION

1 Electromagnetic fields (EMFs) and radiation are a form of non-ionising radiation that ranges from static electric and magnetic fields through to the radiofrequency (RF) and microwave region. Electromagnetic fields arise whenever electrical energy is used, including for industrial, commercial and medical purposes and they are also present around all wires carrying electricity. The strength of the magnetic field depends on the size of the current that is flowing whilst the strength of the electric field depends on the voltage applied. Electric fields are easily shielded whereas magnetic fields are not. The strength of a field is important when considering health effects.

2 The National Radiological Protection Board (NRPB) has produced guidelines which make recommendations on restrictions on exposure to EMFs to prevent adverse effects on health. They refer to 'basic restrictions' and 'investigation levels' which are designed to prevent acute harmful effects of exposure. The guidelines apply equally to workers and members of the public. This OC is not concerned with ionising and optical radiation, and any advice on electromagnetic compatibility and RF ignition should be obtained from RSG/SSG electrical specialists. Exposures of patients undergoing medical treatment and examination are excluded and restriction of their exposure will be a matter for clinical judgement.

ADVICE

3 The NRPB has the statutory function to advise Government on all scientific matters relating to radiation and NRPB's recommendations have been accepted by Government as the basis for the management of health risks from EMFs. In particular, HSE expects employers to comply with the recommendations as evidence that they have carried out their duties under the Health and Safety at Work etc Act 1974 and the Management of Health and Safety at Work Regulations 1992 (MHSW Regulations). Regulation 3 of MHSW

Regulations requires employers to make a suitable and sufficient assessment of risks to health and safety. The purpose of the assessment is to enable the employer to determine what measures should be taken to adequately control the risks arising out of the work activity.

ACTION BY INSPECTORS

4 Inspectors should be alert to the processes described in the ID at [Table 2](#) which may produce EMFs which exceed the NRPB investigation levels. Inspectors may provide copies of the ID to anyone requiring advice to assist them in the assessment and control of exposure to EMFs.

5 Where exposures to EMFs are likely to be at or above the investigation levels, inspectors may ask employers to demonstrate that they have carried out a risk assessment to determine whether the investigation levels have been reached, and if so, have either calculated that the basic restrictions have not been exceeded or have introduced adequate control measures.

ENQUIRIES

6 Technical enquiries from operational inspectors should be directed to the local FOD RSG/SSG radiation specialists.

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ELECTROMAGNETIC FIELDS AND RADIATION

1 This document contains internal guidance which has been made available to the public. The guidance is considered good practice (rather than compulsory) but you may find it useful in deciding what you need to do to comply with the law. However, the guidance may not be applicable in all circumstances and any queries should be directed to the appropriate enforcing authority.

WHAT ARE ELECTROMAGNETIC FIELDS AND RADIATION?

2 Electromagnetic fields (EMFs) and radiation are a form of non-ionising radiation that ranges from static electric and magnetic fields through to the radiofrequency and microwave region. The radiation is described in terms of frequency and extends over a considerable range from zero to 300GHz. The generally recognised boundaries within the range are shown in Table 1.

Table 1 - Regions of the electromagnetic spectrum

	Frequency range	Typical applications
Sub-ELF	0 - 30 Hz	
Extremely low frequency (ELF)	30 - 300 Hz	Power lines, VDUs
Very low frequency (VLF)	300 Hz - 30 kHz	VDUs
Low frequency (LF)	30 kHz - 300 kHz	Security systems
Medium and high frequency	300 kHz - 30 MHz	Induction heating equipment
Very high frequency (VHF)	30 MHz - 300 MHz	Dielectric heaters
Microwave region (super high frequency (SHF), ultra high frequency (UHF))	300 MHz - 300 GHz	Radar, telecommunications, navigational aids

CAN EMFs INTERACT WITH PEOPLE?

3 There is an interaction which is very complex and it varies across the frequency range. When a person is exposed to non-ionising radiation from EMFs, energy is absorbed by the body and very weak internal electric fields are produced. The amount of energy absorbed depends on several factors such as the type of radiation source, the distance between the

source and the person as well as their physical characteristics, including their height. The extent of the interaction is expressed in terms of the induced current density and power, or energy dissipated within the body. These are known as the dosimetric quantities ([see paragraph 8](#)) and are important in providing the relationship between the external field strengths or radiation levels and the possible health effects.

WHAT ARE THE EFFECTS OF EXPOSURE?

Human exposure

4 Human exposure to EMFs can produce well-established symptoms and acute biological effects which vary according to the frequency of the radiation. At frequencies below 100kHz, induced currents are set up in the body which can have an effect on the functions of the central nervous system. At frequencies above 100kHz, especially those in the radiofrequency (RF) and microwave region (>10MHz), both whole body and localised tissue heating can occur leading to a rise in temperature. These are acute effects and they are only likely to be encountered as the result of an incident or an uncontrolled situation involving exposure to high intensity fields. **Such effects are extremely rare and should not occur during normal operations.**

5 In more detail the recognised acute effects are:

- (1) **Perception effects.** These can occur from exposure to both static and time varying fields of frequencies <100kHz. The most common effect occurs from the interaction of electric fields on the body and involves the electrical charge build up moving hairs on the arms or head. These are annoying effects which may lead to microshocks when people touch earthed metalwork. Microshocks in themselves are not harmful but may distract from, or interfere with, concentration.
- (2) **Effects on the central nervous system.** These occur mainly at frequencies <100kHz. They include disturbances to central nervous system functions such as control of movement, memory and visual processes.
- (3) **Body/tissue heating** can occur at frequencies >100kHz and can give rise to whole body and partial body heating depending on frequency and field strengths. However, in extreme cases, (well in excess of the basic restriction), this could lead to overload of the body's thermoregulatory system, inducing a form of heat stroke.
- (4) **RF shocks and burns.** Touching RF-charged conductors may lead to shocks or burns. Radiofrequency burns generally have deep tissue damage and are extremely painful and slow to heal.

Medical devices

6 Electromagnetic fields may specifically interfere with some implanted medical devices such as insulin pumps and cardiac pacemakers. Whilst modern implants are generally more stable, people with such devices should consult the implanting centre about their susceptibility.

Other reported effects of human exposure

7 There are numerous reports of alleged ill-health effects from exposure to EMFs at levels much lower than those which can give rise to acute effects. The allegations range from

reports of non-specific symptoms to those of cancer. However, numerous authoritative reviews have been unable to find convincing scientific evidence to show that exposures to low level EMFs can cause such risks to health. The National Radiological Protection Board (NRPB) has a specialist Advisory Group on Non-Ionising Radiation, currently chaired by Sir Richard Doll, to review reports of the effects of EMFs on health. The Group's first review¹ of the evidence for a carcinogenic effect concluded that there is no convincing scientific evidence to prove that exposure to EMFs causes cancer. In further reviews² of more recent reports covering both occupational and residential exposure, the Group's view remains essentially unchanged but it has said that there is a need for more research. It is conducting a further review of the literature and is expected to report in 1999.

NRPB GUIDELINES FOR RESTRICTIONS ON EXPOSURE

8 Guidelines for restrictions on exposure to EMFs are produced by NRPB³. They are designed to prevent acute harmful effects of exposure and apply equally to workers and members of the public. (Exposures of patients undergoing medical treatment and examination are excluded and restriction of their exposure will be a matter for clinical judgement). The recommendations have been derived from biological information, dosimetric data and from studies of exposed populations. They identify 2 sets of values:

(1) The '**basic restrictions**' are exposure limits. They relate to induced current density or specific energy absorption rates in the body and cannot easily be directly measured. They have been obtained by reviewing published research results to determine at which exposure levels acute effects have been observed. This overview provided an exposure threshold below which effects were not seen. Uncertainties and variations in susceptibility together with a safety factor, were allowed for in arriving at the basic restrictions.

(2) The '**investigation levels**' are derived corresponding values which represent the external electric and magnetic field strengths. These are quantities that can be measured directly. It is possible to calculate from the field strengths whether the basic restrictions have been exceeded. If the EMFs to which people may be exposed are less than the investigation levels, then the basic restrictions will never be exceeded and there is no risk of acute harmful effects occurring. However, even if the investigation levels are exceeded, it does not follow that the basic restrictions will be exceeded. What it does mean is that further investigations should be carried out to assess exposures directly to compare with the basic restrictions.

SOURCES WHERE THE NRPB INVESTIGATION LEVELS MAY BE EXCEEDED

9 Any processes which use or generate high electrical currents or use high frequency sources have the potential to create fields which may exceed the NRPB investigation levels. A list, which although not exhaustive, of the vast majority of industrial processes where the NRPB levels can be exceeded is shown in Table 2. There are also numerous processes, including the use of mobile phones, where the NRPB basic restrictions will not be exceeded. It is not possible to provide an indicative listing.

Table 2 - Processes where the NRPB investigation levels may be exceeded

Industrial application	Typical usage
Induction heaters (<i>ELF</i> , <i>LF</i> , <i>MF</i>)	These are used to heat materials such as metals and crystals and are used extensively in a variety of

	industrial processes. They operate over a range of frequencies and typical applications include drying, bonding, melting, surface hardening, tempering and brazing.
Dielectric heaters (HF, VHF, microwave)	The technique of radiofrequency (RF) heating and drying has been used for many years for preheating, wood-gluing and PVC welding. The heaters generally operate over a wide frequency range with power outputs from one to several kilowatts. PVC welding products include heavy duty tarpaulins and small pencil cases and the equipment will vary from large automatic machines to small manually operated RF sealers. The food industry uses microwave oven tunnels for 'tempering' (defrosting) frozen foods on a conveyor system.
Electrochemical processes (DC)	The main industrial processes are chlor-alkali and aluminium production and electro-plating. These processes tend to use high operating currents which can produce magnetic fields well in excess of the NRPB levels.
Transmitters (HF, VHF, SHF, UHF, microwave)	<p>This broad title is used to cover broadcasting, radio communications and mobile telephony. In all these cases, the transmitting antennae are normally mounted on masts or the tops of buildings or other similar structures, but mobile equipment may have vehicle mounted antennae.</p> <p>For radiocommunications and mobile telephony, the NRPB levels can be exceeded close to (within a few metres of) the beam, but only maintenance workers are likely to be affected. Particular difficulties may arise for workers at high-power broadcasting transmitters.</p>
Navigational aids (LF, VHF, microwave)	There are a number of electronic navigation systems used in the UK operating over a wide range of frequencies. They include marine and aeronautical direction finding beacons and airfield approach and aircraft landing aids. Those systems using low frequency band transmitters produce the highest potential occupational exposures. As in the case of transmitters, the people most likely to be affected are maintenance workers. Also, surveillance radar operating in the microwave region emit high power pulsed beams.

(Note: In each of the above cases, the design of the installation may be such that nobody can get access to the high fields).

GENERAL APPROACH FOR RISK ASSESSMENT

10 The steps that inspectors should expect employers to have taken in the assessment of risk from exposure to EMFs are set out below in the format of HSE's guidance leaflet *Five*

*steps to risk assessment*⁴ and a simple example is given at [Appendix 1](#).

Step 1: Look for the hazards. Employers must identify whether EMFs are present and accessible to people.

Step 2: Decide which of their staff or others might be harmed, and how. In some situations employers need particularly to consider risks to maintenance workers, contractors and members of the public.

Step 3: Evaluate the risks and decide whether precautions are adequate. The employer must assess or measure the field strengths. Below the investigation levels there is no risk of harm and no further action needs to be taken. But if the field strengths exceed the investigation levels there may be a risk and the employer must:

- **EITHER** calculate from measurement of the field strengths whether the basic restrictions are likely to be exceeded. In practice the calculations are very complex and employers will normally need to seek expert advice. If this further detailed assessment shows that the basic restrictions may be exceeded, then adequate controls must be put in place.
- **OR** ensure that people cannot enter the area identified or are otherwise adequately protected.

Step 4: Record the findings. Employers should keep a record of the assessment, any measurements and calculations, and actions taken. This is particularly useful in premises where processes or practices may change. Employers with many pieces of similar equipment can make use of generic risk assessments.

Step 5: Review and revise assessment. Employers need particularly to have systems to identify accidents and incidents with a risk of overexposure and feed any lessons learnt back into the risk assessment.

FURTHER INVESTIGATIONS WHEN INVESTIGATION LEVELS HAVE BEEN EXCEEDED

11 Further investigations will look in greater detail into the exposure situations and may require specialist advice as some of the computations which may be necessary are extremely complex. The investigation levels were derived from the basic restrictions using some simplifying, conservative assumptions. In many workplaces, these assumptions will not all be valid for the specific circumstances that exist, and the further investigations will need to consider a number of other factors. More detailed information on source characteristics is given at [Appendix 2](#).

MANAGEMENT OF RISK

12 If an employer calculates on the basis of measured field strengths that the basic restrictions may be exceeded, then they will need to implement control measures to bring the exposure below the basic restriction levels. Such measures are likely to involve engineering controls but may also include administrative procedures. Engineering controls are source and application specific and they may be introduced at any stage in the process from source design to siting, installation and use. The measures taken will depend on whether the sources are intentional radiators such as transmission antennae or industrial or medical equipment which may leak stray energy. Some factors that can be considered are:

- (1) For processes operating at frequencies less than 100 MHz, the wearing of rubber-soled shoes and thick socks will significantly reduce the induced body current. The extent of the reduction can be assessed by making body current measurements.
- (2) For dielectric heaters, a reduction in whole body specific energy absorption rate can be achieved by allowing the worker to stand on an insulating platform. The appropriate thickness depends on the frequency of the operation. Sometimes changing whether the operator stands or sits can reduce their exposure. Using 2-handed controls to initiate the RF pulse prevents close approach to the applicators and reduces the risk of RF burns.
- (3) Users of induction heaters rely on the manufacturer to minimise field emission from the induction coil through shielding at the design stage. In normal operation, exposure reduction can also be achieved through automated systems for loading and unloading the contents of the induction heater.
- (4) The maintenance of good electrical continuity and earth bonding of metallic screens is important to prevent them from becoming unintentional secondary radiators or a source of RF shock or burns.
- (5) Removing objects that can act as reflectors reduces the possibility of localised high field strengths. Alternatively, moving the source away from fixed reflectors should be considered in appropriate situations.
- (6) In medical applications, exposure to RF radiation comes mainly from the use of diathermy and hypothermia equipment. The equipment consists of a generator cabinet, transmission cables and applicators which couple electromagnetic energy into biological tissues by direct surface contact. A reduction in the stray fields can be achieved by using screened transmission cables and adjusting the cables connecting the generator and applicators. Characterising the regions where there are high fields and switching off the equipment when attending the patient will also reduce operator exposure.
- (7) In the case of magnetic resonance imaging equipment, the sources are usually well-shielded and operator exposure levels are likely to be low. However, new interventional techniques may need staff to be close to the patient and thus within the shielded area leading to more significant exposures. Unit managers will need to have detailed knowledge of the static field configuration in order to restrict staff to those areas where fields are within the NRPB guidelines. Tissue heating may be significant if people touch the search coil RF feeder cables.

FURTHER ADVICE AND INFORMATION

13 Employers seeking additional advice relating to plant or equipment that they use, should approach the product supplier in the first instance. 'At-a-glance' leaflets, eg non-ionising radiations, electric and magnetic fields, and radio waves, are available from the NRPB⁵.

14 The publication *Occupational exposure to electromagnetic fields: Practical Application of NRPB Guidance*, NRPB-R301, (PJ Chadwick, 1998) also contains useful advice.

REFERENCES

15	Reference	ID para ref
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1	<i>Electromagnetic fields and the risk of cancer.</i> Documents of the NRPB. Vol 3, No 1, 1992.	7
2	<i>Report of an Advisory Group on Non-Ionising Radiation.</i> Documents of the NRPB, Vol 5, No 2, 1994.	7
3	<i>Board statement on restrictions on human exposure to static and time varying electromagnetic fields and radiation.</i> Documents of the NRPB, Vol 4, No 5, 1993. HMSO.	8
4	HSE leaflet INDG163 (rev1) <i>Five steps to risk assessment.</i>	10
5	National Radiological Protection Board, Chilton, Didcot, Oxon, OX11 ORQ tel: 01235 831600.	13

APPENDIX 1 (para 10)

EXAMPLE OF A RISK ASSESSMENT

Microwave oven EMF risk assessment

Step 1: Look for the hazard

- Microwave radiation at 2.45GHz.

Step 2: Who might be harmed?

- Catering staff in the kitchen of the staff restaurant.
- Any member of staff using the snack point.

Step 3 Assess risk and review existing precautions

- Oven housing is undamaged, door seals are in good condition, interlocks are working - no emission measurement is necessary: Risk is LOW.
- Daily cleaning to prevent build up of spillages, regular functional check of interlocks, routine inspection for damage to housing (as for portable appliance testing).

Step 4: Record findings

- "Microwave ovens: inspected for cleanliness and damage; interlocks checked - found clean, undamaged and functioning correctly."

Step 5: Review assessment

- If new ovens are installed,
- after maintenance or repair,
- from time to time to confirm precautions are still effective.

APPENDIX 2

(para 11)

DETAILED INFORMATION ON SOURCE CHARACTERISTICS

(1) **Frequency of operation** - Does the operator have to set up each individual operation so that the source is only powered up intermittently? Is the source scanning the location being assessed, eg a rotating radar antenna? Do workers pass through the fields for short periods of time?

(2) **Duty cycle** - If the sources are pulsed or otherwise intermittent, the duty factor is the percentage of the time that power is on.

(3) **Distribution of radiation from the source** - What is the gain of the antenna? What is the angular divergence of the beam (3dB down width, ie half power points)?

(4) **Exposure in the near or far field** - The far field is defined as being the region in which the radiation emitted by an antenna behaves as a uniform plane wave where the electric (E) and magnetic (H) field strengths are related by the impedance of free space (377W) such that power flux density equals $377 \times E^2$ or $H^2/377$. The antenna type and size, as well as the transmitter frequency, will determine the distance at which this condition occurs. In the near field region (for practical purposes this is at distances shorter than approximately twice the wavelength) field strengths do not necessarily reduce uniformly as one moves further from the source. To determine the power flux density at any point in this region requires the measurement of both E and H.

(5) **Secondary radiators** - Ungrounded or badly earthed conducting objects may re-radiate any electromagnetic radiation which falls upon them. They may also act as reflectors. Both these mechanisms can lead to distortion of the fields making theoretical prediction of personnel safety difficult - hence the need to ensure full electrical bonding and earthing of structures, enclosures and equipment housings, particularly after maintenance or servicing.

(6) **Instrumentation** - Appropriate instruments must be used, based upon a consideration of the technical specification of the source. If the assessment is taking place in the near field both electric and magnetic fields will have to be assessed; power density meters will not necessarily read true. Instruments must be capable of coping with the anticipated intensity and spread of wavelengths of the fields. If a number of differing frequencies could be present then the first task may be to use a spectrum analyser to identify key frequencies and potential contributions from harmonics.

(7) **Measurement technique** - Additional measurements of the spatial distribution of fields both vertically and horizontally will need to be made for each frequency. At this stage no components should be discounted. Use of an insulating stand or long, non-conductive handle is essential when measuring electric field strengths as the investigation levels are defined as being unperturbed, in free space. A remote readout (via fibre optics) facility may also be useful to keep the measurer out of the fields. Magnetic fields are not perturbed by the presence of people, so exposure meters incorporating dataloggers worn by workers can provide useful information about how fields change with time and activity.

(8) **Data analysis** - If there are a number of frequencies contributing to individual exposures, their impact will have to be separately assessed and then summed if they

interact with people in the same manner. Exposures to fields below 100 kHz must be assessed separately from those above 10 MHz.

(9) **Dosimetric investigations** - Consideration of the field distribution or source frequency may make it necessary to include measurement of current flow through a person to earth, either by them standing on a parallel plate capacitance instrument or using toroidal induced current measuring devices worn on the ankle or wrist.

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