BDP ENVIRONMENT DESIGN GUIDE

Electromagnetic Fields in the Built Environment – Design for Minimal Radiation Exposure

Don Maisch, John Podd and Bruce Rapley

Summary of

Actions Towards Sustainable Outcomes

Environmental Issues/Principal Impacts

- Sufficient evidence now exists to suggest that a contributing factor to consider in assessing indoor environment quality is the prolonged and excessive exposure to electromagnetic fields (EMFs) in buildings.
- Where scientific inquiry is inconclusive it is appropriate to adopt the 'precautionary principle'.
- The impact of external power-line generated magnetic fields to indoor levels is considered to be minimal in terms of potential exposure and is therefore not detailed in this paper. Radiofrequency and microwave electromagnetic radiation (EMR) are also not covered in this paper.
- It is possible to address potential exposure at the building design stage to significantly reduce and minimise occupant exposure at relatively little cost during planning and design.

Basic Strategies

In many design situations, boundaries and constraints limit the application of cutting EDGe actions. In these circumstances, designers should at least consider the following:

- The electrical service supply and distribution or meter box should not be located on a wall that occupants will be spending extended time near e.g. workstations, bed-head walls.
- Design office layouts to minimise workers' exposure to EMFs from office equipment. This would include the provision of separate ventilation ducts for office equipment such as copy machines, faxes and printers to reduce exposure to chemical emissions.
- Before selecting an electrical heating system inquire with the manufacturer about the magnetic fields emitted. Some heating systems, using electric cables encased in the concrete slab can give off high magnetic fields.

Cutting EDGe Strategies

- Before selecting a building site, note proximity to nearby power and transmission lines, and substations and locate the building as far away as practicable. If there are any concerns over potential adjacent sources of EMF, use a gauss meter to determine the strength of the magnetic fields.
- Cable conduits supplying power to large equipment, such as elevators and roof top air conditioners can carry large loads and therefore have high EMF levels nearby. Ensure as far as practicable that such cable runs follow hallways and other areas as so to minimise close proximity to where people work.
- With multiple apartments bedroom bed-head walls should be placed to ensure that electrical appliances such as refrigerators, stoves, microwave ovens, television and entertainment equipment are not placed on the other side of the wall in an adjacent apartment.

Synergies and References

- Maisch, D, Podd, J and Rapley, B, 2002, *Changes in Health Status in a Group of CFS and CF Patients Following Removal of Excessive 50 Hz Magnetic Field Exposure*, Journal of Australasian College of Nutritional and Environmental Medicine, Vol 21, No 1, April 2002)
- The London Hazards Centre, Fact Sheet: *Electromagnetic Fields*, http://www.lhc.org.uk/members/pubs/factsht/52fact.htm
- The Australian Radiation Protection & Nuclear Safety Agency (ARPANSA) Fact Sheets:
  - Fact Sheet No. 8: *The Controversy over Electromagnetic Fields and Possible Adverse Health Effects*
  - Fact Sheet No. 19: *Electricity and Health*
- *Measuring Magnetic Fields*, meter hire, http://www.arpansa.gov.au/pubs/nir/mag_fields.pdf

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Electromagnetic Fields in the Built Environment – Design for Minimal Radiation Exposure

Don Maisch, John Podd and Bruce Rapley

This paper explores the evidence that another factor to be considered in Sick Building Syndrome and Indoor Environment Quality is exposure to prolonged and excessive electromagnetic fields (EMFs). Enough evidence now exists to justify taking a precautionary approach in building design to significantly reduce and minimise occupant exposure at relatively little cost at the planning and design stage.

1.0 Introduction

According to the Australian Commonwealth Science and Industrial Research Organization (CSIRO) Energy and Thermofluids Engineering Department, volatile organic compounds (VOCs), such as formaldehyde, nitrogen dioxide and respirable particles are considered to be major contributors to indoor air pollution, leading to Sick Building Syndrome. Increasingly, regulators and stakeholders are becoming more focused on the significance of indoor environment quality and occupant wellbeing.

Sufficient evidence now exists to suggest that another indoor 'pollutant' is the prolonged and excessive exposure to electromagnetic fields (EMFs) in buildings. This paper explores potential sources of EMFs in buildings and gives an overview of current EMF standards and guidelines in the Australian context. Also discussed is the Swedish 'Healthy Office Project', presented as an example of a practical precautionary design approach. Suggested design solutions are given to assist the designer in including EMF as criteria to be addressed in the preliminary design stage.

In both the contemporary office building and home environments the ever-increasing use of electrical devices means that occupants may be inadvertently exposed to magnetic fields generated within the building, and at levels that some studies indicate may be potentially harmful to human health. Generally, the addition of external power-line generated magnetic fields to indoor levels is considered to be minimal in terms of potential exposure and is therefore not detailed in this paper. Radiofrequency and microwave electromagnetic radiation (EMR) are also not covered in this paper.

2.0 Electromagnetic Fields

Electric and magnetic fields, which together are termed electromagnetic fields (EMFs), are produced by transmission and power-lines, building electrical wiring and electrical appliances and equipment. Though there are many other sources of EMFs – both man-made and natural – this paper focuses on power frequency EMFs in buildings. These EMFs are in the extremely low frequency (ELF) part of the electromagnetic spectrum with a fundamental frequency of 50 – in some countries 60 – Hertz (Hz).

Electric fields are generated by the voltage present and are measured in volts per meter (V/m). Magnetic fields are generated by the flow of electricity through conducting wires, equipment and other conducting paths, such as metal water supply systems. They are commonly measured in units of milliGauss (mG) or microTesla (μT), with 1 mG equaling 0.1 μT.

3.0 Potential Sources of Exposure

Whereas electric fields are easily shielded by trees, walls and even human skin, magnetic fields are difficult to shield as they pass unhindered through most materials. Both electric and magnetic field strengths decrease with distance. Magnetic fields are the focus of concern because the epidemiological literature largely investigated the possible connection with cancer, especially childhood leukaemia, from magnetic field exposure, but not with electrical fields.

EMF exposure can arise from various sources integral to a building's electrical supply system. Current regulations do not take into consideration the effects of prolonged exposure to environmental level EMF to occupant health in setting standards. Instead, international guidelines – that Australian EMF standards are based on – are designed to provide protection from scientifically established adverse effects that occur at high rather than prolonged levels of exposure. These guidelines do not address scientific uncertainty which is where the precautionary principle applies.

3.1 Substation at Ross House Melbourne

In October 1991, an office located in Ross House, Flinders Lane, Melbourne, was vacated on the advice of a building consultant who had been called in to determine the reason for electrical interference with newly installed office computers. The interference was found to be magnetic fields emanating from an electrical substation in the basement immediately below the office. The measured magnetic field levels were in the order of 94 to 187 milliGauss (mG); this level far higher than would normally be found in an office environment. As a rough comparison, average EMF levels in homes and office spaces are usually less than 2 mG.

Health complaints suffered by two workers located in this office eventually led to a Workers' Compensation case, lodged by the workers for payment of ongoing medical treatment for symptoms of chronic fatigue syndrome (CFS) while working in the affected area. For both workers, symptoms began after starting work in the office about 15 months earlier. An investigation by Workcare Victoria included an evaluation of the health status of former employees who had also worked in the same office. All previous employees who were interviewed by the investigators independently reported similar CFS symptoms, which disappeared after ceasing to work in the office, or while away on vacation. Symptoms reported included:

- Anaemia
- Fluctuating hormone levels
- Chronic tiredness
- Insomnia
- Problems with concentration
- Facial rashes
- Listlessness
- Light headedness
- Headaches
- Increased susceptibility to viral infections

3.2 Prolonged EMF Exposure Study

In early 1998, prolonged exposure to 50 Hz power frequency magnetic fields were investigated with the hypothesis that they may be a risk factor for immune system-related disorders, an issue outside of the EMF standards that only address immediate health effects. An ensuing paper argued that prolonged exposure to excessive 50 Hz (power line frequency) EMFs may act as an immune system stressor, giving rise to symptoms similar to those reported in CFS. This paper was followed by a pilot study of residential building EMF exposures of a group of CFS patients living in Melbourne, Adelaide and Hobart. The findings were published in the Journal of the Australasian College of Nutritional and Environmental Medicine (JACNEM Volume 21, No. 1 April 2002) and presented at the 2nd International Workshop of Biological Effects of EMFs (Rhodes, Greece, October 2002).

This preliminary study consisted of 49 subjects suffering from symptoms that were medically diagnosed as CFS, and who were exposed to varying strength magnetic fields in their home environment. Subjects were divided into two groups: those experiencing prolonged exposure of 2 mG or more (Group A) and those with exposure to less than 2 mG (Group B). The exposure levels in Group A – averaging 7.1 mG – were identified and reduced to below 2 mG, whereas Group B's existing low exposure levels – averaging 0.67 mG – were left unchanged. Both groups were monitored for six months for any changes in health status. At the end of six months, Group A had a significant (self-reported) improvement in health, including improved sleep, compared to Group B (Table 1).

The findings of this study suggested that the EMF exposure levels experienced by members of Group A may have been a factor in their ill-health. An interesting observation was that it was predominantly EMF sources within the homes (Table 2), not external sources – such as power-lines – that contributed to the exposure levels. Having the electrical distribution meter box on a bedroom wall was the single largest source of exposure. (Note that the average exposure of Group A was only 7.1 mG in comparison to the higher levels discussed in the remainder of this paper.)

	Overall Improvement in Health			Improvement in sleep
	None	Slight	Definite	
Group A	45%	0%	55%	64%
Group B	68%	18%	14%	12%

Table 1. Self Reported Percentage Change in Symptoms Six Months after Initial Exposure

Number of Subjects	Source of Exposure
1	Electrical currents on domestic water pipes
1	Electrical currents on domestic water pipes and street power-line
4	Bed-head in close proximity to electrical meter box
2	Sleeping with an energised electric blanket
1	Water-bed heater
1	Water-bed heater and phone-charger by the bed-head
1	Chair placed adjacent to wall with high EMFs from appliance

Table 2. Sources of EMF Exposure in Group A

3.3 Building Electrical Substation/Distribution Panels

In renovating existing buildings, any existing electrical substations that are retained for that purpose should be given preferential treatment in the initial design phase. As seen in the case of Ross House in Melbourne, areas immediately adjacent to the substation (above and below) should be designated as storage or equipment areas, and not rooms where people spend a significant amount of time. Furthermore, taking Ross House as an example, the average magnetic field exposures, at the time of survey, were in the order of 31 mG in the room areas above the substation. In comparison, other areas in the building averaged 0.7 to 1.5 mG, which is the expected range commonly found in office buildings. (Reference EMRASE Electromagnetic Field Survey Report: 16 October 1991 at Ross House, 1991)

After shielding was completed, which included the electrical supplier balancing the electrical loads on the substation, average levels in the affected rooms dropped to 7.4 mG. (Reference Ross House 15 November 2002 Spot Survey, Emfacts Consultancy, 2002)

In new buildings, the same applies, but there will be greater opportunity to place sub stations/distribution panels in areas remote from working and living spaces. It is worth noting that the magnetic field strength is proportional to the net current through the conductor and inversely proportional to the distance from its centre.

3.4 In-floor Electrical Heating

Heating in which energised electrical cabling is embedded in the concrete floor may be of concern, depending on the type of system used. A number of manufacturers specifically mention the reduction of EMF levels in their products. Some claims include the elimination of EMFs by cancelling out magnetic fields by using twin conductor cables and the total elimination of the magnetic field at floor level.

However, emitted EMF levels depend upon the manufacturer, and their awareness of advising consumers the advisability of reducing EMFs as much as possible. In April 1998, readings were taken of the floor heating unit in a private residence in Hobart. Measured levels of 100 mG on the floor and approximately 12 mG on seats of chairs in the living room were recorded. The occupant claimed to see a worsening of symptoms of Chronic Fatigue when using the heating system in the winter season. Building consultant, John Lincoln (Sydney), has measured floor heating systems with levels of up to 800 mG on the floor and 90 mG at lap level. These levels are far in excess of what is generally encountered in buildings – i.e. usually below 2.0 mG – and could be expected for many hours during the winter months

In the home, in-floor electrical heating is of concern, particularly to small children who may spend much of their day playing on the floor. It must be noted that there is now firm and consistent epidemiological data showing a doubling of the incidence of childhood leukaemia in ambient power-frequency (50 Hz) magnetic fields of 0.4 microtesla (4.0 mG) or higher. Some manufacturer's, mindful of the potential harmful effects of EMFs in their products, advertise that their products are designed to emit minimal EMFs, comparable to other similar proprietary products.

4.0 The Swedish 'No Risk' and 'Healthy Office' Projects

In April1992, the Swedish National Institute of Occupational Health (NIOH) published the results of a survey of 731 employees at five major Swedish workplaces. The study was conducted in collaboration with two hospitals in Stockholm, and two Swedish government departments. The survey found that one in seven employees enrolled in the survey were having problems with EMF fields in the workplace, predominantly in office places. Reported symptoms included '…dizziness, prickly sensations, fatigue, weakness, headaches, breathing problems, perspiration, depression, heart palpitations and forgetfulness.'

In 1996, the Swedish Union of Clerical and Technical Employees in Industry (SIF), the largest trade union for white-collar workers in Sweden, published a pamphlet entitled, Hypersensitive in IT Environments. This publication aimed to provide facts, support and advice to its members about excessive EMF exposure in the workplace. A follow-up project by SIF, No Risk in the IT Environment (1999), aimed to identify hazards in the workplace and seek solutions. The report stated:

'Completely new health problems have surfaced at our workplaces. Information Technology (IT) and the vast proliferation of electrical equipment that it has brought into our daily working life have created a new risk environment. Much of this has not been investigated, and the possible consequences to our health cannot be ignored. These invisible risks – often in the form of a chemical efflux and physical radiation…are at the centre of a project initiated by SIF…'

An essential part of the project was 'The Healthy Office Project', run in conjunction with the Lule College and Institute of Technology. This program advised how best to design the modern IT office building to reduce or eliminate both electromagnetic and chemical emissions in the built environment. The projects aims were:

'… connecting the mass of knowledge that exists among researchers with a number of small practical projects that are based on the concept of minimizing electromagnetic fields for people working in their vicinity. Classrooms and offices that have been cleaned from electrical fields give us the practical opportunity of testing solutions that can lead to better working environments. We are working on measuring techniques for measuring frequencies of 50 Hz and more, suspecting that these frequencies have an effect on biological systems.'

5.0 Current EMF Exposure Guidelines and Regulatory Framework

Currently there are no mandated standards regulating 50/60 Hz EMFs in Australia. However there are recommendations set out by the Australian National Health and Medical Research Council (NH&MRC) in their 1989 'Interim Guidelines on Limits of Exposure to 50/60 Hz Electric and Magnetic Fields'.

These guidelines are based on the previous guidelines developed by the International Non-Ionizing Radiation Committee of the International Radiation Protection Association (IRPA/INIRC). For twenty four hour residential exposures to magnetic fields, the limit is 1,000 mG, and for eight hour occupational exposures, the limit is 5,000 mG.

However the NH&MRC guidelines are of limited use when addressing environmental level EMF exposures because they are primarily meant to protect against immediate adverse health effects, such as induced body currents (shocks) at extremely high levels of exposure. This was pointed out by a spokesperson from the Australian Radiation Laboratory (ARL) in 1991 when he said that the limits (referring to the WHO/IRPA

recommended exposure limits which were identical to the NH&MRC Interim guidelines) were

'…not intended to provide protection against possible cancer induction by continued exposure at the lower field levels implicated in the (epidemiological) studies.'

In 1999, the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) took over responsibility for reviewing the 1989 Interim Guidelines from the NH&MRC and convened two committees (working and consultative) to determine a revised power-line frequency exposure standard to replace the interim guidelines. It is expected that they will closely follow the power-line exposure guidelines published by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). These are essentially the same as those originally devised by IRPA/INIRC (above) and still focus primarily on providing health protection against immediate health hazards at high levels of exposure, based on the certainty of scientifically established effects at those high levels.

In the majority of Western countries, national radiation agencies and standards organisations have adopted the ICNIRP guidelines as national Standards as a requirement under World Trade Organisation (WTO) requirements. In Australia, Standards Australia requires that all Australian and New Zealand standards

'…not act as a barrier to innovative development, or otherwise unreasonably or unlawfully restrain competition or trade.'

In this context there are no EMF standards to address environmental level EMFs that are commonly encountered in and around buildings. In the absence of such guidance, the onus falls on individual concerned organisations to enact their own precautionary EMF limits to protect people under their duty-of-care.

ARPANSA's current policy on 50/60 Hz EMF is explained in their Fact Sheet No. 8, available on the ARPANSA web site.

6.0 Strategies for Minimising Magnetic Fields in Buildings – Applying the Precautionary Principle

The Normal offer the following guidlelines to reduce to reduce magnetic field exposure:

6.1 Office/Apartment Buildings

- Before selecting a building site, note proximity to nearby power and transmission lines, substations and locate building as far away as practicable. If there are any concerns over potential adjacent sources of EMF, obtain a gauss meter to determine the strength of the magnetic fields.
- Ensure that any internal electrical substations are not located adjacent to rooms where people will be spending long periods of time on a daily basis. This would include areas directly above and below the substation. Electrical cabling to and from the substation can also be significant emitters of EMF so their location in the building requires additional consideration.
- Ensure that no work-stations are in close proximity (less than two metres) from small distribution boxes.
- Cable conduits supplying power to large equipment, such as elevators and roof top air conditioners can carry large loads and therefore have high EMF levels nearby. Ensure as much as practicable that such cable runs follow hallways and other areas as to minimize close proximity to where people work.
- Following the practice in Sweden, design office layouts to minimize workers' exposure to EMFs from office equipment. This would include the provision of separate ventilation ducts for office equipment such as copy machines, faxes and printers to reduce exposure to chemical emissions.
- With multiple apartments bedroom bed-head walls should be placed to ensure that electrical appliances such as refrigerators, stoves, microwave ovens, television and entertainment equipment are not placed on the other side of the wall in an adjacent apartment.

6.2 Housing

- The electrical service supply and distribution or meter box should be located on a wall that no one will be spending extended time near. Avoid placing these on a bedroom wall.
- If a power-line is adjacent to the proposed home, place bedrooms on the far side of the building to reduce night time exposure.
- Electrically isolate any metal water piping between the home and street main by having a short piece (say two metres) of plastic water pipe inserted in the line between the street supply and the home. This will eliminate the alternative low-impedance path for the return current.
- Before selecting an electrical heating system inquire with the manufacturer about the magnetic fields emitted. Some heating systems, using electric cables incased in the concrete slab can give off high magnetic fields.

7.0 Conclusion

It is obviously a prime consideration for architects, designers and planners to ensure, as much as possible, the health and safety of people in the built environment that they have created. Sufficient evidence now exists to justify taking a precautionary approach in building design to eliminate one possible factor in Sick Building Syndrome. Such an approach would involve reducing or eliminating unnecessary EMF exposures when this can be relatively easily accomplished for little cost to the consumer in the early stages of design.

References and Further Resources

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The Australian Radiation Protection & Nuclear Safety Agency (ARPANSA) Fact Sheets:

- Fact Sheet No. 8: *The Controversy over Electromagnetic Fields and Possible Adverse Health Effects*
- Fact Sheet No. 19: *Electricity and Health*

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Biography

Don Maisch completed his Associate in Applied Science Degree in Architectural and Structural Building Design in the United States in 1973 and worked as a design draftsman in the nuclear power-plant division at Stone and Webster Engineering in Boston before migrating to Australia in 1975. His particular interest in EMF and buildings began in the early 1990's as a researcher for Senator Robert Bell in Hobart, Tasmania. During this time he wrote numerous Senate submissions and reports on various aspects of EMF exposure standards. He is an associate member of the Australasian College of Nutritional & Environmental Medicine and has published four papers in their journal and has conducted numerous EMF building surveys in Hobart, Melbourne and Adelaide. He has served as a member of the Standards Australia TE-7 Committee: Human Exposure to Electromagnetic Fields and is currently a member of the consultative committee on setting power-line EMF standards for the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA). He is currently completing a PhD thesis on radiofrequency risk assessment externally through the University of Wollongong and maintains a web site at http://www.emfacts.com.

John Podd obtained his PhD in psychoacoustics from Victoria University of Wellington (New Zealand) in 1983. Since then he has lectured and researched in the School of Psychology, Massey University (New Zealand). His interest since the mid 90's has been in the effects of electromagnetic fields on biological systems (especially on human behaviour), and he has authored a number of publications and conference papers on the topic. He is a member of both the Bioelectromagnetics Society and the Association of Psychological Science (United States), and reviews papers for the *BIOELECTROMAGNETICS* journal.

Bruce Rapley has been actively researching the field of bioelectromagnetics for 30 years. He worked on the effects of low frequency magnetic fields on agricultural crops before turning his attention to cytogenetics and human health. In 1990 he founded the Bioelectromagnetic Research and Information Network of New Zealand, (BRAINNZ) bringing together a multi-disciplinary team to investigate the effects of exogenous energy on living systems. With a background in biological systems (BSc) and technology (MPhil), Rapley has designed a number of experimental systems to study the effects of low frequency EMFs on plant and animal systems. His Masters thesis focused on the application of low frequency pulsed magnetic fields on the peripheral nervous system in humans as a possible treatment for Raynaud's disease. Rapley has published a number of papers on bioelectromagnetics and continues to be involved in experimental design, fostering university students undertaking post-graduate degree programmes. He now operates his own consulting company, Atkinson and Rapley, in New Zealand, specialising in environmental problems and their effects on human communities.