analogous to thermoluminescence analysis, involves cooling an ionic crystal in a field, switching off the field and then reheating the crystal connected to an ultra-sensitive electrometer which detects the microcurrent resulting from the randomisation of the aligned vacancy-impurity electric dipoles (Bucci & Fieschi *Phys. Rev. Lett.* **12**, 16; 1964; Strutt, Weightman & Lilley *J. Phys. E. Sci. Instr.* **9**, 683; 1976). This technique could perhaps be applied with advantage to α-$LiIO_3$, to monitor the microcurrents resulting from the randomisation of segregated ionic impurities.

It would be fascinating to know why X-ray diffraction intensities from α-$LiIO_3$ are affected by electric fields so much less strongly than are neutron diffraction intensities. Perhaps the active impurities will need to be identified and their atomic scattering factors for X rays and neutrons identified, before sense can be made of this anomaly within an anomaly. □

Standards for microwave radiation

from R. P. Blackwell

THERE has been growing concern in recent years over the possible biological consequences of exposure to microwave and radio frequency radiation, partly stimulated by the thousand-fold difference between the maximum permissible exposure standards current in Western and Eastern Europe. The much stricter Eastern standards have raised questions of safety in the West, but a realistic appraisal of the basis for this difference is hard to achieve.

Microwaves and radio frequency radiation are absorbed to a greater or lesser extent by biological materials, the energy appearing as heat; the predominant mechanism being dipole relaxation of water molecules. The photon energies of this radiation lie in the range 10^{-3} to 10^{-7} eV; orders of magnitude below the activation energies of molecular interactions (Cleary, *Health Phys.* **25**, 387; 1973). The generally accepted view is that the biological changes which are observed, such as cataract formation in the eye, are a result of heat production, although the view that non-thermal effects are important at low levels of exposure is held by some, particularly in Eastern Europe.

The Western standard of 10 mW cm^{-2}, which is considered to be the maximum safe exposure, was derived from thermal considerations. Because the body effectively deals with the transport of quantities of heat greatly in excess of the basal metabolic rate of 1 W kg^{-1}, whole body exposure at a power density which results in the dissipation of about 1 W kg^{-1} of heat is considered to be safe. The Soviet exposure standard seems to be the result of a different philosophy; their industrial safety standards often represent an ideal rather than a practical limit. They assume that any detectable biological change constitutes a hazard and consequently their exposure standard of 10 μW cm^{-2} was reached by adding safety factors to a power density at which no change has been observed.

Many Soviet papers report biological effects at power densities which do not seem capable of producing any thermal change, and are therefore often ascribed to 'athermal' effects. An appraisal of much of this research is difficult. Many reports which are quoted in reviews are not available in translation; most of those which have been translated are difficult to follow. Of the reviews available, that by Baranski and Czerski (*Biological Effects of Microwaves*, Dowden, Hutchinson & Ross, 1973) is among the most recent and comprehensive. Many of the reports of experiments performed by Soviet workers have been criticised, particularly in terms of dosimetry and experimental detail. For example many of the apparent effects on the nervous system detected by electroencephalography (summarised by Baranski and Czerski) need careful interpretation. The presence of recording electrodes during irradiation and simultaneous recording makes it impossible to rule out artefacts due to thermal and electrical stimulation by the electrodes themselves.

A large proportion of reports from Eastern Europe concern behavioural, electrophysiological and strongly subjective changes of a generalised nature, which are notoriously difficult to quantify. Fatigue, memory loss and loss of concentration have been reported. Such reports include, for example, surveys of the health of people exposed to low levels of microwave radiation in the course of their work. The body of evidence produced in the West is not in accord with many of those findings.

A recent publication of the National Research Council of Canada (*The Biological Effects of Radiofrequency and Microwave Radiation*, Assenheim *et al.*, NRCC 16448; 1979) provides an objective, well referenced synthesis of the important topics in this field. What is particularly useful is the attention paid to explaining the relevant backgrounds in physics and biology, and the philosophy behind the setting of exposure standards. Research in this field is complicated by the experimental problems of exposure and dose measurement. The interaction of electromagnetic radiation and biological tissues depends on several variables, including the wavelength of the radiation and the size and electrical properties of the tissues. Diffraction and reflection may occur at tissue interfaces, which may lead to focusing and resonance, with the consequent uneven distribution of heat, and formation of 'hot spots'. Assenheim *et al* provide a comprehensive survey of the important topics in this area, dealing with both the prediction of absorption patterns and the techniques for temperature measurement required.

There is now sufficient material available, for example the *R. F. Dosimetry Handbook* of Durney *et al.* (Report SAM-TR-78-22, USAF School of Aerospace Medicine, Texas), to enable reasonable estimates to be made of the power distribution in a given situation. Thus it is now possible to extrapolate experimental data on biological effects to man, and to predict with a reasonable degree of accuracy the pattern of power deposition in man in most exposure situations, and the resultant biological effects, if any. Such information is necessary for the design and implementation of realistic, practical safety standards.

Many questions remain unanswered Perhaps one of the most interesting is posed by the work of Bawin *et al.* (*Ann. N. Y. Acad. Sci.* **247**, 74; 1975). They report that changes in the calcium ion efflux of chick and cat brain tissue *in vitro* can be modified by exposure to amplitude modulated VHF fields of 1 mW cm^{-2}. Unmodulated fields do not produce an effect; however electrostatic fields alternating at the modulation frequency (between about 6 and 30 Hz) do. These exposure values are somewhat lower than might be expected. This could have implications for effects on the central nervous system, if a similar process occurs *in vivo*.

There remain many problems associated with experimental work, particularly in terms of physiological measurement in a microwave field. Such measurements rely on transducers which normally contain some metallic components, and these may distort the field and lead to unpredictable power deposition patterns. It is possible that some of the confusion over low level effects is a result of this. For example, a metal coaxial recording electrode, implanted in cat cortex, can cause a complete shift in the pattern of power absorption, and an increase of two orders of magnitude in power deposition near the electrode tip.

Although the controversy over thermal versus athermal effects has not been completely resolved, it has had the effect of stimulating a re-appraisal of exposure standards throughout the Western world. One major development which any revised standard must take into account is the resonance effects which occur in man in the low VHF region. It is likely that more attention will also be paid to considering the amount of power that temperature-sensitive organs, or those with a poor blood supply — for example the lens of the eye and the testis — can safely dissipate. □

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